THE FREQUENCY OF ALTERNATE CONCEPTIONS IN SOME AREAS OF MECHANICS AMONGST SOUTH AFRICAN SCHOOL PUPILS: A LONGITUDINAL AND CROSS-CULTURAL STUDY

A dissertation submitted in fulfilment of the requirements of the degree of Master of Philosophy

by

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DECLARATION

I declare that this thesis is my own unaided work unless where otherwise stated. It has not been submitted before for any degree or examination in any other university.

Signed by candidate

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ABSTRACT

This study, the first of its kind in Southern Africa, was undertaken in order to determine and compare the incidence of various alternate conceptions in some areas in mechanics amongst pupils from standards 4 through to 9, i.e. from ages ca. 11 to 17, in selected schools in the Western Cape and Transkei, South Africa.

After a careful study of the relevant literature a questionnaire was designed for the purpose of identifying the frequency of various alternate conceptions in the selected areas in mechanics. This questionnaire was administered to 2326 pupils under carefully controlled conditions during August and September 1987.

In analysing the data the frequency of particular alternate conceptions in the following groups of pupils were compared:

(i) by school standard
(ii) by geographical area
(iii) by language group
(iv) by gender
(v) by urban and rural regions in the Cape
(vi) by subject choice i.e. science pupils and non-science pupils

An analysis of the data shows that in most of the areas in the field investigated remarkably small differences exist in the frequency with which different alternate conceptions are held by different groups of pupils. In most cases differences could be related to the pupils' school standard. However, in the fields of circular motion, projectile motion and static equilibrium, clear differences were found to exist between boys and girls as well as between pupils in schools in the Western Cape and Transkei.

Furthemore, in most cases examined the accepted scientific conception was the least popular, particularly in the field of force and motion where conceptions linking force and motion were overwhelmingly selected by pupils in all of the groups. However, an exception was the standard 9 science pupils, i.e. 16 - 17 year olds following the science course in high school, who in some cases favour the accepted scientific conceptions by a small majority.

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CHAPTER 1

Introduction:

The research presented in this thesis deals with some of the ideas which children use to explain everyday events and the ways in which they interpret these events. In this context Ausubel (1968,p.iv.) pointed out the importance of such prior ideas in further learning. New knowledge interacts with existing knowledge and becomes part of it (Novak,1978.). Osborne and Wittrock (1983) stress that the individual's existing knowledge determines which parts of his sensory input he will pay attention to and which parts he will ignore. The learner generates links between the incoming information and those parts of his memory or prior knowledge which he thinks are relevant. He now uses the information to which he has linked the sensory input in order to make sense out of the sensory input i.e. to understand what he or she is seeing or hearing. If this is true, then it is clearly extremely important in science teaching to have some idea of what children think about particular situations which are widely used in introducing and explaning of various key science concepts.

Changing views of children's ideas in Science:

Our understanding of the ideas held by learners in science has changed considerably during the last ten years. Traditionally ideas held by learners which were in conflict with normal science were considered to be misconceptions. The task of the teacher was to identify these misconceptions and correct them before learning could occur. In early attempts to uncover some of the popular misconceptions held by learners, Doran (1972) investigated the misconceptions students held about the particle nature of matter, **Za'rour** (1975) the misconceptions held in a number of areas of physics, earth and space science and **Helm** (1978) the misconceptions held by pupils in selected topics in physics. Although Za'rour quotes **Garone's** opinion that the misconceptions can be traced to improper reliance on common-sense and misinterpretation of experience, the investigators were more interested in cataloguing the misconceptions, because of the obvious importance to curriculum developers and classroom teachers, (Doran,1972), than in investigating the origin or nature of these ideas. **Leboutet-Barrel**, (1976), however, started to look at the nature of the mistakes made by children in science and concluded that:

1. empirical terms used by children are not integrated like the concepts of a physicist by physical laws or reinforced by theory, but are based on their perceptions or personal action;
2. preconcepts are given only subjective values and as such cannot be expressed in mathematical terms: a weight is heavy, a force is powerfull, etc;
3. preconcepts are often considered as a quality of an object: a body possesses force, moving bodies come to rest because the force is "used up", etc;
4. conceptual vocabulary is poor but increases in quality around the ages of 14 and 15. Thus children at this age are able to envisage the simultaneous actions of opposing forces on a body, use standards of reference when making comparisons and begin to define concepts

in terms of their characteristics rather than subjective values. This change occurs spontaneously in both boys and girls;

5. the deeply ingrained empirical notions are replaced with difficulty by the newly acquired ones. This spontaneous knowledge is an obstacle to learning and acquiring new ideas in physics.

Leboutet-Barrel concludes that it is extremely important to explore the area of preconceptions and that it is crucial to make an inventory of the entire range of conceptual errors shown by pupils in the course of learning as these present an obstacle in the acquisitioning of new ideas.

While Leboutet-Barrel describes in some detail some of the characteristics of children's reasoning in science, Viennot (1979), asserts that all of us "share a common explanatory scheme of 'intuitive' physics which, although we were not taught it in school, represents a common and self-consistent stock of concepts and which, however wrong it may be, resists attempts to change or modify it". Here for the first time we see an attempt to move away from what was previously considered to be reasons for learning difficulties in science, to describing the nature of a system of thought shared by all of us. She calls this kind of reasoning "spontaneous reasoning" and the mistakes made by learners are seen as an insight into spontaneous reasoning. In this way the mistakes made by learners are no longer only of importance to teachers and curriculum developers, but they are the tools whereby the actual thought processes of the learner can be investigated. Viennot is also of the opinion that the knowledge content of spontaneous reasoning is very resistant to change and will outlive any teaching which contradicts it. As far as mechanics is concerned, the system represents "a worked-out and effective system of thought, despite being in conflict with the yet more worked out Newtonian scheme. It deals without contradiction with most situations encountered in daily life." (Viennot,1979.) In more detail, she has found for example that for many learners there exists a "pseudo-linear " relation between force and velocity which can be described as follows:

1. If a body is not moving then zero force is acting on it even if its acceleration is not zero.
2. If a body is moving then a net force is acting on it even if the acceleration of the body is zero.
3. If the velocities of two moving bodies of equal mass are different then the forces acting on them are different even if the accelerations are the same.

Furthermore, she found two general tendencies in the velocity-force relation. These are the tendencies to:

1. attribute physical quantities e.g. force, to objects themselves. Thus bodies are seen to move because they have a force;
2. to look for a force in the direction of motion in order to account for the motion;

While Viennot reached the conclusions which she did after analyzing the results of tests designed to uncover underlying misconceptions, **Saltiel and Malgrange** (1980) set out purposely to "explore and analyze spontaneous ways of reasoning (SWR) of students in kinematics (uniform motion in Galilean frames)". They compared the answers of eleven year old children with those of university students in their first and fourth years and concluded that there was very little variation from one group to the next. This, they say cannot be attributed solely to school learning, but rather to the existence of an organized system which they call "the natural model" as opposed to the kinematic model of motion. The natural model involves two interacting components:

(i) one which is purely descriptive and describes motion. This component involves two different aspects:

(a) distances travelled and trajectories are frozen in a unique and purely geometrical space;

(b) there are two kinds of motion; real or true motion which is intrinsic because it has a recognized dynamical cause and apparent motion which is perceived as an optical illusion.

(ii) the other which is causal and explains motion and results from the permanence of a link between motion and its causes. Motion and velocity are considered to be permanent physical properties of the moving body alone, independent of observers and tend to be defined by reference to the driving forces which cause them rather than by the frames.

According to Saltiel and Malgrange, the natural model is rarely found in its pure state but co-exsits with the kinematic model so that students stand somewhere between the two. They further stress that the model does not necessarily lead to coherent answers, as would an actual theory, but it does permit a coherent explanation of the answers to their test as a whole. Like Viennot, the authors consider SWR to represent a well structured set of concepts which is essentially independent of the knowledge learnt at school. It may indeed co-exist with the learnt knowledge. It should not be considered a distortion of school knowledge but rather as an "original mental construction" which develops before teaching commences. Although the authors do not suggest how this knowledge is acquired, it is interesting to notice that they consider it to be learnt early and that it is constructed by the individual.
The existence in learners of a structured set of concepts which are at variance with accepted scientific dogma appears to be accepted now by most authors. **Driver** (1980) calls the ideas which form part of this knowledge structure "alternate conceptions". She considers these concepts to be ordered into frameworks which she calls "alternate frameworks". **Gilbert, Osborne and Fensham** (1982) refer to it as "children's science". It also appears to be widely accepted that these conceptions or networks of conceptions are constructed at an early age by the individual through the experience of the individual with objects and through language usage.(Claxton,1982; Driver,1981)

Ogborn, (1985) addresses the problem of why certain alternate conceptions associated with motion exist. He is not concerned with why people or how people construct some personal conceptions, as Claxton for instance is, but rather is interested in finding out why the conceptions which are constructed are what they are, i.e. he is interested in the "content" of alternative conceptions or, as he says, "a theory of the ordinary person's commonsense theory of motion". He has developed a fairly detailed alternate theory of motion that would explain some of the ideas held by learners in the area of motion and force.

In a further refinement **Guidoni** (1985) analyses "natural thinking". Natural thinking, he says, is a non-separable part of a complex working structure, itself highly structured and open to continual change. We cannot set it aside to see what will happen to it, for it is nested inside any specialized thinking and will influence even our own efforts to reflect on it. It is part of an ever on-going process but not an "objectifiable stable entity". He describes the function of natural thinking as driving behaviour within a context according to a purpose. When Guidoni goes on to discuss the dynamics of natural thinking it is clear from what he says that, to him, the concept "natural thinking" is a very real concept.

There can be no doubt that this field of enquiry has changed considerably since the early work of Doran, Za'rour and Helm from one in which the interest lay in exposing and cataloguing misconceptions held by learners to one in which cognitive psychological terms abound and in which the discussion no longer centres as much on what students think but rather on why and how they think as they do.

The position of this study:

This study involves the identification of some of the ideas which South African children have about various concepts in physics and as such may be seen to be similar in many ways to the work of Helm, Doran and Za'rour. However, there is a sharp difference in that the situations used will be everyday ones for the pupils and as such the information elicited from them will be some indication of how they explain the day-to-day world around them.

Viennot, (1985), is of the opinion that a programme for research in science education should seek to:

* demonstrate regularities in different kinds of students' productions and to describe these regularities in terms of conceptual frameworks or ways of reasoning;
* investigate the conditions under which these conceptual frameworks can be changed.

The underlying conceptual frameworks can be inferred from regularities in responses, although there are serious problems associated with this. While it may well be possible to make some inferences about the conceptual frameworks of pupils in this study, this is not our primary purpose. The intention of this study is to bring about an awareness amongst *teachers and others involved in teaching* or preparing science curricula for use in our schools that:

1. children do not enter classrooms without ideas about the world around them;
2. these ideas are not at all the ideas which we ourselves have acquired as part of our own science education;

3. in a class there will almost always be a number of modifications of a basic idea;
4. children use these ideas to make sense of what they hear and see;
5. the ideas they hold will determine the way in which children interpret reality as well as the examples used in teaching.

It is our firm belief that these messages are important for practitioners in the classroom - more so than simply informing them about conceptual frameworks.

From what has been said about some of the aims of this study, we are of the opinion that it should be seen as falling within the constructivist approach to learning.

The relevant theory of learning:

In reviewing the influence of cognitive psychology on the teaching of science in schools, Driver (1982) concludes that there are basically three main traditions in research into learning which have made major contributions to learning and instruction in science. She lists these as:

1. The tradition of developmental psychology with its age - related restrictions on learning (Piaget).
2. the behaviourist tradition which ignores developmental restrictions with its optimistic claim that all that is required for learning to take place is appropriate structuring of the learning material (Gagne).

3. the rapidly emerging tradition of constructivist psychology.

This tradition is similar to the behaviourist tradition in that it recognizes that the outcome of a learning experience depends not only on the instruction provided but also on the already existing conceptual framework of the learner.

Most authors in the field of "alternate conceptions" or "childrens' science" are in agreement that this work is best seen within the constructivist tradition. (Hewson, Osborne, Driver, Gilbert, Pope, Claxton.)

The constructivist approach:

The constructivist approach to learning in science is based on a cognitive theory of personality, namely the *Personal Constructs Theory* of George Kelly first put forward in 1955.

1. *Personal Constructs Theory*:

(i) General:

This theory of personality, like the theories of Freud and Rogers, was developed primarily out of considerable contact with clients during therapy. (Pervin, 1970, p.333.) It is primarily a theory of man's efforts to conceptualise (i.e.to construe) his environment. It is a cognitive theory of personality in that it emphasises the ways in which an individual perceives stimuli, the way he interprets and transforms these stimuli in relation to already existing structures and the ways in which he behaves in relation to these interpretations and transformations. (Pervin,1970,p.333) The theory is holistic. It emphasises individual differences and the stability of behaviour over time and across situations. The first consideration of the theory is the individual person, not parts of him or processes manifested in his behaviour. Pervin (1977,p.334) says of Kelly's theory that: "it is an extremely imaginative effort to interpret behaviour in cognitive terms."

(ii) Kelly's view of man:

Theories of personality have in them implicit philosophical assumptions about the nature of man. To appreciate any such theory it is crucial that one should be fully aware of these underlying assumptions. In the case of Kelly he assumes that man is a Scientist.

> *"To a large degree - though not entirely - the blueprint of human progress has been given the label of "science". Let us then, instead of occupying ourselves with man- the biological- organism or man- the lucky- guy, have a look at man the scientist"* (Kelly,1955,p.4)

Man experiences events, notices similarities and differences among these events, formulates concepts or constructs to order his observations and uses these constructs to anticipate or predict events. Man is therefore active.

> *"Man looks at his world through transparent patterns or templates which he creates and then attempts to fit over the realities of which the world is composed ...... Let us give the name constructs to these patterns that are tried on for size. They are ways of construing the world."* (Kelly,1955,p.8-9)

While all men are Scientists in that they all use constructs and follow the same psychological processes in using these constructs, individuals are unique in the way in which they use a particular construct.

It is clear from the above quotation that for Kelly there is no objective absolute truth and that events or phenomena have meaning which depends only on the way in which they are construed by the individual.

> "*.....whatever nature may be, or however the quest for truth will turn out in the end, the events we face today are subject to as great a variety of constructions as our wits will enable us to contrive.*"(Kelly in Millon,1973,p.209.)

According to Pervin,(1970,p.336) Kelly's view of Man has two major consequences:

Firstly,there is the view that man is oriented towards the future. Kelly is of the opinion that:

> "*Anticipation is not merely carried out for its own sake; it is carried on so that future reality may be better represented. It is the future which tantalizes Man, not the past. Always he reaches out to the future through the window of the present.*" (Kelly, 1955,p49.)

Secondly, it suggests that the individual has the capacity to represent the environment rather than merely respond to it. Individuals have the ability to continually interpret, reinterpret, construe and reconstrue their environment. Life is a representation of reality and it is this quality of life which enables man to make and remake himself. Only man has the ability to link the past with the future and to construct his own way of viewing things. Man is both free and determined as the:

> "...... *personal construct system provides him with both freedom of decision and limitation of action - freedom because it permits him to deal with the meaning of events rather than forces him to be helplessly pushed about by them, and limitation, because he can never make a choice outside his world of alternatives he has erected for himself.*"(Kelly,1955,p.58.)

Man is free to construe events but is then bound by his constructions. He can change his constructions by reconstructing his environment and his life. Seen in this way, man is neither a victim of his past history, nor of his present circumstances unless he wants to construe himself in that way. (Pervin, 1970,p.337)

(iii) <u>Kelly's philosophical position:</u>

As we have stated above, theories, be they of personality or otherwise, have underlying philosophical assumptions which it is crucially important to understand if the theory is to be fully appreciated. In the case of the Personal Constructs Theory, the underlying assumption is:

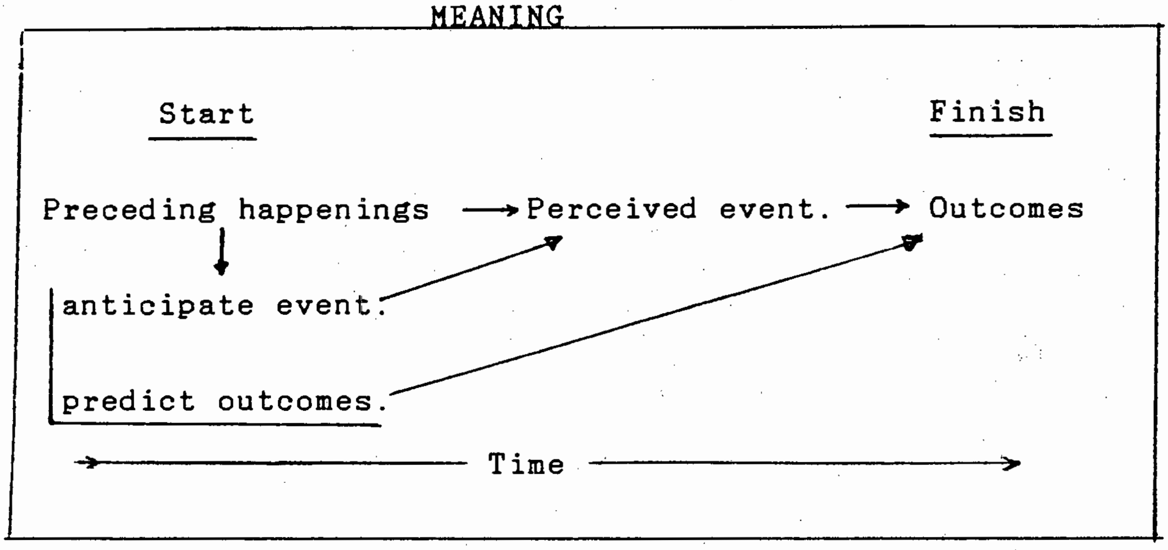
> ".....*that whatever nature may be, or howsoever the quest for truth will turn out in the end, the events we face today are subject to as great a variety of constructions as our wits will enable us to contrive.*"(Kelly in Millon, 1973,p.209)

This philosophical position Kelly calls "constructive alternativism". According to this position there is no objective reality or absolute truth to discover. Man construes events by making representations of phenomena in order to make sense out of them. Inherent in this view is the idea that for any event a very large number of alternate constructions exist which may represent the event differently.

> " *But it does remind us that all our present perceptions are open to question and reconsideration, and it does broadly suggest that even the most obvious occurrence of everyday life might appear utterly transformed if we were inventive enough to construe them differently*".(Kelly in Millon, 1973, p.209).

(iv) <u>The meaning of events:</u>

Constructive alternativism stresses the importance of events and that the individual gives meaning to the event. The meaning given to an event is: "anchored in its antecedents and its consequents." (Kelly in Millon, 1973, p.210). In other words, the meaning an individual links with an event is determined by what preceded the event and what the outcomes of the event were. For an event to have meaning the passage of time is important as events can be seen to have a start and a finish. The following diagram is an attempt to represent the above view of the meaning of an event.



The preceding happenings are the means whereby the event is anticipated and allow for the prediction of the outcomes of the event which follows. Thus the meaning of an event also includes the way in which it is anticipated (Kelly in Millon,1973, p.210). It follows from this that if identical events are identified by different means (different precedents) then these identical events will have different meanings. Further, if the assumed outcomes of identical events are different, then the meanings given to the same event will also be different. Similarly, events which are different will be considered identical if their precedents and outcomes are perceived to be the same.

So, to summarize:

* an event is anticipated by preceding happenings;
* an event has outcomes;
* the outcomes of an event can be predicted from the preceding happenings which leads to the event being anticipated;
* preceding happenings, event and outcomes together

constitute meaning for an event;

* whether events are perceived as being similar or different will depend on whether the preceding events and outcomes are perceived as similar or different.

It is through events that we confirm our predictions and construe meanings (Kelly in Millon,1973,p.210). However, as the same event may have different meanings, the same event may confirm different constructions. Different and even incompatible events may confirm the same construction. Meaning therefore assumes the "shape of the argument which led him to his predictions" (Kelly in Millon, 1973,p.210), i.e. meaning is given by the line of reasoning used to lead to the prediction. The only outside check we have for our constructions are events which confirm or do not confirm our predictions or expectations. Kelly comments on this view of meaning as follows:

> "*This is a long way from saying that meaning is revealed by what happens, or that meaning is something to be discovered in the natural course of events, or that events shape men and ideas. Thus in constructive alternativism events are crucial, but only man can devise meaning for them to challenge.*" (Kelly in Millon,1973,p.210)

It follows from this view of meanings of events that if a particular construction successfully predicts the outcome of a particular event that it need not necessarily be a good construction of reality as:

(i) a different interpretation of events may have lead to an equally successful prediction;

(ii) our expectations may have influenced our perception of what actually happened.

So, although events may be in agreement with a construction we cannot be sure that they have proved the construction to be true as there are always other alternate constructions, some of which may be better. All that can be done is to "project our anticipations with frank uncertainty and observe the outcomes in terms in which we have a bit more confidence." (Kelly in Millon,1973,p.210). It is important to realise that the importance of events and their perceived meanings lie in the fact that they are the only means we have of checking our constructions of reality.

(v) <u>The nature of constructs</u>:

To describe any individual we need to know *what* he is like, *how* did he get to be like that and *why* does he behave like he does (Pervin,1970,p.57.). To answer the "what is he like" question, Kelly, in describing "man the scientist" uses the concept of the "construct". "A construct is a concept the individual uses to categorise events and to chart a course of behaviour". (Pervin,1970,p.341) According to Kelly we anticipate events by construing or interpreting their replications. We experience events and interpret them, placing a structure and meaning on such events. While we are experiencing events we notice that some events share common characteristics which distinguish them from other events. We notice similarities and contrasts amongst events. This is important as this construing of a *similarity* and *contrast* pole leads to the formation of a construct (Pervin,1970,p.341.). Without constructs life would be chaotic. No two events are ever exactly the same and we make abstractions by construing events as being similar to each other and as being different from other events. In doing so, we develop a construct and impose some order and regularity on the world. Constructs are not:

> *"essences distilled by the mind out of available reality. They are imposed upon events and not abstracted from them. There is only one place they come from : that is from the person who is to use them. He devises them. Moreover, they do not stand for anything, or represent anything, as a symbol, for example, is supposed to do."* (Kelly in Millon,1973, p.213.)

Now, knowing what constructs are not, let us see what they are. Kelly sees them as reference axes, not unlike Cartesian axes in mathematics, upon which we may project events in an effort to make sense out of them. They act as guidelines for locating events, including ones which have not yet occurred. They help us to locate events, understand them and anticipate them.(Kelly in Millon,1973,p.213.). However, while Cartesian axes have an infinite number of points, constructs only have two. "A construct is the basic contrast between two groups" (Kelly in Millon, 1973,p.213) A construct has a similarity pole and a contrast pole. At least three elements are necessary to form a construct; two must be perceived as similar to each other and one as different from these two. The way in which the two elements are construed to be similar form the similarity pole of the construct. The way in which they are different from the third element forms the contrast pole of the construct.(Pervin,1970,p.341.) Constructs therefore refer to the nature of the distinction one attempts to make between events.(Kelly in Millon,1973,p.213.) There is not an infinite number of points between the similarity and contrast poles but subtleties and refinements in the construct are made by using the constructs of quantity (nothing - a lot) and quality (good-bad). In this way, for instance, the the construct black - white in combination with a quantity construct can lead to a new scale of: black, slightly black, slightly white and white.(Pervin,1970,p.341.)

Constructs allow us to discriminate between events and by successive application to two events at a time, events can be placed on a scale. The construct itself however, is absolute. It may change with time, may not be accurate, but it must be absolute.(Kelly in Millon,1973,p.214.)

The same construct may be applied to a number of different events with varying degrees of success. The events to which its application appears to be the most useful are called the *range of convenience* of the construct. Within the range of convenience of the construct there are some events to which the construct, when applied, has the maximum usefulness. These events form the *focus of convenience* of the construct.

We can categorise constructs in a number of ways. For instance:

(a) *core constructs* - constructs which are basic to a person's functioning;

(b) *peripheral constructs* - constructs which may be altered without serious changes to the core construct;

(c) *permeable constructs* - constructs which admit newly conceived elements into their range of convenience;

(d) *impermeable constructs* - constructs which lead to the rejection of new elements;

(e) *tight constructs* - constructs which lead to unvarying predictions;

(f) *loose constructs* - constructs which lead the individual to expect a different set of outcomes under similar conditions;

(g) *verbal constructs* - constructs which have consistent word symbols associated with them;

(h) *pre-verbal constructs* - constructs which have no word symbol associated with them. They might have been learnt before the development of language.

The constructs used by a person for interpreting and anticipating events are organised as part of a system. Within this system the constructs are organized into groups in order to minimize incompatibilities and inconsistencies. The arrangement is hierarchical. A *superordinate construct* includes other constructs within its context while a *subordinate construct* is one which is included in the context of the superordinate one. Constructs may be superordinate in some part of the system and subordinate in other parts of the system. (Pervin, 1970,pp.341 - 343.)

People differ in the organization of their constructs. An individual's construct system defines his personality. His construct system is his personality. We employ constructs to interpret our world and to anticipate events. Two people are similar because they use similar construct systems. To understand someone, one has to know something about the constructs which he or she uses, the events included under these constructs, the way in which the constructs tend to function and the way in which they are organised in relation to one another to form a system. People belong to the same cultural group because they share certain ways of construing events and because they share the same kinds of expectations about certain kinds of behaviour. (Pervin, 1970, p.343.)

(vi) <u>Process in Personal Construct Theory</u>:

Process in personality theory tries to answer the questions:

* Why does someone behave as he does ?
* What drives his behaviour ?

As mentioned earlier (p.7) Kelly sees humans as psychologically active. We do not have to be prodded into action. The direction in which our actions will take us is stated in his basic postulate, namely:

> *"A person's processes are psychologically channelized by the ways in which he anticipates events."* (Kelly in Millon,1973,p.210)

This postulate implies that we:

> *"seek prediction, anticipate events, reach out to the*

> *future through the windows of the present. In experiencing events, the individual observes similarities and contrasts thereby developing constructs. On the basis of these constructs the individual, like the scientist that he is, anticipates the future. As he successively construes the replication of events, he successively modifies his constructs in the service of more accurate and efficient prediction of his environment. Constructs are tested in terms of their predictive efficiency."* (Pervin,1970,p.350.)

The direction of behaviour is determined by the fact that:

> "*A person chooses for himself that alternative in a dichotomized construct through which he anticipates the greatest possibility of extension of his system."* (Kelly in Millon,1973,p.214.)

Man selects the course of behaviour which he believes will offer the greatest opportunity for anticipating future events. While real scientists try to develop better theories, ordinary people try to develop better construct systems.

Personal Construct Theory can be viewed as consisting of a basic postulate and some eleven corollaries, some of which are set out below in an attempt to give some idea of its structure.

Basic postulate: A person's processes are psychologically channelized by the ways in which he anticipates events.

1. *Construction corollary*: A person anticipates events by construing their replications.

2. *Individual corollary*: Persons differ from each other in their construction of events.
3. *Organization corollary*: Each person characteristically evolves, for his convenience in anticipating events, a construct system embracing ordinal relationships between constructs.
4. *Dichotomy corollary*: A person's construct system is composed of a finite number of dichotomous constructs.
5. *Choice corollary*: A person chooses for himself that alternative in a dichotomized construct through which he anticipates the greater possibility for elaboration of his system. Note that the choice is between alternatives expressed in the construct and not between objects divided by the construct. A construct governs what man does. When we make a choice we align ourselves in terms of our constructs.
6. *Experience corollary*: A person's construct system varies as he successively construes the replication of events. The construct may be applied to a different part of the environment (Kelly uses the term"galaxy") or it may become a slightly different kind of distinction or its relations to other constructs may be altered. (Kelly in Millon,1973,pp.210 -216.)

(vii) <u>Growth and development:</u>

Kelly is not explicit about the origin of the systems of constructs. Constructs are derived from construing the replication of events, but Kelly makes no effort to elaborate on the kind of events that would lead to the different kind of construct, e.g. tight constructs or permeable constructs. Pervin is of the opinion that children who experience the opportunity to examine many different events and have many different experiences will develop complex cognitive structures. On the other hand, children who experience long-standing and severe threat will develop constricted and inflexible construct systems. The question of which factors determine the content of construct systems is of critical importance to Pervin. He feels that this is particularly so in education since part of education appears to be the development of complex, flexible and adaptive construct systems.(Pervin, 1970, p.354.)

(viii) <u>Change in constructs and construct systems:</u>

Kelly sees three conditions as favourable to construct change:

1. There must be an air of experimentation. Constructs must be seen as being tried on for size; these become the hypotheses which lead to further experimentation and reconsideration on the basis of experimental evidence.
2. The provision of new elements. New elements unbound by old constructs should be recognised and confronted.
3. The availability of validating data. The knowledge of results facilitates learning. New elements introduced and attempted by old constructs will lead to invalidation of the construct system. This leads to new hypotheses being formed for which validating data must be available if experimentation is to be checked. (Pervin,1970,p.360).

Kelly's ideas about change must be seen in their proper place, namely in treating clients in psychotherapy. His is not essentially an educational theory. However, it is extremely useful to the science educator because as we will point out later on, Science is in itself a creation of the human mind as far as the concepts and ideas used by scientists are concerned (Driver,1986). Furthermore, Science can be viewed as a carefully checked construction of the real world. It is also the opinion of many researchers in learning in science that when children interact with their physical environment, they develop construct systems that are useful in predicting the outcomes of events (Claxton, Driver, Hewson, Osborne, Bell, Gilbert). Just as the observations by Scientists about certain phenomena are effected by the theory which they are working within, the observations as well as the sense made of their observations by children will depend on the construct system which they have developed to deal with their physical world.

2. *The application of Personal Construct Theory to learning in Science:*

(i) <u>The constructivist view of Science:</u>

Kelly was of the firm opinion that there is no objective, absolute truth and that events only have meaning depending on the way in which they are construed by the individual. The constructivist view of Science is that far from Science being about the "real" world, concepts such as electrons, quarks, electromagnetic fields, etc. are not part of our sense impressions and are in fact not even abstracted from the "real" world. Most recent philosophers of Science reject the notion of the existence of an objective base of observations against which theory can be checked. (Driver and Oldham,1986.) The dominant view is that while we may assume the existence of an external world, we do not have direct access to it. Science is not so much a discovery as a carefully checked construction. The task of Science is to invent theories which aim to represent the world. This point of view is very much in line with that of Kelly who thought that the role of Science was not to discover truth, but to develop construct systems that are useful in anticipating (predicting) events (Pervin,1970,p.337.). Driver (1986) quotes Einstein and Infeld as follows:

> "*Science is not just a collection of laws, a catalogue of facts. It is the creation of the human mind with its freely invented ideas and concepts. Physical theories try to form a picture of reality and to establish its connections with the wide world of sense impressions.*"

While **Einstein and Infeld** clearly distinguish between the world of ideas and concepts of the Scientist and the world of sense impressions, **Popper** in fact discerns three worlds:

* the world of sense impression;
* the individual's constructions of the world;
* the public world of the scientists' shared constructions as documented in books and research reports. (Driver,1986.)

According to **Koestler** (in Pope and Gilbert,1983.) theorizing in Science is highly personal and highly emotional. It is a myth that scientists' reasoning is strictly logical and "lacking in the sensuous and original quality of poetic imagination". Concepts and theories do not follow from observation in a simple inductivist way. **Head and Sutton** (in Pope and Gilbert,1983) liken the construct system to a mosaic which changes with time. Affective factors integrate with cognitive factors in the person's attempts to make sense out of experience. We see in events occurring in nature only what the concepts which we use to interpret these events allow us to see. (Novak,1978.) It is concepts, not the methods of inquiry, that are at the core of rational human thought, including the rational basis of science and mathematics.(Kuhn and Toulmin in Novak,1978.)

(ii) <u>The constructivist view of the learner:</u>

Very much in line with Kelly's idea of constructive alternativism, the learner is seen as having the following characteristics:

* He lives in a world which is real.
* All his observations are theory-laden.
* He uses personally appealing explanatory hypotheses to cope with events in his environment.
* He tests these hypotheses through interaction with reality against personally appealing criteria.
* Reality provides him with guidance as to the adequacy of the hypothesis tested
* When he judges hypotheses which he has tested as inadequate, either the hypotheses or the test criteria are modified or replaced.(Gilbert and

Swift,1985.)

Hewson (1980) stresses the active role of the learner in the construction of his own personalized knowledge as opposed to the view that the learner is the passive recipient of collected wisdom. According to Hewson, there are two assumptions about human thought and behaviour which underlie the constructivist view of the learner:

1. The knowledge which he already possesses is of critical importance in his attempts to make sense of his experiences. His observations are theory-laden.
2. He strives to make sense of the natural world.

   "*They seek to find meaning in their varied experiences. They wish to differentiate the undifferentiated and incessant flow of information they receive. They look for structure in the world around them, and attempt to construct conceptions of these experiences. These conceptions, these models, these theories are attempts by individuals to provide an explanation of the meaning and purposes of their perceived world*" (Hewson,1980)

(iii) <u>The constructivist view of learning:</u>

Learning, according to Hewson,(1980) is a constructive activity which involves the interaction of the learner's existing knowledge, beliefs and skills with the ideas presented resulting in a synthesis of old and new which leaves neither unchanged. The learner's existing knowledge consists of organised units or conceptions which contain a wide variety of bits of information interrelated with one another to form an organised structure and the appropriate procedures for using this structure. These conceptions can be used to make sense out of a new situation or phenomenon, construct another conception which is more appropriate to the new situation, solve a problem or tackle another task. Each individual's knowledge is unique, though not infinitely diverse.(Hewson,1980) It is important to appreciate that the sense made out of any event is dependent not only on the situation itself but also on the individual's intentions, beliefs, emotions and prior knowledge. (Driver and Oldham, 1986.) The learner is active in that he has to continually construct new meaning as he interacts with the material to be learnt.

Driver and Bell (1986) present a constructivist view of learning as follows:

1. Learning outcomes depend not only on the learning environment but also on the knowledge of the learner.
2. Learning involves the construction of meanings. Meanings constructed by the learners from what they see or hear may not be those intended by the teacher. Construction of meaning is influenced to a large extent by learners' existing knowledge.
3. The construction of meaning is a continuous and active process.
4. Meanings, once constructed, are evaluated and can be accepted or rejected.
5. Learners have the final responsibility for their learning.
6. There are patterns in the types of meanings learners

construct due to shared experiences with the physical world and through natural language.

(iv) A constructivist model of learning:

The constructivist tradition contends that individuals constantly strive to erect knowledge structures which will enable them to act on, predict, describe and explain their environment.(Osborne and Wittrock, 1985.) For Wittrock, learning with understanding can only occur if learners themselves actively construct or generate meaning from sensory input. This proposition is central to his model. In this he complements the ideas of Kelly.(Osborne and Freyberg,1985,p.83.) In collaboration with Osborne, Wittrock has developed a model of learning called "The Generative Learning Model" (Osborne and Wittrock,1983.). According to Hewson and Hewson (in Osborne and Wittrock,1985) this model is central to the constructivist tradition.

The fundamental premise of generative learning is that people tend to generate perceptions and meanings that are consistent with their prior learning. These perceptions and meanings are something additional both to the stimuli and the learner's existing knowledge. To construct meaning requires effort on the part of the learner as links must be generated between stimuli and stored information. (Osborne and Wittrock, 1985.) The brain is not a passive consumer of information. It actively constructs its own interpretations of information and draws inferences from them. It ignores some information and selectively attends to other information. It is more than a blank slate which passively records incoming information. The stored memories and information processing strategies of the brain interact with the sensory information received from the environment to actively select and attend to the information and to construct meaning.(Osborne and Wittrock,1983) The generation of meaning is a fundamental cognitive process in comprehension. Meaning has to be actively constructed by the learner. This he does by inventing a model or explanation that organises the information selected from the experience being attended to in such a way that it makes sense to him, fits his logic, his real world experience or both. People retrieve information from long-term memory and use their information processing strategies to generate meaning from the incoming information, to organize it, code it and to store it in long-term memory.(Osborne and Wittrock,1983.)

The generative learning model, then, is concerned with the influence of existing ideas from which sensory input will be selected and given attention, the links that are generated between stimuli and aspects of the memory store, the construction of meaning from sensory inputs and the information retrieved from long-term memory, the evaluation and possible subsumption of the constructed meanings.(Osborne and Wittrock,1985.)

The key postulates of the model are:

1. The learner's existing ideas will influence what use is made of the senses and in this way the brain can be said to actively select sensory input.
2. The learner's existing ideas will influence what sensory input is attended to and what is ignored.
3. The input selected or attended to by the learner has

of itself no inherent meaning. Statements have meaning only to the person who makes them. The sounds which he uses to convey the idea have no meaning in themselves.

4. The learner generates links between the input selected and attended to and parts of memory store.
5. The learner uses the links generated and the sensory input to actively construct meaning.
6. The learner may test the constructed meaning against other aspects of memory store and against meanings constructed as a result of other sensory input. This involves the generating of links to aspects of memory store and the comparison of the newly constructed meaning with other related ideas that can be constructed from memory store. Is the newly constructed meaning compatible with prior constructions?
7. The learner may include (subsume) constructions into memory store. If the newly constructed meaning makes sense in terms of its evaluation with other aspects of memory store, it may become incorporated into memory and in so doing may influence and possibly alter the memory store. The greater the number of links generated to other aspects of memory store and the greater the number of these links that reaffirm that a useful constructed meaning has been made, the more likely it is that the idea will be remembered and make sense to the learner.

8. The need to generate links and to actively construct, test out and subsume meanings requires individuals to accept a major responsibility for their own learning. All the activities involved in learning with understanding require that the individual makes an active intellectual effort. (Osborne and Wittrock,1985.)

As far as instruction is concerned it is clear that the generative model places central importance on the memories, prior knowledge and experience which pupils bring with them to the learning experience. It stresses the active involvement of the learner in his or her own learning. In terms of the model, teaching can only be understood by knowing the generations it induces in the learner. (Osborne and Wittrock, 1983.)

(v) <u>A constructivist view of concept change:</u>

There are three important ideas about learning in the constructivist tradition:

1. People strive to make sense of the natural world.
2. The knowledge which the learner possesses is of critical importance in his or her attempts to make sense of his or her experience.
3. Different people may construct different or alternate conceptions from the same information (and may insist that theirs is the only sensible one.) (Hewson,1981.)

When an individual learns, there is an interaction between existing ideas, new ideas and the information presented to him. This interaction produces a synthesis of old and new so that both become changed. (Hewson,1981.) Thus learning can be seen as a process of conceptual change during which:

1. the old concept must be discarded;
2. a new conception must be accepted;
3. a conflict between the old conception, other beliefs and past experience must be resolved;
4. the new conception must become available to interpret new experiences at the appropriate moment in the future.(Hashweh,1986.)

Conceptual change may take place in at least one of the following three ways:

1. New conceptions may be added through the individual's further experience, development and contact with other people.
2. Existing concepts may become reorganised as a result of exposure to a new idea or as the result of thought processes. *Posner et al* (1982) refer to these two processes as assimilation.
3. Existing concepts may be rejected as a result of some conceptual reorganization or because they are displaced by a new concept. This Posner et al call accommodation.

After careful consideration of a number of models of conceptual change, **Hashweh** (1986) considers the model of Posner et al to be the best developed. This model was developed by drawing on the work of philosophers of science, especially Kuhn, Lakatos and Toulmin, on the ways in which concepts change in Science. The basic postulate of the model developed by Posner et al (1982) is that learning is a rational activity. Ideas are accepted and comprehended because they are seen as intelligible and rational. Judgement is made on the basis of available evidence which includes the learner's current concepts. These current concepts guide and organise his or her investigation into a new phenomenon. Posner et al stress that they cannot agree with the empiricist view that the mind is a blank tablet upon which experience writes. Without existing concepts, they suggest, it would be impossible for the learner to ask any question about the new phenomenon, to know what would count as an answer to the question, or to distinguish relevant from irrelevant features of the phenomenon. Concepts do not exist in isolation. They are a part of a conceptual ecology. The intellectual environment in which a person lives, i.e. his cultural beliefs, language, accepted theories, observed facts and events, determine which concepts will be inhibited and which will develop. This is not unlike the process of natural selection in biology. (Hewson,1985) The intellectual environment is seen as an ecological niche and conceptual ecology is seen as the dynamic interaction between a person's knowledge structure and the intellectual environment in which he or she lives.

To facilitate a radical conceptual change a conceptual ecology must contain the following:

1. *Anomalies:* The character of the specific failures of a given idea is an important part of the ecology which selects its successor.
2. *Analogies and metaphors*: These serve to suggest new ideas and to make them

intelligible.

3. *Epistemological commitments*:
   (i) Explanatory ideals: Most fields have some subject matter-specific views concerning what counts as a successful explanation in that field.
   (ii) General views about the nature of knowledge: standards such as elegance, parsimony, economy and not being *ad hoc*. These ideas do not depend upon which subject the person is working in.

4. *Metaphysical beliefs and concepts*:
   (i) Metaphysical beliefs about science: beliefs about the extent of orderliness and symmetry of the Universe; beliefs about the relation between science and commonplace experience.
   (ii) Metaphysical concepts of science: Scientific concepts often have a metaphysical quality in that they are beliefs about the ultimate nature of the Universe and as such cannot be refuted empirically.
5. *Other knowledge*:
   (i) Knowledge from other fields.
   (ii) Competing concepts. The concept selected must have more promise than its competitors. (Posner *et al*,1982)

According to Posner *et al*, conceptual change or exchange will occur if the following conditions are met:

1. There must be dissatisfaction with the existing conceptions. The existing concept may not be able to be reconciled with new knowledge or a new experience which cannot be ignored. It is also possible that the dissatisfaction may occur from within the concept itself if it is seen to violate some epistemological commitment, e.g. if it is clumsy or unnecessarily complicated. (Hewson,1981)
2. The new conception must be intelligible. The person has to be able to construct a coherent representation of the new concept. The person has to see that it is internally consistent.
3. The new conception must be initially plausible. It must appear to have the capacity to solve problems generated by its predecessors. Is it consistent with other ideas?
4. The new concept must be fruitful. The new concept may remove anomalies experienced by its predecessor or it may suggest new experiments or approaches. Advantage must be gained, unsolved problems solved and understanding increased.

When a person who has a concept about a certain phenomenon is faced with a new concept relating to it , then the following may happen to the new concept:

1. It may be rejected.
2. It may be incorporated into the existing conceptual

network by : (i) rote memorization;

(ii) replacing the old concept and being reconciled with remaining concepts. Hewson refers to this process as "conceptual exchange"(Hewson,1981).

(iii) being reconciled with the existing conceptions by the process of "conceptual capture". This happens when the person notices significant links between the two concepts, notices that the concepts do not contradict each other and that they are part of the same integrated set of ideas. (Hewson,1981.)

(vi) <u>The application of Personal Construct Theory to learning in Science:</u>

Claxton (1985), has adapted Kelly's personality theory to learning in Science. He is of the opinion that the difficulties which children have in learning science and that teachers have in teaching science can be found in the the following "basic assumptions". Some of these assumptions can be supported by research and some are matters of intuition and conviction.(Claxton,1985.)

1. Children know a lot of science. This can be substantiated by research which show that children do not enter the classroom without any ideas or intuitions about many scientific topics. These ideas are not always in agreement with the ideas of

accepted science.

2. Children are scientists. Children have theories which underlie and produce their ideas of the world. Understanding is not acquired in parrot fashion but arises from a more or less consistent framework of ideas which has been built up over a long time.
3. Children are not consistent scientists. Children do not possess one grand theory, but rather a host of what Claxton calls "mini-theories", some of which are inconsistent with one another. The theory which they use depends on the circumstances and changing the circumstances will often have them change their opinions without noticing any conflict.
4. Mini-theories have a focus of convenience and a range of convenience. Initially a mini-theory starts out as an attempt to explain or make sense of a particular kind of experience (the focus of convenience) but later it becomes expanded to include other kinds of experience to which it is successfully applied. This developed domain of the mini-theory is called its range of convenience.
5. All knowledge and skills possess a range of convenience. No cognitive mechanism such as skills, abilities, etc are context-free. Claxton argues that all cognitive mechanisms and representations are context-specific i.e. are useful in certain situations only, are evoked by those situations and are used to explain those situations.

6. When existing theories are inadequate, we learn. The failure of a theory is a powerful stimulus for its development. Children possess a number of learnt strategies to cope with theory failure.
7. We vary in our personal commitment to our mini-theories. We are willing to discard some theories readily while others we cling to very dearly. **Lakatos** would call the theories which we hold dearly the "central core". They are very resistant to change as they determine how we view the world. The level of commitment to a mini-theory is crucial in determining how we will respond to its disconfirmation.

Mini-theories are seen by Claxton as being similar though more general than Kelly's constructs.

Our dealings with the world, and in this case with the biological and physical worlds in particular, are guided or mediated by a theory which has arisen partly from direct experience with the world and partly from informal learning. All our actions, expectations and explanations arise out of such theories. The results of actions taken which were based on the theories form the experimental data upon which the theories grow and feed. Initially mini-theories are born to make sense out of a particular experience or event. This experience or event is the focus of convenience of the theory. Later it may be found that the same theory may be used to successfully predict other events and so gradually the domain of the theory expands and its range of convenience grows. We discover the situations in which the theory works well and in so doing we refine its boundaries. Much of the young child's learning is of this kind. (Claxton,1985.) According to Claxton each mini-theory will contain:

1. specifications of the *situations* to which it applies (S);
2. *predictions* about the situation (P);
3. *actions* to be taken in the situation (A);
4. *descriptions* of the situation (D);
5. *explanations* relevant to the situation (E). ("SPADE")

The theory tells us what is likely to happen next given what is happening now. It tells us what to do on the basis of the predictions in order to bring about one state of affairs rather than another. It tells us how to divert the flow of events in our own interest. (Claxton,1985) The SPA bit operates best in an unconscious, unarticulated, spontaneous and intuitive way. There is no need to understand it. Once a child can talk he can bring into consciousness the set of descriptions and explanations associated with a particular theory operating within a particular domain of his experiences. The domain of experience may be fixed and invariant, such as the experience "going to bed", or variable such as "a day at the beach". The first kind of experience will lead to the development of rigid theories while the latter will lead to the development of more general-purpose mini-theories.

Claxton sees mini-theories applicable to science as originating in:

* early childhood experiences;
* the everyday use of language;

* learning in school.

He refers to these different domains as the domains of GUT SCIENCE, LAY SCIENCE and SCHOOL SCIENCE.

(a) Gut Science:

The domain of gut science is the child's world of immediate experience. Its foundations are laid in the first years of life and derives from the child's first-hand explorations of and interactions with his physical and biological environments. He drops things, rolls things, plays with the dog or cat etc. Gut science becomes part of the child, it manifests itself in his spontaneous reactions, intuitive judgements and everyday perceptions. It is tested against the criterion of whether it works and is useful. Claxton sees the sensorimotor child as a lively and intelligent scientist - albeit an intuitive one. He formulates hypotheses, notes the consequence of his behaviours, and modifies the content and scope of his theories.

Gut science is characterised by the fact that most of it is incoherent; consists of many theories, each with its own domain, and has very little concern with the integration of and consistency between domains. Much of it is inarticulate, not available to consciousness and incapable of being expressed. The descriptions and explanations of gut science are tied closely with the child's experiences. Gut explanations often boil down to "because I know it" - not intellectually but experientially.

(b) Lay science:

Lay science has its origin in the form and content of the language that a child grows up to speak and in the accounts and images of experiences conveyed to him by peers, parents and the media. In other words, it originates in his culture. The structure of his language in subtle ways determines whether to him the world is a cause-and-effect place or whether cause and effect are the same. Common cultural wisdom may lead to the idea that water drains clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere whether or not this is in fact true. Because of the nature of its origin, lay science is not based on the child's direct experience. It is accepted passively from people whom the child trusts. With time these ideas may become so much part of his world view that he is not even aware that they are there. This makes lay science particularly difficult to change.

Lay science may also originate visually i.e. through what the child sees. Television, science fiction films and comic books all lead to an immense store of knowledge, beliefs and fantasy which the child cannot if confused, test directly but which give him points to argue and converse about. Some lay science may be evaluated with respect to its utility but mostly its function is to be entertaining and to allow successful conversation with parents and peers. As such, most lay science can be articulated but, like gut science, is incoherent and piecemeal. Children do, however, improve the coherence and acceptability of their lay science through discussion with friends and parents.

(c) School science:

Claxton asserts that initially school science applies to a world of make-believe in so far as it deals with lines of no width, frictionless pulleys, weightless ropes, etc. Eventually this world becomes the "ideal" world. The child is confronted with a world which is far removed from his real world, a world where his experiences are not to be trusted. He has to accept knowledge because he is told that it is right or true in spite of the results of his own experience. The knowledge he receives is carefully articulated, conscious, orderly, coherent and deliberately transmitted and received.

(d) <u>The interaction between gut and lay science:</u>

When a child is confronted with new knowledge at school this knowledge is confronted by the already existing stock of theories which he has in his gut and lay science domains. Gut science is purely experiential. Lay science originates in his language and in the socially transmitted and frequently wrong and inaccurate scientific explanations which he picks up from his elders and other people whom he trusts, as well as through exposure to the media. Many of the mini-theories of gut and lay science address the same event without the individual being aware of it. Quite often the theories may actually be in conflict with each other in that the action produced by gut science and the explanation produced by lay science are in conflict. The resolution of conflict between his experiential knowledge and his socially derived knowledge is an important developmental enquiry, especially when it is realised that the knowledge presented at school will be " screened" by the existing theories.

The conflict between theories may be resolved in a number of ways once it has become apparent. As a result of investigation:

* the conflicting theories may become integrated into one

theory;

* the one theory may become part of the other;
* a new theory may be separated to deal with the area of conflict;
* it may be realised that one of the theories is misplaced and as a result this theory is then relocated.

The outcome of any of these ploys is that the system of theories is improved. However, it is also possible that conflict resolution does not occur at all because the child does not like giving up a particular theory. Ways of denying that conflict exists are found in various defensive mechanisms. He may not want to investigate the conflict or actually feel a need to investigate areas of conflict. It is also possible that it is threatening to him to give up a particular theory as he feels strongly identified with it himself. In a sense giving up the theory is giving up part of himself. In such a case learning becomes a threat to the child, to his knowledge structure and to his social stability. The child may opt to ignore the conflict or to relocate the one theory by rewriting the situation specifications i.e. "When do I use this theory"? In this way children will respond quite differently to a science problem given to them in a classroom situation than they will if the same problem is presented to them at home or at play with their friends. They have in effect insulated school science from their gut and lay science theories.

(vii) <u>The implications of a constructivist approach to science teaching:</u>

Earlier in this chapter evidence was presented which suggests that children have their own ideas about science topics which are taught at school. These ideas are often not the same as those we wish to teach and these ideas act as a screening device in that the new information given to the children is compared with the existing information about the situation under discussion. This interaction between existing knowledge of the child and the new knowledge presented to him results in some unexpected outcomes. Gilbert *et al* (1982), have identified the various possible outcomes as follows:

1. The new view is rejected but some of the language used to introduce it may become part of the child's way of expressing his own ideas.
2. The new view is rejected but becomes compartmentalized as the child knows that it is useful for passing examinations. The new information has little or no effect on his actual view of the world.
3. The new information is misinterpreted as a result of the existing knowledge and is now seen as actually reinforcing his own ideas.
4. The scientific idea is learnt, understood and appreciated by the learner but not properly integrated; the result is that some of it may be self-contradictory.
5. The new idea is accepted and properly integrated

with the rest of his concepts. The child's view of the world has now changed in a consistent way.

An aim of science teaching is to replace the ideas of the children with ideas accepted in science. Learning involves the changing of concepts and teaching should provide a rational basis for conceptual change. (Posner *et al*,(1982.) The ideas discussed under the model of conceptual change therefore apply in the teaching situation. This means that:

1. The child must be dissatisfied with his existing conceptions.
2. A new conception must be introduced and seen to be intelligible, plausible and fruitful.

Nussbaum and Novick, (1982) have developed a teaching strategy which is based on Posner *et al's* model of conceptual change. They propose the following steps in using their strategy in the classroom:

1.(a) Create an "exposing event" which requires the pupils to invoke their alternate conceptions or mini-theories to interpret it.
(b) Encourage the pupils to describe their ideas both verbally and pictorially.
(c) Assist pupils in stating their ideas clearly and concisely, thereby making them aware of the elements in their own alternate framework or mini-theory.
(d) Encourage confrontation in which pupils debate the pros and cons of their different ideas and increase their awareness and understanding of the

differences between their own frameworks and those of their classmates.

2. Create a "discrepant event", i.e. one which creates conflict between exposed alternate ideas and some observed phenomenon which they cannot explain.

3. Support their search for a solution, encourage them to test their ideas against experimental evidence and encourage emerging accommodation. Encourage pupils to articulate and elaborate the desired conception when it is proposed.(Nussbaum and Novick,1982.)

It is clear that central to this teaching strategy is the idea of conceptual conflict. Claxton is of the opinion that conceptual conflict is quite easy to avoid as the mini-theories in conflict may be in different domains, e.g. one may be located in gut science and the other in lay science.

For conceptual conflict to occur and for the successful accommodation of the new idea, he stresses that the following conditions must be met:

1. The two conflicting mini-theories must cover the same event but belong to different domains
2. They must be simultaneously active.
3. They must generate conflicting predictions, actions and explanations
4. The conflict must be perceived and recognised by the learner.
5 The learner must feel a need to resolve the conflict.

6. Appropriate learning strategies must be engaged.
7. Defensive strategies must be avoided.
8 A satisfactory resolution to the conflict must be found.

It is quite clear that the strategy proposed by Nussbaum and Novick includes many of Claxton's requirements. However, Claxton is at pains to stress that it may not be easy to produce the desired conflict between conflicting mini-theories as they are very context-dependent and that the one which is used to deal with a particular situation may not be the one which is evoked by a very similar situation if the context is seen as being different. This of course makes the selection of situations to explain, introduce or exemplify a concept rather difficult.

The generative learning model stresses that the existing ideas of a learner interact with incoming sensory information in such a way that he selects from the information only that which will make sense of the situation in terms of his existing knowledge. If this is true then it follows that:

1. the metaphors and analogies used in teaching may not have the expected effects.(Claxton, 1985.) The everyday use of language interferes with the acquisition of new technical terms.
2. the observations made during practical work and the inferences drawn from these observations may not at all be the ones which the practical was designed for. Driver, (1981) is of the opinion that much more time must be spent by pupils and teachers to think and talk through the implications and possible explanations of

the observations which they have made during an experiment. The laboratory is an amazing place for beginners in science and they should be given time to familiarise themselves with the apparatus, sights, sounds and smells which are generated by their experiment. The attention of the children should be guided during practicals to make the observations which we consider to be relevant. This implies detailed and carefully structured worked out practical sheets.

3. As far as *curriculum development* is concerned the implications are that the material presented in the primary school and the ideas that children have should interact in a way that will make sense and be meaningful to the children. The material should be relatable to the prior experiences and prior knowledge of the children in a range of ways to both the needs of the children and the society. The material should be testable by the children through simple investigation.(Osborne and Wittrock,1985) In the junior secondary phase the emphasis should shift to the challenging of the ideas which the children have and which are incompatible with further learning in science.

4. The questioning skills of children must be developed. This should be seen as being of prime importance. (Osborne and Wittrock,1985.) The teacher should set an example here by acting as a Socratic tutor.(Posner et

al, 1982.) Children must learn to ask critical questions about their own ideas and those of others. Perez and Alis (1985) stress that for conceptual change to occur, children must acquire a new method of dealing with the natural world. They must ask questions, put forward hypotheses, design experiments to test them, carry out the experiments, analyse the results carefully and in so doing move away from their "methodological superficiality" which led them to the "wrong" ideas in the first place.

5. Claxton sees the role of the *teacher* as one who will be:

   "deliberately contriving disparities, persuading children to entertain these disparities as felt conflicts, and supporting them through the process of conflict resolution so that they do not opt for a premature or defensive solution, but persist until a satisfactory reconciliation and integration of the two, originally disparate, theories is found and consolidated......he will spend more time asking pupils what they think than telling them what he thinks, and will have to be prepared to let them design and run their own tests, even if flawed, with great self-restraint."

It is quite clear from what has been said that one of the immediate consequences to us would be that we need to cover less material, teach less, listen more and reflect very much more upon our own existing ideas about our subject and about the way in which it should be taught. Should we be teaching less of the facts of Science as has been discovered over millenia and more of the method used to make those discoveries possible?

CHAPTER 2.

Review of the literature

Introduction:

Practising science teachers have long realised that the way in which their pupils viewed the world around them differed in numerous ways from the view portrayed by science. However, as we have pointed out in chapter 1, interest in the way in which children " see" the world around them and the way in which they reason in Science has increased sharply during the past decade. The following table from Osborne and Freyberg (1985, pp. 13-14) covers some of the areas that have been investigated to date:

Specific Topics	
Kinematics:	Caramazza, McCloskey and Green, 1981; Trowbridge and McDermott, 1980, 1981; Jones, 1983.
Mechanics:	Leboutet-Barrell, 1976; Viennot, 1979; Champagne, Klopfer and Anderson, 1980; Hewson, 1981a; Gilbert, Watts and Osborne, 1982; Clement, 1982, 1983; di Sessa, 1982; Minstrell, 1982; White, 1983; Watts and Gilbert, 1983; McCloskey, 1983; Champagne, Gunstone and Klopfer, 1983.
Force:	McCloskey, Caramazza and Green, 1980; Osborne and Gilbert, 1980b; Sjoberg and Lie, 1981; Gunstone, Champagne and Klopfer, 1981; Watts and Zylberstajn, 1981; Watts, 1983a.
Energy:	Stead, 1981; Watts, 1983b; Duit, 1983; Solomon, 1983.
Friction:	Stead and Osborne, 1981a.
Floating and Sinking:	Rowell and Dawson, 1977; Rodrigues, 1980; Biddulph, 1983.
Gravity:	Gunstone and White, 1980, 1981; Stead and Osborne, 1981b; Watts, 1982.
Pressure:	Engel and Driver, 1981; Sere, 1982.
Heat:	Erickson, 1979, 1980; Tiberghien, 1980.
Temperature:	Stavy and Berkovitz, 1980; Strauss, 1981; Driver and Russell, 1982.

Light:	Guesne, 1978; Stead and Osborne, 1980; Eaton, Anderson and Smith, 1982; Goldberg and McDermott, 1983; Anderson and Karrgvist, 1983.
Change of State:	Andersson, 1980; Osborne and Cosgrove, 1983.
Electric Current:	Tiberghien and Delacote, 1976; Andersson and Karrqvist, 1979; Russell, 1980; Fredette and Lochhead, 1980; Osborne, 1981, 1983; Fredette and Clement, 1981; Hartel, 1982; Shipstone, 1982; Cohen, Eylon and Ganiel, 1983.
Chemical Change:	Schollum, 1982; Andersson and Renstrom, 1982.
Burning:	Schollum and Happs, 1982.
Particulate Nature of Matter	Novick and Nussbaum, 1978, 1981; Nussbaum and Novick, 1982; Osborne and Schollum, 1983; Brook, Briggs and Driver, 1984.
Earth Sciences:	Nussbaum and Novak, 1976; Nussbaum, 1979; Happs, 1982a, 1982b, 1982c; Klein, 1982; Sneider and Pulos, 1983.
Living:	Angus, 1981; Tamir, Gal-Choppin and Nussimovitz, 1981; Brumby, 1982.
Plant:	Bell, 1981a.
Animal:	Bell, 1981b; Bell and Barker, 1982.
Natural Selection:	Deadman and Kelly, 1978; Brumby, 1979; Kargbo, Hobbs and Erickson, 1980.
General Reviews	Driver and Erickson, 1983; Gilbert and Watts, 1983.

Since our own interest is essentially in mechanics, this literature review will concern itself with investigations into the beliefs of school children and university and college students in the areas of force, gravity and the motion of falling objects, the trajectories of falling objects and velocity.

A: Force

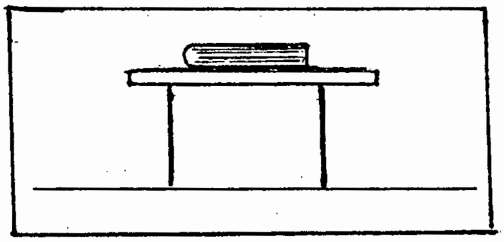
The concept of "force" is central to understanding and learning in mechanics and hence in physics as a subject. In this review we will be looking at the beliefs held by students and children in the areas of:

1. forces acting on bodies at rest;
2. Newton's Third Law;
3. force and motion.

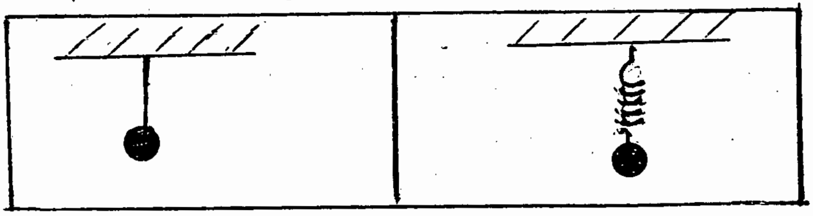
1. *Forces acting on bodies at rest, or "passive" force.*

McDermott (1984) refers to these forces as "passive" and defines such a force as one "which adjusts itself in magnitude in response to an applied force." Researchers in this area have typically presented their subjects with two situations, namely:

(a) an object at rest on a supporting surface, e.g. a book lying on a table:



(b) an object at rest suspended by a string or spring:



The subjects were required to identify the forces acting on the objects. The results obtained show clearly that many of the subjects do not recognise the presence of the passive upward force.

In a study of pupils' conceptual understanding in physics, **Driver** in 1973 (in McDermott, 1982, p.3) spent several months closely observing four junior high school pupils in the laboratory school at the University of Illinois while they were conducting experiments and discussing the material presented with each other and with their teacher. Their remarks were recorded and later transcribed. The children found it very difficult to accept that a table or chair could exert a force when there is no motion involved. For them the ability to exert a force was associated with something that was alive. These views proved to be very resistant to change and were still a problem at the end of the school term.

Minstrell (1982) working with his high school class of 25 pupils in the United States recorded similar difficulties with the concept of a normal force. Before any formal teaching of force had begun he asked his pupils to draw the forces acting on a book lying on a table and to explain in their own terms what keeps the book at rest on the table. Their classroom discussions were recorded and transcribed. All 25 pupils included in their sketch the downward force due to the earth's gravitational attraction, but only 50% showed the upward force exerted by the table. Furthermore, many of them considered air pressure to be responsible for keeping the book stationary. Among those who believed that the book remained where it was because of a combination of forces, many believed that the downward forces must be greater than the upward ones to keep the book down.

Helm (1978) administered a multiple choice questionnaire to 33 first year physics students at Rhodes University in South Africa, 460 matric pupils from English-medium private and Cape Education Department schools as well as 65 teachers of Mathematics and Physical Science. The paper consisted of 20 questions designed to reveal the existence of misconceptions and difficulties in the understanding of physical concepts. In one of the questions the subjects had to select the false statement concerning the forces acting on a block resting on a table. 67% of the students, 53% of the pupils and 59% of the teachers selected the correct item. 16% of the pupils and 9% of the teachers thought that the item which specified that the block had two forces acting on it, i.e. the earth's gravitational force and and the upward force of the table, was false. **Ivowi** (1984) adapted Helm's paper for use in Nigerian schools. He administered the test to 257 15 - 17 year old pupils from 8 Nigerian secondary schools. In answering the question regarding the block lying on the table, 55% of the pupils selected the correct item, with 11.7% of the pupils indicating that they thought that the item which specified that the block had two forces acting on it, the earth's gravitational force and the upward force of the table, to be false. Furthermore, 14.4% of the pupils considered the item which stated that the forces acting on the block to be equal and opposite, to be false.

In an attempt to discover more about the "intuitive preconceptions " of children about forces and equilibrium as well as any changes which occur in their conceptual framework as a result of maturation and instruction, **Terry, Jones and Hurford** (1985) in Wales presented a number of children from two comprehensive schools with a sketch of a box resting on a table and asked them to explain in their own words what kept the box there. They were also asked specifically if it was necessary for the table to exert a force on the box. Their sample consisted of 57 pupils in the midpoint of their third year, 46 pupils in the midpoint of their fourth year and 55 pupils in the midpoint of their fifth year of study of physics. In addition, the third year group had done a course on force in their integrated science course but had had no formal instruction in Newton's First Law or equilibrium. The fourth year group had been introduced to Newton's First Law and had some experience of Newton's Second Law. The fifth year pupils had received instruction in all three of Newton's laws. They found that:

(i) The third year group could identify only one force acting on the box: the downward force due to gravity. They asserted that it was not necessary for the table to exert an upward force on the box. In later discussions they found it difficult to accept that inanimate objects could exert a force at all. Only 5% correctly indicated the forces acting on the box and only 6% thought that the table could exert a force.

(ii) A small number of fourth year pupils had developed an understanding of static equilibrium. 16% gave the correct answers to the forces acting on the box and 25% were aware that the table exerts a force on the box. Over 50% stated that the box remained at rest "because no external forces acted on it"

(iii) 59% of the fifth year pupils could not explain this simple case of static equilibrium. Only 54% thought that the table must exert an upward force on the box but very few were explicit in their overall description of the equilibrium situation. Many of them invoked Newton's Third Law as a reason for static equilibrium.

In a follow-up on this investigation, pupils were asked to draw the forces acting on the box when it was:

(i) suspended by a spring;

(ii) supported on the palm of the hand.

In case (i) about 50% of the third year pupils now identified two forces acting on the the box , i.e. the downward force due to gravity and the upward force exerted by the spring. Over 40% could identify two forces in case (ii).

Sjoberg and Lie (in McDermott, 1984 , p.2) conducted a survey in Norway by administering a written questionnaire to over 1000 subjects from all three levels of the upper secondary school, future teachers, university students and graduate physics students. The aim of the study was to identify some common conceptual errors and to estimate their frequency and persistence through different levels of physics instruction. The subjects had studied physics over periods ranging from less than a full year to several years. In one of the questions the subjects were asked to identify the forces acting on a stationary pendulum. They found that about 50% of the secondary school pupils who had one year of physics omitted the tension in the string while about 40%

of the future teachers and 10% of the graduate students failed to indicate this force.

Halloun and Hestenes (1985) administered a diagnostic test in physics to determine the initial knowledge about motion held by students taking a first course in physics at the Arizona State University. Their test was of the multiple choice type and it was written by 1500 students and 80 pupils at a nearby high school. The aim of the test was to develop a diagnostic tool to predict future performance in the physics course. To investigate more deeply the "common sense" beliefs of the students about motion, the researchers interviewed 22 students in depth about their answers to the questionnaire. They found, amongst other things, that for many of the students only living things are recognised as being able to exert a force.

2. *Newton's Third Law*

Research into the beliefs held by students and pupils about the forces present in situations to which this law applies has centred on:

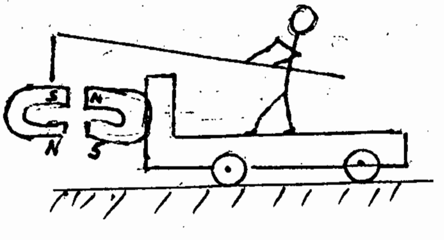
(i) identifying action-reaction pairs;
(ii) interaction between objects;
(iii) interaction forces between objects of unequal mass and
(iv) action-reaction pairs where motion is involved.

(i) Identifying action-reaction pairs:

Terry and Jones (1986) asked 39 16 year old pupils who had just completed an O-level course in physics in Wales to interpret in terms of Newton's Third Law a variety of situations in which two objects interact with each other. The task consisted of a series of line drawings depicting the situation. The questions were designed to show how pupils understand the Third Law. One of the questions dealt with the static situation and showed a man standing on the ground. The pupils were asked to identify the Third Law force which is "paired" with the weight of the man. Only two pupils correctly identified this force as the force exerted by the man on the earth. Over two thirds of the remainder identified this force as the one exerted by the ground on the man. In another problem the pupils were shown a stone falling freely under gravity and once again they had to identify the Third Law force which is paired with the gravitational force acting on the stone. Only 4 pupils correctly identified this force while about half of them cited air resistance as the paired force.

(ii) Interaction between objects:

In the **Terry and Jones** investigation cited above the pupils were asked to predict the outcome of situations in which two objects interacted with each other. In one of the problems the diagram showed a man trying to get a cart to move using two magnets as shown in the sketch:



The pupils were asked to discuss the possibility of the cart moving. About 90% thought that it would and gave as their reason the attractive force between the two magnets. In a question linked to the previous one two people were shown standing in a boat. The pupils were asked to explain what would happen to the motion of the boat if one person pushed against the other. Only 15% of the pupils responded correctly to this question.

(iii) Interaction forces between objects of unequal mass:

In his survey of misconceptions in Physics amongst South African university students and school pupils and teachers, **Helm** (1978) asked subjects to compare the direction and magnitude of the gravitational force acting between two bodies of unequal mass which are far away from any other massive bodies. The one body was half as massive as the other. 79% of the student group, 64% of the pupils and 34% of the teachers thought that the less massive body exerted a smaller force than the more massive one. **Terry and Jones** (1986) showed their pupils in Wales two situations depicting two roller-skaters connected by a rope. In the one case the roller-skaters were of equal mass and in the other case the one roller-skater was clearly more massive than the other. The pupils were asked to predict what would happen if one of the skaters pulled on the rope. Over 90% of the pupils correctly predicted that in the first case they would move towards each other. However, in the case involving skaters of unequal mass about 50% of the group thought that the more massive skater would remain stationary while the less massive one would move towards him. When further asked to compare the force exerted by an insect on the windscreen of a moving car with that of the car on the insect, 60% thought that the force exerted by the car on the insect would be greater than that exerted by the insect on the car.

(iv) <u>Action - reaction pairs where motion is involved:</u>

Watts and Zylberstajn (1981) administered a multiple-choice questionnaire which used line drawings depicting various situations, in order to investigate the prevalence of non-Newtonian ideas about force and motion amongst British school-children. An interesting aspect of their questionnaire was that the children were asked to include a reason for their choice. Their sample consisted of 125 pupils who were at the end of their third year of studying physics as a subject at school. These children were about 14 years old and in transition between doing physics as a compulsory subject or as an elective one. They attended four comprehensive schools in Reading and London. Two questions dealt with a tug-of-war situation in which one of the participants was winning. 82% of the pupils thought that the person who was winning was exerting a greater force on the rope.

Maloney (1984) investigated the understanding of the interaction between two blocks by students at Creighton University in Nebraska. The following situations were depicted:

(a) the blocks were at rest and in contact with each other;
(b) the blocks were moving with constant velocity with one block pushing or pulling the other;
(c) the blocks were being accelerated with the one block

pushing or pulling the other.

In addition, in each case the two blocks could be of equal or of different masses. The questionnaire used depicted the situation under consideration by means of a sketch. In each case the same three options were provided namely:

A exerts a larger force than B;

The forces are equal;

B exerts a larger force than A.

Maloney's sample consisted of volunteers from three different groups of students. Group one were students who were just starting a one year general course in physics, group two consisted of non-science majors enrolled in a general education science course and group three consisted of junior and senior chemistry majors enrolled in a one year chemistry course in which general physics was a prerequisite.

As a result of his work **Maloney** was able to identify a number of "rules" which the students had used when solving these problems. 11% of the sample thought that, irrespective of the situation, the greater mass always exerted a greater force. 16% of the students thought that only in moving systems does a greater mass exert a greater force. 19% thought that when moving, the block causing the motion, i.e. the one which is pushing or pulling the other one, exerts the larger force. 8% thought that only in accelerating systems will the larger mass exert the larger force while a further 9% thought that only in accelerating systems does the block causing the motion exerts the larger force. In a follow-up study, Maloney looked at the rules employed by students who did not take college physics and those who had. His sample consisted of 62 non-physics and 68 experienced physics students. He found that the more experienced group used different rules from the less experienced. They were much more likely to consider the "at rest" and "constant velocity" situations as being the same. Fewer students in this group used mass as the only basis for their decisions. The interesting thing is that although the groups used different rules in solving the problems, the difference in success was not great. No non-physics students used the correct strategy to solve the problems while only 6 physics student used the correct strategy. 24% of the non-physics group used the rule that for moving systems the block causing the motion exerts the larger force. 25% of the physics group used the same rule when working with accelerating systems, i.e. the block causing the acceleration exerts the larger force. A further 25% of this group used the rule that for accelerating systems the larger mass exerts the larger force.

In summary then it appears that:

(i) pupils experience great difficulty in correctly identifying Third Law force pairs;

(ii) pupils have great difficulty in analysing the interaction between objects;

(iii) pupils think that when bodies of unequal mass interact then the more massive one exerts the larger force;

(iv) when motion is involved the agent causing the motion is seen as exerting the larger force;

(v) as those who teach Newton's Third Law will be able to vouch for, this is a very difficult area for pupils and teachers alike.

3. *Force and motion:*

According to **McDermott** (1984) the beliefs which children and students hold about force and motion have been investigated by using one of the following four methods:

(i) written tasks;

(ii) interview about instances techniques;

(iii) laboratory tasks;

(iv) computer simulations;

(i) Written tasks:

In a paper dealing with the concepts which young French people have in mechanics, **Leboutet-Barrel** (1976) describes a study from which he concludes that students consider forces to be one of the following two types:

(a) real interaction forces which act upon masses such as gravity or the tension in a string;

(b) a force associated with the motion of the body. The force has the same direction as the velocity and becomes zero at the same time as the velocity does. It is thought of as a property of mass such as inertia or impulse.

Viennot (1979) presented a written questionnaire to about 2000 French, Belgian and British students. Two thirds of the students were at university level and the other third at school level.

One of the questions in the questionnaire showed six balls thrown in the air by a juggler. The balls were all at the same height but were travelling with different velocities and on different trajectories. The velocity and path were indicated for each ball. The subjects were asked to indicate whether the forces acting on the balls were the same. About 50% of the subjects thought that the forces were unequal. From the responses to this question and to others, Viennot concludes that her subjects think that:

(a) if the velocity is zero, then the force acting on the body is zero, even if its acceleration is not zero.

(b) if the velocity is not zero then the force acting on the body is not zero even if the acceleration is zero. In other words, there is a force acting in the direction of motion of a body when it is travelling with constant velocity;

(c) if the velocities of bodies of identical mass are different, then the forces acting on them are different even if the accelerations are the same.

McCloskey, Caramazza and Green (1980) carried out a study in which they wished to determine the understanding of the principle that objects move along straight lines in the absence of external forces. Their sample consisted of 47 undergraduate students at the Johns Hopkins University in Baltimore. 15 of the students had not had any high school or college physics, 22 had completed one high school physics course and 10 had completed at least one course in physics at college. The students were shown sketches of curved tubes down which a ball was allowed to roll. They had to sketch the path which the ball would follow upon emerging from the tube. Another of the questions showed a ball being swung in a circle at the end of a string. Again the students were asked to draw the path the ball would follow after the string breaks and the ball travels freely. To ascertain why the students sketched the paths which they did, they were interviewed after the test. The investigators found that overall 36% of the students drew curved pathways. 49% of the students who had no physics at all, 34% of the students who had completed one course in physics at high school and 14% of those who had completed one year or more of physics at college level drew curved pathways. In the post-test interviews most of these students indicated that they believed that an object moving through a curved tube acquires a force which causes it to continue on a curved path. This force gradually dies away and the path will tend to become straight after a while.

McCloskey (1983) describes a study carried out by himself, **Kohl** and **Washburn** in which American high school pupils and college students had to solve several problems about motion and explain their answers. They found that in many cases the subjects held the idea that a force "of motion" of the object kept it moving and that this force is gradually dissipated due to friction or some other opposing force. **Kohl, Washburn and McCloskey** (in McCloskey, 1983) tested the knowledge about motion amongst high school pupils before and after they had completed a physics course. They found that 93% of the pre-course and 80% of the post-course pupils held the idea that moving bodies have a force acting on them in the direction of the motion. This idea is clearly a very tenacious one amongst students in many nations. In the study by **Sjoberg and Lie** (1981) cited on page 59 above, their subjects had to indicate the forces acting on a swinging pendulum. The authors report that a "substantial" number included a force in the direction of the motion of the pendulum.

In the study by **Watts** and **Zylberstajn** (1981) cited on page 63 above, six questions were included to test the idea that motion implies a force in the direction of motion. Three questions dealt with the forces acting on a stone which has been thrown vertically upwards and three with the forces acting on a cannon ball in flight after it had been fired from a cannon. About 85% of the pupils associated force with motion. The stone was very frequently seen to have a force acting upwards away from the person's hand as it moves upward, and in the case of the cannon ball a force directly away from the cannon which moves it through the air. Furthermore, a large number of the children thought that the force acting on the body decreases as its velocity decreases.

Clement (1982) asked 150 first year students enrolled in a pre-engineering physics course at the University of Massachusetts to indicate the direction and relative magnitude of the forces acting on a coin which has been thrown vertically upwards. The students all had high school physics but no courses in physics at university level. 18 of the students had to solve the problem during an individual interview which was video-taped. Only 12% of the students could correctly solve the problem. The most common mistake was the addition of a force in the direction of motion of the coin. This idea was also brought out very strongly in the interviews with expressions such as " the force of the throw, the upward or original force, the force that I am giving it."

In a further problem students were shown a rocketship floating along in space The rocket motor was fired for a short while and students were asked to sketch the path along which the rocket ship would travel while the motor was being fired and after it had been shut off. Only 11% of the subjects could draw the change in the trajectory correctly while only 38% could correctly predict its path after the motor had been shut off. 41% thought that it would return to its original direction of travel. It would appear that students believe that there is an initial force acting on the rocket on its initial path and that after the motor is shut off, this force takes over again. **Clement** calls this the "motion implies force" preconception. This preconception includes the following ideas:

(a) continuing motion, even at constant velocity, implies the presence of a force in the direction of motion that is greater than any opposing force;

(b) changes in an object's speed may be accounted for by a force which "dies out" or "builds up".

Clement went on to administer the same test to a group of students after they had attended a course in mechanics. Although there was an improvement in the scores of the post-course students, "an alarmingly high number of students still gave wrong answers of the same kind on these very basic problems." For instance only 25% of the post-course students could solve the coin problem.

Osborne (in Osborne, 1985, p.45) reports on a study which he carried out amongst children in New Zealand to ascertain the prevalence of the view that the presence of a force is required to keep an object moving, as had been found by **Watts** and **Zylberstajn** in their study on children in England. He selected a representative sample consisting of 200 children in each of the age groups 13 , 14 and 15 years old. The children all did science at school. In addition he selected 100 each of 16 and 17 year old pupils studying physics at school. A multiple choice questionnaire was used in which one of the questions included a sketch of a person throwing a ball upwards. The ball had left the person's hand and sketches were used to indicate the forces acting on the ball. The pupils had to select the correct sketch for the ball on the way up, at the top of its flight and then on the way down. Osborne found that 46% of the 13 year olds, 53% of the 14 year olds and 66% of the 15 year olds consistently selected a force in the direction of motion. About 55% of the 15 and 16 year olds held the same view. Only about 22% of the overall sample consistently selected the correct option.
In their study reported above **Halloun and Hestenes** found that 65% of their subjects held the belief that "every motion has a cause".

In an unreported preliminary study to this one, in 1986 P.E. Spargo and myself administered a test to 213 first year engineering students at the University of Cape Town as well as to the Method of General Science group in the School of Education. The test was written by the engineering students before any instruction in university physics had begun. We wanted to find how widely the notion that motion implies a force in the direction of motion was held by these students, virtually all of whom would have passed through a Physical Science course at a South African school as part of their matriculation course. A multiple choice test was used in which we supplied five different options. The subjects were asked to indicate the forces acting on:

(a) a swinging pendulum at different points along its path;

(b) a ball which has been thrown horizontally away from a person once it has left the person's hand;

(c) a ball thrown vertically upwards once it has left the thrower's hand.

The following table summarises our results.

Question.	Group.	Percentage selecting options involving a force in the direction of motion.
Pendulum	Engineers	62
	Teachers	78
Horizontal ball	Engineers	68
	Teachers	90
Vertical ball	Engineers	68
	Teachers	92

It is clear from the above results that the idea that a force which acts in the direction of motion is associated with a body when it is moving with constant velocity is an extraordinarily tenacious one. The engineering students represent a very select academic group of pupils from our schools and although these students are expected to use Newton's First and Second Laws in calculations, it would appear that few of them actually understand the implications of the First Law. The results achieved by the student teachers are of great concern. It is quite clear that this group has a very poor grasp of the implications of the First Law and that they will without doubt transmit some of their lack of understanding to their pupils.

(ii) <u>Interview about instances:</u>

This method of investigating a subject's understanding of a physical concept was developed by **Osborne and Gilbert** (Osborne and Gilbert, 1980). The technique consists of showing a subject up to 20 cards, each depicting a familiar situation. Line drawings are used to represent the situation. The cards include situations which contain an instance of the concept under investigation and situations which do not contain an instance of the concept under investigation. The subject is asked, for each situation in turn, whether he or she considers it to contain an instance of the particular concept or not. He or she then has to supply reasons for his or her choice. The discussion is taped and later transcribed. This method allows the subject to ask questions to clarify any ambiguities, real or perceived, before answering the question. It also gives the investigator the freedom to discuss with the subject reasons or lack of reasons for a particular answer .

In a study by **Osborne and Gilbert** (1980) 40 British pupils of average scholastic ability ranging in age from 7 to 19 years were interviewed about the concept "force". Analysis of the interviews showed that:

(a) children consider forces as having to do with living things: only living things can exert a force;

(b) constant motion requires constant force. The idea that the force which caused the motion initially can be "used up" while the object is moving, is very common.

(c) the quantity of motion is seen as being proportional to the quantity of force. Motion here is not seen as acceleration. No motion implies no force. Moving fast implies a large force.

(d) if a body is moving, then there is a force acting on it in the direction of its motion.

(e) forces are seen as residing inside objects and make things happen.

(iii) <u>Laboratory tasks:</u>

McDermott (1984) reports on work done by **Lawson** at the University of Washington. **McDermott** does not give details about the sample of students used but it would appear that they were drawn from different levels of competence in physics. Some at least were from a physics honours course. His aim was to explore student understanding of, amongst other things, the concept of force and the connection between force and motion in the laboratory. Understanding of the concept was assessed by seeing whether the subject could apply the concept, or a relation between it and another concept, to the motion of objects in the laboratory. The students observed demonstrations and performed tasks that required the manipulation of apparatus. Student activity and answers in response to questions asked, were recorded during individual demonstration interviews. The apparatus consisted of a smooth glass table upon which one or more dry ice pucks were placed. The student could use a blast of air from a hose to apply a force: a brief blast to apply an instantaneous force or a constant force by keeping the hose a fixed distance from the puck. As the distance between the puck and the hose increased the force exerted by the blast decreased.

In the first task the students were required to make a relatively massive puck move in a straight line with constant speed. To achieve this the students tried one of the following procedures:

> a constant blast, a steadily decreasing blast, a series of short blasts or a single short blast.

The use of a constant blast represents an underlying belief that a constant force is required for uniform motion to continue while the application of a single blast represents an underlying understanding of Newton's First Law.

After having completed the manipulations, the students were asked to explain the motion of the puck and to describe the forces acting on it at different points along its path. **Lawson** found that about half the students applied the incorrect procedure on the first trial by applying a constant blast. In another task the students were required to deflect through an angle of 45 degrees to the original path a puck moving at constant velocity in one direction. Here the most common incorrect procedure was to aim the hose at the moving puck in the same direction as the student wanted it to go. The rate of success on this task was similar to that on the uniform motion task.

The actions and answers of the students indicate that they lacked a consistent conceptual system. Their use of the word force and other technical terms was ambiguous and unstable. *It was clear that their problems could not be adequately summarised as the simple belief in the necessity of of a force in the direction of motion.* For many students force and momentum were not distinct concepts. McDermott lists a lack of understanding of vectors and an inability to apply vector algebra to the situation at hand as well as having very vague ideas of acceleration and its association with force as further factors which were involved in the poor performance of the students on the tasks.

In a study designed to investigate the combined effect of mathematical skill, conceptions about motion and reasoning skills, **Champagne, Klopfer and Anderson** (1980) presented tests in these various fields to 110 first year physics students at the University of Pittsburgh. To test the preconceptions about motion held by the students they were asked to observe the motion of objects during free fall and in various other situations on an Attwood machine. They had to describe their observations, answer questions about the motion of the objects and then justify their answers. Some questions asked the students to predict the motion they expected before they observed it. The responses were recorded in a preprinted answer booklet and protocol analysis was carried out on these to reconstruct the student's conception about the motion of objects.

An analysis of the protocols showed that the students do not enter the introductory university physics course with a lack of ideas about the motion of objects. In fact, the authors stress that each student appears to have a "rich accumulation of interrelated ideas that constitute a personal system of commonsense beliefs about motion." The contents of this commonsense belief system is qualitatively different from the formal Newtonian system of mechanics and can be characterised by the following four rules which were derived from the protocol analysis:

(a) a force, when applied to an object, will produce motion;

(b) under the influence of a constant force objects move with constant velocity;

(c) the magnitude of the velocity is proportional to the magnitude of the force; any acceleration is due to an increase in the force;

(d) in the absence of forces objects are either at rest or, if they are moving, they are slowing down, thereby consuming the momentum which they have stored under the influence of the original force.

It is very interesting to note the amazing similarity between these ideas extracted from university students and those collected from children by **Gilbert and Osborne.** The latter authors point out that this pre-instructional system has a loose structure, displays little interconnectedness and lacks an overlying formalism. *As a result it is highly flexible and can accommodate new information locally without producing conflict in other parts of the system. In this way new facts can be learnt without a major reconceptualization being involved.*

(iv) Computer tasks:

DiSessa (1982) developed a series of computer games to explore the understanding of force and motion amongst eight sixth grade pupils from a school in suburban Boston; i.e. the pupils were about 12 years old. They were chosen to represent the entire range of academic abilities and they all had eight weeks of roughly four hours per week of experience using the computer language Logo in a classroom environment. The games featured a "dynaturtle" that moved in a "Newtonian computer environment". The pupils were asked to make the dynaturtle move at different speeds and in different directions by applying a suitable "kick". This kick was a discrete version of a force and specified the change of velocity according to the relationship F = ma. In a game called "Target" the pupils had to direct the dynaturtle to strike a target with minimum speed on impact. In discussing the results of the study, **DiSessa** says that " in view of the striking difference in the abilities between and style which the student's exhibited in their other work, we were greatly surprised to see how uniform their responses were to the dynaturtle. Students seemed to have definite non-Newtonian expectations which were contradicted by the behaviour of the dynaturtle." The pupils seemed to believe that objects would move in the direction in which they were pushed regardless of the direction of their initial motion. In general the results of this study are very similar to those found in laboratory settings. (McDermott, 1984.)

White (1983) presented a series of force-and-motion problems, consisting of a spaceship in deep space being manoeuvred by an impulse motor, to 40 high school science pupils in an upper middle class suburb in Boston. The average age of the group was 16.4 years. Pupils had to explain how they would use the motor to manoeuvre the spaceship in various ways. One question for instance asked them how they would use the motor to make the spaceship travel in a circle. The results showed that many of the pupils had difficulty in determining the effect of a force on an object's speed and many neglected to take into account the object's current speed when attempting to predict how a force would alter it's direction of motion. The idea that objects move in the direction in which they are pushed seemed to be well established. **White** also concluded that an analysis of the reasons for selecting the wrong options reveals the existence of inconsistent ideas about force and motion. Based on this work **White** designed a game in which the spaceship is manoeuvred on a screen in a frictionless environment to give pupils an idea of the behaviour of a Newtonian object and to supply them with immediate feedback to their responses. Significant improvement followed in a written post-test after the games were played on the computer. (McDermott, 1984.) As a result of the work done by **Lawson**, **DiSessa** and **White**, McDermott (1984) concludes that to ascribe "Aristotelian" beliefs to students seem inadequate to account for the errors made in these more complicated situations.

B: Gravity

Research into the understanding of children and students about gravity has investigated the relationship between gravity and height, gravity and the atmosphere, gravity and the earth, as well as the speed of falling bodies. The methods of investigation used by the different investigators can be divided into:

(i) questionnaire studies;

(ii) interview studies;

(iii) interview about instances and a follow-up survey using a questionnaire;

(iv) laboratory demonstrations which require prediction and explanation of motion under the influence of gravity.

(i) Questionnaire studies:

Za'Rour, (1975), used a multiple choice questionnaire to investigate the misconceptions in science and the prevalence of the misconceptions held by Lebanese high school and university students in the Beirut area. His sample consisted of 1444 high school pupils from grades 9 and 11 and first year students at the American University of Beirut. One of the questions asked the subjects to compare the time of fall of two metal balls which were dropped at the same time but differed in that the one ball is twice as heavy as the other. 37.3% of the 9th graders, 30.1% of the 11th graders and 42.1% of the university students thought that the heavier ball would reach the ground first but not in half the time taken by the lighter ball.

Whitaker (1982) presented a questionnaire consisting of five questions about falling bodies to 100 students who were enrolled in an introductory physics course. The group consisted of 40 students who had taken physics at high school and 60 students who had not taken physics at high school. One of the questions asked the students to compare the time of fall of a 50 lb ball with that of a 5 lb ball if the balls were dropped simultaneously. 10% of the group who had studied physics at high school thought that the heavier ball would fall faster while 18% of those who did not study physics at high school though that the heavier ball would fall faster. The most popular reason given for this choice was:

(a) the heavier ball will travel faster than the lighter one;

(b) the mass of the heavier ball is greater; therefore it will accelerate faster;

(c) there will be more gravitational pull on the 50 lb ball than on the 5 lb ball.

In their study on children in the London and Reading area (see p.63 above) **Watts and Zylberstajn** included two questions to test the idea held by children that the heaviness of an object increases with height. This idea was reported by **Driver** in 1979 and again in her book (1983). In one of the questions the children were asked to compare the force acting on two identical cars placed on a slope with the one car being higher than the other. 48% of the children thought that the car at the top of the slope would be pulled down with a greater force than the one lower down. Furthermore, it would appear that many of the children saw the slope to be increasing the higher one goes up the incline, as 20% of the children saw the top part of the hill to be at a greater angle than the lower part.

In another question two objects of equal mass were shown connected to each other with a string and suspended across a pulley with one of the objects closer to the ground than the other. The children had to predict what would happen if the objects were released and free to move. 78% of them thought that the unaided objects would move until they were at the same height because, amongst other things, "The force on the block in mid-air is a lot stronger than the one on the ground so they become equal".

To test the beliefs children hold about gravity, the atmosphere and space, **Watts and Zylberstajn** included a sketch of an astronaut standing on the moon. A spanner which he is holding in his hand is released and the children were asked to predict what would happen to the spanner. 80% of the responses indicated that the spanner would either rise upward away from the surface of the moon or that it would stay where it was above the surface. The reasons given centred on the fact that the moon has no atmosphere and therefore no gravitational pull.

Maloney (1985) designed a study to identify the rules used by students in solving conservation of energy problems. His subjects were 80 volunteers who formed two populations: one group did science as a major and the other group did not. The students were from Creighton University in Omaha, Nebraska. As a part of the study the students were shown sketches which showed two carts with similar or different masses on an incline from where they would be released simultaneously from different heights. The students had to compare their speeds at the bottom of the incline. In another task carts of different masses and speeds were shown at the bottom of an incline and the heights reached by the carts up the incline had to be compared. In a further task carts were shown being released down one incline and the height reached up another incline had to be predicted. Although the aim of this study was not to investigate the beliefs of the students about gravity, the author infers from his results that well over 80% of the students were probably using the idea " heavier falls faster" in solving the problems.

(ii) Interview studies:

Selman, Krupa, Stone and Jaquette (1982) carried out a Piagetian study into the development of the understanding of science phenomena by children of working and middle class suburban white parents in the United States. Amongst the phenomena investigated were the two unseen forces of gravity and electromagnetism. Their subjects were 105 children ranging form pre-school through kindergarten to first grade. The children were interviewed to establish a score for logical reasoning ability and also for their understanding of gravity and electromagnetism. The scores on the logical reasoning test and the other two tests were compared statistically to see whether there was any relationship between them. Some children who scored low on the logical reasoning test scored high on the electromagnetism interview.

This was not the case for the gravity interview. The authors suggest that the children probably had more first hand experience with electrical phenomena than gravitational ones in their everyday life and that this would have given them greater opportunities to hypothesise about them than in the case of gravitational phenomena. This is difficult to accept. One would like to suggest that the reason is just the opposite, namely that the children had in a sense been over-exposed to gravity and had constructed reasons to explain their observations - reasons which are quite acceptable to them and because these "theories" work, they feel no need to review them regularly.

Ruggiero, Minzoni, Cartelli, Dupre and Vincenti-Missoni (1985) carried out an investigation into the common-sense beliefs which connect the elements weight, air, gravity and the phenomena of free-fall. 22 Italian middle-school children in the 12 to 13 year old age group were interviewed. The children were presented with a written questionnaire. As a result of the interviews a further set of questions were added and a further 40 children were interviewed. Of interest to us was their finding that children link the force of gravity with the presence of an atmosphere, that the moon possesses no gravity and that things fall because it is natural for them to do so. More particularly, 27.5% of the children though that in the absence of air, objects become weightless while 40% thought that falling was a natural process for which the presence of air is essential.

In the interview part of their investigation, **Halloun and Hestenes** (1985) found that some of the students thought that gravity:

(a) does not act in a vacuum;
(b) increases as a falling object approaches the ground;
(c) acts in different ways during free fall and during constrained fall;
(d) is a constant force and does not produce constant acceleration;
(e) causes heavier objects to fall faster than lighter ones.

(iii) Interview about instances:

Using the interview-about-instances approach, **Watts** (1982) interviewed 20 children from schools in and around the Greater London area. The pupils ranged from first to sixth form academically and from 12 to 17 years old in age. Each interview lasted for 40 minutes. From an analysis of the protocols Watts identified the following "alternate conceptions" of gravity held by the pupils:

(a) Gravity is a force that requires a medium to act through. All of the pupils thought that gravity needed something to travel through. The most common medium suggested was air.
(b) Where there is no air, there is no gravity. There is no gravity in space or on the moon. Its upper limit is the upper limit of the atmosphere.
(c) Gravity increases with height.
(d) Gravity is constant: moving objects try to but fail

to counteract gravity

(e) Gravity begins to operate when objects start to fall down and continues until the objects are at rest on the ground.

(f) Gravity is a large force.

(g) Gravity is selective. It does not act on all things in the same way, nor on the same things in the same way at all times.

(h) Gravity is not weight. Gravity can act with weight to keep things down.

In order to find how widespread these ideas were amongst children, **Gilbert and Watts** (in: Appraising the understanding of science concepts: 'Gravity') employed a survey-about-instances approach. Here children were presented with a sketch representing some event and had to select a multiple choice option for their answer to the question. The options presented to them would include those found by Watts. An explanation was also required. A final question asked children to complete the sentence: "Gravity is.........."

It is not clear how many pupils were used in this survey and there is also no information about their ages, but the authors found that children consider gravity:

(a) to hold things down on the ground;

(b) to be a downward push which prevents things from floating off the earth;

(c) is concerned with things falling downwards.

The sentence completion test yielded a number of responses which appeared to have been learned from textbooks, e.g. "Gravity is an attractive force between two objects." However, a number of responses indicated the involvement of the atmosphere as in "Gravity is a pressure down on things from the atmosphere".

(iv) Laboratory demonstrations and explanations:

Champagne and Klopfer (in McDermott, 1984) worked with twelve academically talented seventh and eight grade pupils who took part in a special science programme at the University of Pittsburgh. At the start of the programme the pupils were given a number of tests to investigate their preconceptions about free fall. In each test the investigator described a simple demonstration and asked the pupils to predict with reasons what would happen. The investigator then performed the demonstration and asked the pupils to explain any differences between their prediction and the actual observation. In one of the tests a single object was dropped a short distance and the pupils were asked to compare its speed at two different heights. Because of the short distances involved it was very unlikely that the pupils could observe any differences in the speed and so their preconceptions would be exposed. In another demonstration two objects of unequal mass were dropped from the same height and the pupils had to compare the times of fall of the two bodies. Further information was gathered by watching the pupils as they planned and conducted experiments involving free fall, or falling constrained by a modified Attwood's machine. The pupils could also use computer simulations which made it easy to observe the effects of changing the various parameters involved. The experimenters noted the activities and comments of the pupils and asked questions to probe their thinking. They found that:

(a) pupils realised that speed increases during free fall but many thought that the speed was proportional to the gravitational force even for relatively massive objects falling through short distances;

(b) about one third of the pupils thought that the time of fall was shorter for the heavier object;

(c) it was obvious that many of the pupils confused the concepts of mass and weight and of velocity and acceleration;

(d) some of the abler pupils reached the correct conclusions about objects in free fall by starting from the false premise that speed is proportional to force. This is a very striking illustration of how correct answers may conceal serious misconceptions.

In a further study by **Champagne and Klopfer** (1980) (reported on page 87 above),in which university students were used in similar tests i.e. to predict and then to explain differences between their prediction and actual observations, they found that most of the students thought that objects fall at constant speed by arguing that the speed depends only on the weight of the object and as this remains constant, so must the speed. Some students who were aware that falling bodies accelerate rationalised these conflicting ideas by arguing that the force of gravity increases nearer the ground as there is little or no gravity in space, which is far away from the ground. More specifically, they found that about 20% of the students thought that when an object is dropped it reaches its maximum velocity instantaneously and then falls at constant velocity. 80% of the students believed that, if all other things are equal, heavier objects fall faster than lighter ones and about 80% believed that "closer to the earth means heavier" for objects suspended on an Attwood's machine.

Gunstone and White (1981) at Monash University in Australia, investigated the understanding of gravity among more than 400 physics students by asking them to write responses to questions based on classroom demonstrations. In one of the demonstrations they mounted a bicycle wheel as a pulley and hung a bucket of sand on one side and a block of wood of equal mass on the other side. The bucket of sand was purposely placed higher than the block of wood. The students were asked to compare the weights of the two objects. More than 30% did not think that the weights were equal and many of the incorrect answers implied that the block was heavier because it was nearer the floor. **McDermott** (1984) states that this view that lower is heavier was also found to be prevalent amongst college students enrolled in a first year general physics course at the University of Pittsburgh. In the light of Watts's finding that children in England believe that gravity increases with height, it is interesting to speculate on the reasons for the differences observed between his sample and that of the American researchers. The context of the questions are probably important in determining the answers given.

In their review of the literature on misconceptions, Gilbert and Watts (1983) find that a number of studies indicate that:

(a) There is a close connection between the atmosphere and gravity. Gravity is concerned with the earth's atmosphere and extends only as far as the earth's atmosphere. Therefore there is no gravity in space, on the moon or, for some, underwater.

(b) Gravity acts differently on different objects and varies according to circumstances. It seems to increase with height, it makes heavier objects fall faster, acts on an astronaut's boots but not on hydrogen balloons. It causes objects nearer the ground to be heavier.

(c) It is associated with downward-falling objects, i.e. it only starts to act on objects when they fall.

C: Motion

In this section we review studies concerned with beliefs about the path along which objects will travel under two sets of circumstances:

(i) The object has initially travelled in a circle or on a curve and the constraining force has now been removed. This will be referred to as curvilinear motion.

(ii) The object had an initial horizontal velocity and has been released to fall freely. This will be referred to as projectile motion.

The beliefs which are held about these paths have been studied by:

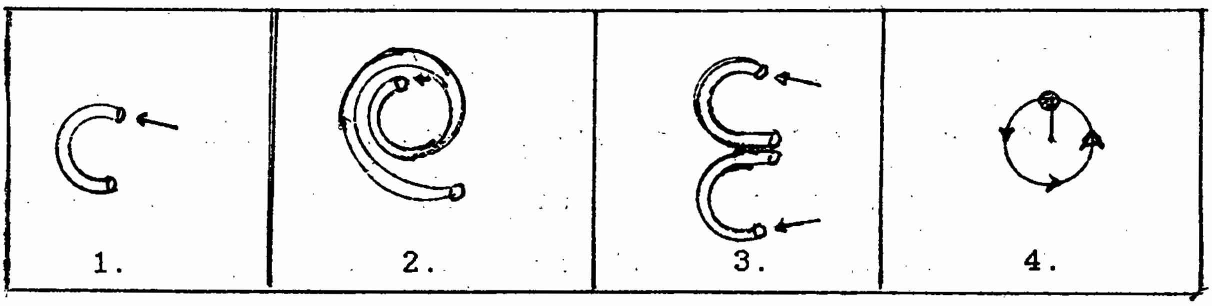
(a) using questionnaires;

(b) laboratory observations.

(i) Curvilinear motion:

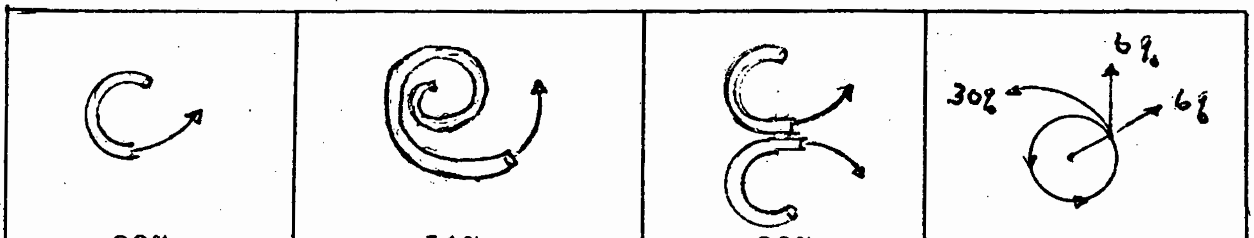
(a) *Questionnaire studies:*

McCloskey, Caramazza and Green (1980) wished to assess the understanding of the principle that an object will move in a straight line in the absence of an unbalanced external force. Their sample consisted of 47 undergraduates enrolled in various courses at Johns Hopkins University in Baltimore. Of the 47 students, 15 had taken no high school or college physics courses, 22 had completed one high school physics course and 10 had completed at least one college physics course. Each subject was presented with 13 simple problems, each one of which consisted of a line drawing and instructions which explained the drawing and specified the task to be completed. The following four sketches represent the four problems which are of interest to us.



Problems 1-3 show a metal tube down which a small ball is allowed to roll. The ball shoots out of the end of the tube and the subjects were asked to draw the path the ball would follow upon emerging from the tube. They were instructed to ignore air resistance. In sketch 4 they were told that they were looking down onto a metal ball which was being swung horizontally around a man's head. They were to assume that the string breaks when the ball is at the point where it is shown and asked to draw the path along which the ball would travel after the string had broken. The results of the test indicated that "many of the subjects clearly did not know that objects move in straight lines when no external force acts on them". 36% of the pathways which were drawn were curves. 49% of the students with no physics courses, 34% of the students who had one year of high school physics and 14% of the students who had completed one or more years of college physics drew curved paths. Furthermore, careful analysis of the data showed that while only 33% of the students had drawn a curved path for the ball emerging in 1, a full 51% had drawn a curved path for the ball in 2. A large number of those who had drawn a curved path for both 1 and 2 had drawn a path with a greater curvature in 2. This would suggest that many people believe that when a particle is forced to travel in a curve then it will continue to do so even after external forces no longer act on it and that the amount by which the path will curve depends on the amount by which the original path curved or perhaps on the time for which the particle was initially forced to travel in a curve, i.e. for how long the constraining force has acted on the particle.

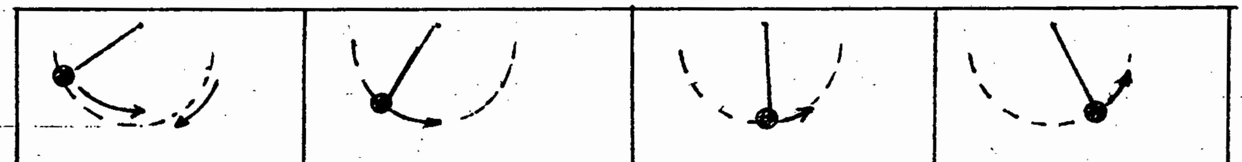
For the problem involving the ball being swung around a man's head, 30% drew curved paths. The sketches on the next page show the most frequent incorrect answers to each of the questions.



33% 1	51% 2	30% 3	4

It is also interesting to note that in post-test interviews some of the students who had indicated radial paths for the ball released in question 4 expressed the opinion that a centrifugal force pulled the ball outwards while the rope held it in and that when the rope broke the centrifugal force"yanked" the ball outwards.

In a further study **Caramazza, McCloskey and Green** (in Nickerson,1985) asked college undergraduates to draw the path that the bob of a pendulum would follow if the string were to be cut at the point indicated with the bob moving in the indicated direction. (See sketches below)



1	2	3	4

Only about one third of the students showed an appreciation of projectile motion. Common "mistakes" included the following:

(a) the ball would continue moving to the left if the string was cut when the pendulum is at the extreme left point of its swing;

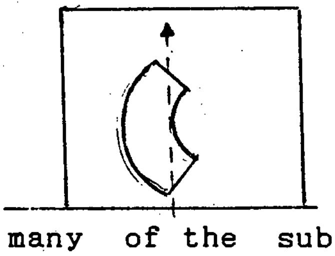
(b) the ball would fall straight down under the condition shown in sketch 3;

(c) the path the ball would follow is an extension of the string irrespective of where or when the string is cut;

(d) the ball would continue in the arc of the pendulum for a short while before falling straight down.

(b) *Laboratory observations:*

In an investigation into the role which the intuitive beliefs of people play in their interactions with real situations, **McCloskey and Kohl** (McCloskey, 1983) asked subjects to push a small puck mounted on a ball bearing through a 90 degree segment of a circle which was painted on a table. (See sketch)



They found that while many of the subjects knew that the puck could pass through the segment of the circle if it was pushed straight, 25% moved the puck in a curved path before releasing it, believing that it would follow the arc of the segment. They report that most of the subjects who tried this strategy were visibly surprised when the puck did not travel along a curved path!

(ii) Beliefs about projectile motion:

(a) *Questionnaire studies:*

In his investigation into the understanding of trajectory motion, **Whitaker** (1983) included the following three questions to test the understanding of freely falling bodies which have an initial horizontal velocity.

1. A train is travelling along a smooth straight track with a speed of 60 miles per hour. One of the boxcars has a hole in the floor. Directly above the hole is a bolt in the ceiling. Suddenly the bolt comes loose and falls. The bolt will:

   A. hit the floor in front of the hole.
   B. fall through the hole.
   C. hit the floor behind the hole.

2. A rider on a galloping horse holds a heavy ball out to his side and drops it. The ball will hit the ground:

   A. immediately below the point where it was dropped.
   B. immediately below the point the horse and rider are when the ball reaches the ground.
   C. some position other than A or B. Please specify.

3. A boat is sailing rapidly along the surface of a smooth lake. A heavy ball is dropped from the top of a high mast. The ball will fall and:

   A. strike the deck at the foot of the mast.
   B. strike the deck behind the foot of the mast depending on the speed of the boat.

C. strike the deck in front of the mast depending on the speed of the boat.

Clearly the idea tested here is whether the subjects were aware of the effect of the initial horizontal velocity of the falling object. If they do not take this into account then they will believe that the object will fall straight down and in the case of the boxcar and boat, strike the ground behind the reference point as this point would have moved forward during the time that the object was falling. In the case of the horse and rider, the ball will be thought of as hitting the ground behind the horse and rider as they would have moved forward relative to the ball. The results may be summarised as follows:

Description of subjects.	Percentage who believe that the object will fall straight down in the case of:		
	Boxcar	Galloping horse	Sail boat
No high school physics	40	16.7	61.6
High school physics	32.5	27.5	45

Intrinsic in this belief is the notion that force is required to keep a body moving. Once the body is free to fall, the cause of the forward force is removed and the body will fall straight down. Whitaker quotes some of the reasons given by his subjects which support the above idea:

"The bolt decreases in (horizontal) speed the second it leaves the ceiling".

"Gravity pulls it down; this is all that is acting on the ball."

"The ball has lost its momentum and is pulled down".

"The force of the moving boat will make the ball fall behind the mast".

"Once the ball is dropped there is no further force being applied in a forward direction."

Apart from illustrating the beliefs of the subjects about trajectory motion, this study also supports other studies which link beliefs about the necessity of force for motion. Furthermore, a closer examination of the number of subjects who responded correctly to these rather similar questions suggests that the "understanding of the concepts involved may not be as firm as one might expect." (Whitaker,1983) This conclusion is tantamount to saying that the responses depend on the question asked. This conclusion also follows from the results summarised in the table.

Malgrange and Maury (in Saltiel and Malgrange, 1980, p. 78.) report that nine students out of ten believe that a heavy body thrown upwards by a man on a moving pavement will fall behind him because:

"when the ball is in the air, there is no physical link between it and the pavement"

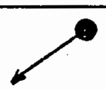
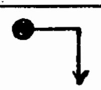
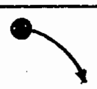
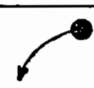
"the ball looses it horizontal speed instantaneously"

"the ball must go up and down along the vertical"

There are clearly similarities between the reasons given by the students in this investigation and those reported by Whitaker. Saltiel and Malgrange believe that for some people the path of a free falling object is along the vertical in spite of the conditions under which it is falling. This belief is not unlike a rule which they can use under any set of conditions. The investigators refer to the first two reasons quoted above as being of the "dynamical" type while the last one is of the "geometrical" type. These two types of argument are used interchangeably and are believed to reinforce one another in what the authors refer to as the "natural model" of reasoning.

Although the test used by Halloun and Hestenes (1985)(reported on p.60 above) also included some items involving circular as well as projectile motion, the authors do not report the percentage selection of the different options.

In the test which Spargo and I administered to University of Cape Town first year engineering students, as well as to students following the Method of General Science course in the School of Education, (reported on p.71 above), we asked the subjects to select the path along which they thought that a ball would fall if it was dropped from the window of a rapidly moving car, with the car moving from left to right.
The following table summarizes our results:

Path					
Engineers. Teachers	3% 5%	0% 5%	1% 3%	83% 56%	12.5% 31%

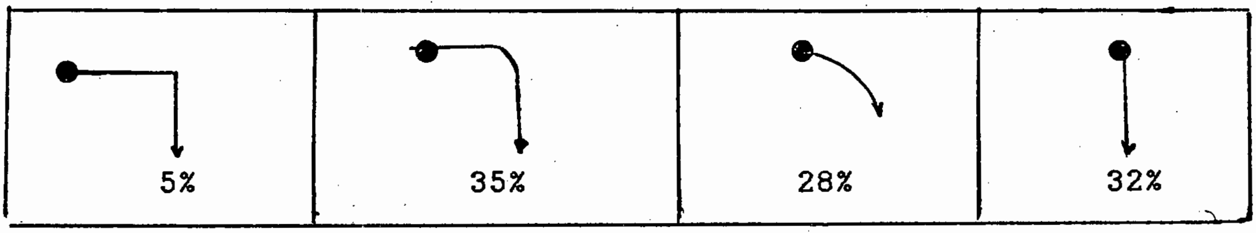
In a further test Spargo asked the students in the post-graduate primary education group to sketch the path that a brick would follow if it were dropped from an aeroplane. Various items of landscape were included in the sketch to act as landmarks. 12

students completed the sketch and only 2 drew a forward parabolic path while 5 indicated that the brick would fall straight down. 5 indicated that it would fall backwards away from the aeroplane.

(b) *Laboratory observations:*

To investigate the beliefs held by students about projectile motion, **McCloskey and Washburn** (in McCloskey, 1983) asked undergraduate students to walk across a room and while they were walking to drop a golf ball onto a target marked on the floor. They found that almost half of the subjects released the ball when they were directly over the target, apparently in the belief that it would fall straight down. One subject walked past the target before dropping the ball in the belief that it would move backwards while falling. More specifically, the investigators found that 45% of their subjects knew that the ball would travel forward while falling, 49% thought that it would fall straight down, while 6% thought that it would travel backwards while falling. Furthermore, the strategy employed for hitting the target showed that subjects who had taken one course in physics were more likely to drop the ball before the target than those who had not studied physics at all. However, 27% of the students who had taken physics dropped the ball directly over the target.

In a further problem on projectile motion, **McCLoskey et al** (in McCloskey, 1983) asked their subjects to draw the path along which a metal ball would fall if it was pushed over the edge of a cliff at high speed. The subjects were instructed to ignore air resistance The paths on the next page were drawn and the percentage of the subjects drawing that path is indicated:



In another task the students were asked to draw the trajectory of a bomb dropped from a plane which was travelling at high speed. Air resistance was to be ignored. McCloskey reports that more than 33% of the subjects indicated that the bomb would fall straight down.

D: Velocity

(i) In one dimension:

In our own study we included a question which tested the idea that children believe that at the moment when two moving bodies are opposite each other during the act of overtaking, they will have the same speed. The possession of this belief by students students was first described by Towbridge and McDermott (1980) and although other work on the understanding of velocity has been done, we will concentrate on this study and only mention the others in passing as they do not directly concern our own study. **Towbridge** and McDermott worked with 126 students from the University of Washington. The students were enrolled in a variety of introductory courses but all were doing physics. The group included 22 in-service teachers. To assess student understanding of some aspects of motion the authors used what they call the "individual demonstration interview" which involved the student being shown a simple physical situation and being asked to respond to a specified sequence of questions. In order to demonstrate a number of linear motions they used steel balls which were automatically released and allowed to roll along straight U-shaped aluminium channels. The apparatus allowed them to demonstrate, in a reproducible way, two motions which the students were asked to compare. The questions followed a regular format but allowed for the exploration of any particular aspect of the student's thinking that may have been of interest. Each interview lasted from 20 to 30 minutes and was audiotaped and sometimes videotaped. The dialogue was transcribed and analysed in detail. Over 300 individual demonstration interviews were conducted on a pre-and post-course basis.

The students had to compare the simultaneous motion of two balls in two of the tasks. the tasks were decided upon on the basis of a number of exploratory interviews and a number of preliminary trials. In each of the two tasks, in which the students were shown two identical balls rolling on parallel U-channels, one of the balls moved with non-uniform velocity. The major difference between the tasks was that in the one case each ball passed the other while in the other case no passing occurred.

Task 1: In this task a ball, A, travelled with uniform motion from left to right while another ball, B, travelled in the same direction. However, this ball had started with a greater initial velocity than ball A but as it was required to travel up a gentle slope it would slow down and eventually come to rest. B at first passed A and was later passed by A. The students observed the motion of the two balls. Initially they were shown the balls separately but later they saw both balls simultaneously. During the interview they were asked whether the balls ever had the same speed.

Task 2: Because the perception of passing is so striking and so much more obvious than the phenomenon of keeping the same distance apart, this task involved no passing. In this task one of the balls was always ahead of the other and the balls had the same speed for only one instant during the demonstration. Ball B had the same motion as before i.e. with a high initial velocity up an incline and gradually decelerating to rest. Ball C was started from rest at a point ahead of B and accelerated uniformly down a gentle incline. The balls never overtook each other. Again the students had to decide whether the balls ever had the same speed.

For our study the most important finding of the above study was that on the pre-course interview 33% of the students confused the concepts of speed and position. The following excerpt from **Towbridge and McDermott** illustrates the problem:

Interviewer : Let's look and see whether these balls ever have the same speed. (Balls are released.)

Student : It looks like they have the same speed twice. One is about a quarter of the length of the incline and then again three-quarters

I.: And how can you tell ?

S.: Because both balls reached the same position on each track.

This student believes that when two objects have reached the same position then they must have the same speed. Another interesting

belief voiced by some of the students is that being ahead implies having the greater speed. This would follow from a belief that bodies have the same speed when they are next to each other.
On the post-course interviews Towbridge and McDermott found that 20% of the students still retained their belief that position determines speed. In every case in which an error was made, they found that students had used a position criterion to determine relative velocities, ie. ahead means faster, opposite means equally fast.

Halloun and Hestenes (1985)(reported above on p.60) included a question in their questionnaire which was designed to test belief about relative speed and position. They report that over 30% of the students in their sample believed that when two particles are opposite each other then they are travelling with the same speed.

(ii) In two dimensions:

Saltiel and Malgrange (1980) gave two-dimensional relative motion problems to 700 French university students and 80 eleven year old children. They found that the two populations responded in similar ways in that they thought that velocity is an intrinsic property of an object and independent of a reference frame. Velocities would be added without taking the reference frames into account. The authors say that motion and velocity are considered as permanent physical properties of the moving body alone, independent of observers and tend to be defined through reference to the driving forces which cause them and not with respect to frames. The concepts of force and velocity are not very clearly distinguished. Furthermore, they found that travelled distances and trajectories are "frozen" in space and independent of the observers, i.e. trajectories and distances travelled are considered to be independent of the position of the observer. Students appeared to consider two kinds of motion: true motion, which is intrinsic because it has a recognised dynamical cause, and apparent motion which is perceived as an optical illusion.

(iii) The vector nature of velocity:

Erickson and Aquirre (1984) interviewed 20 grade ten, i.e. 15 year old pupils, (9 girls and 11 boys) from Vancouver, Canada, in an attempt to explore their understanding of the vector nature of position, displacement and velocity. In one of the problems, which involved a boat on a river, they found that 80% of the pupils thought that the magnitude of the velocity component contributed by the motor to be changed in some way because of its interaction with the current. This was in spite of the fact that the interviewer took pains to distinguish between the perceived resultant velocity of the boat as it moved across the river and the component velocity of the boat due to the motor.

Chapter 3

Method

Introduction:

To make sense out of the different methods used to investigate a field of inquiry which initially dealt with "mistakes" made by students, be they children or older, in their science studies it is important to consider very briefly the changing views of these "mistakes". Initially these mistakes were considered to be the result of faulty learning due to agents such as poor textbooks, bad teaching, etc. so that these incorrect responses or ideas were considered to be conceptual mistakes and could therefore be considered to be misconceptions. Basic to this approach is the view that all instances of a concept have the same properties in common and that these properties are necessary and sufficient to define the concept. A non-example of a concept is anything which excludes one or more of the critical properties which define the concept. To accept as an example of a concept a non-example is to display a misconception.(Markle and Tieman in Gilbert and Watts,1983) This view of a concept is, according to Gilbert and Watts(1983),the "classical" view.

Knowledge is now assumed as being stored in the mind in hierarchical layers which can be broken down into smaller parts and studied independently. It follows that to acquire knowledge these hierarchical layers have to be established; progress is only possible once the preceding step has been mastered. (Gilbert and Watts, 1983.) In this way misconceptions are viewed as flaws in the system which have to be corrected before learning can occur. Researchers who subscribe to this view of concept and of learning have an interest in the quantitative aspects of the concepts held by students. They wish to ascertain what the wrong ideas are so that these may be isolated, repaired and restored in order that proper learning can occur. They wish to explain why it is that wrong learning has occurred.

According to Gilbert and Watts (1983), there are two other views of concepts which they call the "relational" and the "actional" views. The "relational" view stresses the fact that concepts do not exist in isolation but rather in relation to other concepts. An instance is judged in terms of the degree to which it is a member of a particular concept and the concept in terms of its relationship to other concepts. Word association tests and "semantic networks" are typical of research based on this view of concept

The "actional" view considers concepts to be active, constructive and intentional.(Gilbert and Watts,1983.) Concepts are seen as ways in which experience is organized so that any new experience leads to a restructuring of existing concepts. The important thing to notice here is the idea that concepts are constructed and reconstructed by the individual. There is a dynamism present which is absent in the classical view. The individual's personal conceptions are respected and treated as his source of knowledge. Ideas which would have been called misconceptions by adherents of the classical view of concepts are here seen as efforts by the individual to make sense of his world and as such is afforded epistemological status and may for instance be called "children's science". Researchers with this idea of concept are interested in the qualitative aspects of concepts, i.e. the nature of a person's concepts, so that they can understand why he has the ideas which he has.

Thus, it would appear then that research in this field can be placed on a quantitative-qualitative continuum with the aims changing from explaining mistakes made by students, be they children or adult, to understanding why they made those mistakes.

In their attempts to investigate the ways in which students and school children view some concepts in science, investigators have used a variety of methods which reflect their view of concept and of learning. The methods most frequently used may be grouped as follows:

1. Written tasks:

Written tasks can be subdivided into:

(a) **Multiple choice tests:**

Investigators using these tests have a classical view of concepts and have typically selected as their distractors responses which they suspect to be commonly held misconceptions or potential misconceptions. These are usually derived from students' answers to free response questions in a variety of situations such as interviews or answers to examination questions, as well as interviews with teachers and the investigator's own experience. Furthermore, the distractors may be presented in written form or as sketches. This type of test was used by Doran, Za'rour, Helm, Ivowi and Halloun and Hestenes in their diagnostic test. A typical example of each type of question would be:

In the following account of the forces acting on a block resting on a table which statement is false?

(a) A block at rest on a smooth table has two forces acting on it, viz the earth's gravitational force on it, downwards, and the force of the table on it, upwards.

(b) Since no motion occurs vertically, these two forces must be equal and opposite.

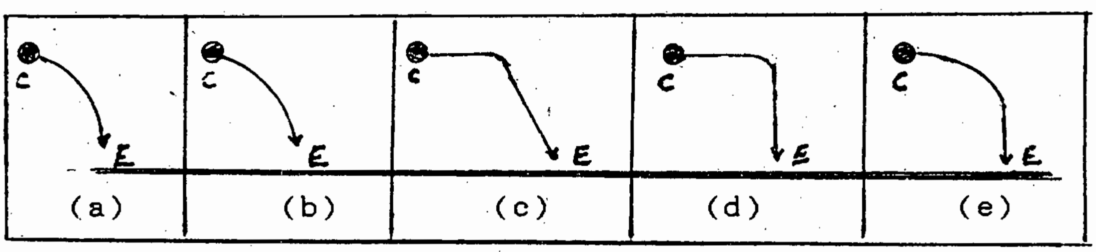
(c) From Newton's Third Law, it follows that no friction exists between the table and the block.

(d) The block is in equilibrium.

(e) The system demonstrates that forces always occur in pairs. (Ivowi, 1984)

and

Which path will the ball follow after it leaves the track at C?



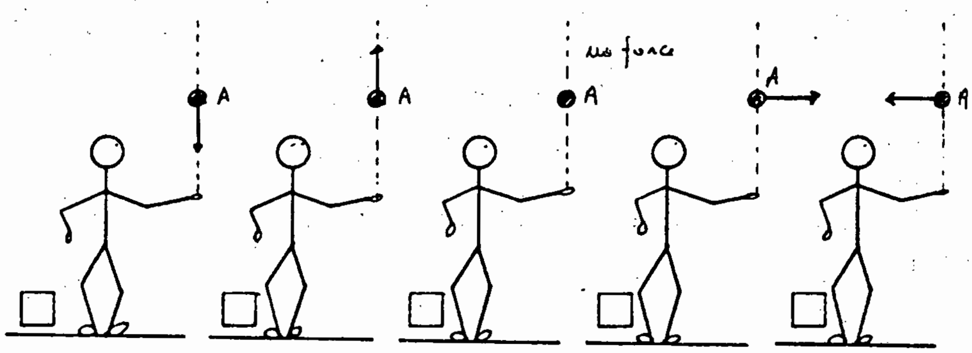
(Halloun and Hestenes, 1985)

Helm (1978) points out that while the testee is restricted to using only the misconceptions available in the distractors, this need not be a serious limitation if one has drawn these distractors in the way that has been described.

(b) Multiple choice tests with reasons:

Researchers with an "actional" view of concepts have also used multiple choice tests but have asked testees to supply a reason for their choice. This overcomes the fixed response problem and also provides insight into the thought process of the student. Watts and Zylberstajn (1981) collected their distractors from interviews using the "Interview about Instances" technique described below. (p.113). The following is an example of the questions used:

Now, which picture do you think best shows the force on the stone when it is passing through the point A on <u>its way down</u> ?



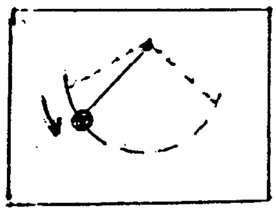
Explanation:

Multiple choice questions with reasons asked were also used by Whitaker (1983), in a study of projectile motion as well as by Maloney (1984,1985) in studies designed to discover the rules students use in solving problems concerning Newton's Third Law and problems concerning the conservation of mechanical energy.

(c) Free response written answers:

This technique asks the testee to give his own responses to a question. He may be required to write an answer (Viennot,1979,Saltiel and Malgrange,1980,Terry and Jones,1986) or to use a sketch to indicate the magnitudes and directions of forces acting on a body (Clement,1982), or to sketch the path of a projectile.(McCloskey,1983) The following question is an example of the kind used:

> The sketch shows a ball which is swinging from a string. Draw the path the ball will travel along when the string is cut at the position shown.



(From McCloskey et al in McDerMott,1984)

In what may be considered to be a further sophistication of written responses, Champagne et al(1980) developed what they called the "D.O.E." test which involves the subjects, which in their case were students at the University of Pittsburgh, observing a demonstration being carried out. They had to describe their observations, answer questions about the observed demonstration and predict further happenings before they saw them. The responses were recorded in a preprinted booklet. This method was also used by Gunstone and White (1981) but they expected their subjects not only to predict the outcome of certain actions but also to explain any discrepancies between their prediction and observation. The advantage of this method is that a large number of subjects can be involved at one time and a tremendous amount of data collected but, as Gunstone and White point out, it is a problem to reduce this amount of data to manageable size.

(d)**Essay on a topic which includes the concept under study:**
This method tries to use the student's own ideas about a particular physical situation and his own imagination to conjure up circumstances which are difficult to represent. The technique requires the identifying of the concept under discussion as represented in popular literature. An extract containing the word which describes a concept, e.g. energy, is read to the class to trigger discussion and to show the non-scientific meaning of the word. The teacher poses a few questions but gives no answers. The pupils are now required to produce some imaginative writing in response to an essay title given to them. The title must be such that a wide range of thought will be elicited. The essays are then collected and serve as the focal point during subsequent interviews with the pupils.(Moorfoot,1983.) The interview is recorded. The researcher asks prepared questions aimed at discovering the manner and extent of the scientific understanding of the concept.

2.<u>Interviews:</u>

(a) **The clinical interview:**
The use of this method fits perfectly with an "actional" view of concepts. The best way to find out what anyone thinks or knows about something is to ask him. This is one of the oldest techniques used in the exploration of children's thought and was used extensively by Piaget. (Sutton,1980.) The interviewer attempts to combine two features, i.e. that of letting the child talk freely while at the same time trying to probe the basis of his reasoning. The subject is presented with a situation which

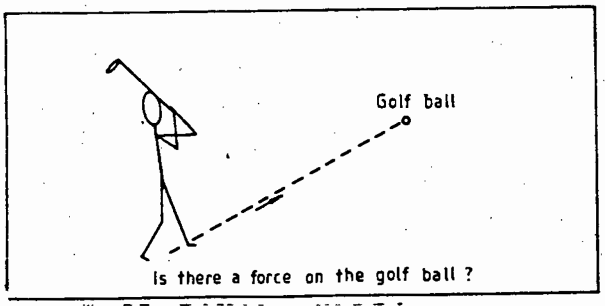
may vary from being asked to solve problems presented to him or being shown a demonstration or being asked to do an experiment himself. The interview starts with open questions and acceptance of all answers in an attempt to follow the child's reasoning wherever it leads. Later the investigator may encourage elaboration of earlier answers, ask the reasons for some inferences made by the child and ask for predictions based on the situation under study. The interview is recorded and later transcribed. While there can be very little doubt about the fact that this technique really allows the investigator to probe the ideas of his subject in great depth, there are problems associated with the transcription of long interviews and the cataloguing of responses.(Sutton,1980.) In spite of the problems associated with this technique, it is widely used by investigators, e.g. Terry *et al*(1985), Driver and Warrington (1985), Clough and Driver (1985), White (1983).

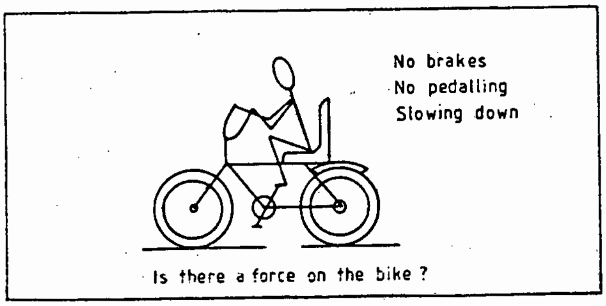
The clinical interview often forms part of what can be termed a multifactorial approach to understanding the understanding of subjects and may be used in conjunction with written work and laboratory demonstrations. In their study of how students understand the concepts of velocity and acceleration in one dimension, Towbridge and McDermott (1980,1981) used what they call the "individual demonstration interview". The student is shown a simple physical situation and is asked to respond to a specified sequence of questions. While the questioning follows a regular format, it is possible to explore any particular aspect of the student's thinking that may be of interest. The interviews lasted from 20 to 30 minutes and were recorded and sometimes videotaped. The dialogue was transcribed and analysed in detail. Over 300 of these interviews were conducted.

(b)**Interview about Instances:**

This technique was developed by Osborne and Gilbert and consists of presenting a subject with a set of line drawings that show situations which may or may not represent an example of the concept being investigated. Some borderline cases, i.e.unusual or unorthodox applications of the concept, are also presented. The subject is asked for his reason for each choice and wherever possible his own language is used. An informal conversation is allowed to develop around the sketches presented. Many of the sketches contain a dynamic element and the subject may be asked to predict the outcome of the situation presented. The interview allows the subject to ask questions to clarify real or perceived ambiguities before answering and gives flexibility in discussing reasons or lack of reasons for a particular answer. The pictures are not presented in any set way and the interview lasts for about 40 minutes. The interview is recorded and later transcribed. (Osborne and Gilbert, 1980, Watts and Gilbert in: Appraising the understanding of science concepts)

The following sketches show some of the cards used in a typical interview on force:





3.Laboratory tasks:

In pursuing what is possibly a "relational" view of concept, the Physics Education Group at the University of Washington have used laboratory tasks to investigate student understanding of force, the relation between force and motion, the work-energy and impulse-momentun relations.(McDermott,1984.) Part of the investigation involved the subject using some simple apparatus to carry out a task which is carefully selected to reveal his underlying understanding of the physical laws involved. The subject may be asked to use an air-hose to make an air puck move with constant speed. The use of a constant blast here is taken to be consistent with the belief that to move requires the constant application of a force.

4.Computer tasks:

DiSessa (1982) developed a series of games to investigate the understanding of force and motion among pupils of different ages. The games involved moving a "dynaturtle", which obeyed Newton's laws of motion, on a computer screen. The pupils were asked to make the dynaturtle move at different speeds and in different directions by applying a suitable "kick". A "kick" is an impulse applied to the turtle and specifies the change in velocity according to Newton's Second Law. The computer is programmed to record each keystroke and timing thereof. The subject is instructed in how to use the turtle and the game starts. The subject is allowed to ask questions and has to explain why he or she selects the particular strategy which he or she is applying at the time. The interview is recorded and analysed. The recorded moves are viewed and included in the analysis of the protocol.

OUR METHOD:

To understand the choice of an instrument designed for the collection of data one must have as clear an idea as possible of the task for which it was intended.

Aims:

By making use of a few selected and well studied basic concepts in kinematics and mechanics we wished to:

1. determine how the frequency with which alternate conceptions held by South African pupils compare with those of the samples reported in the literature.

2. investigate and compare the distribution of alternate conceptions held by South African pupils:

   (a) across standards (i.e. grades);
   (b) according to sex;
   (c) according to home language: English, Afrikaans or Xhosa;
   (d) according to geographical area, comparing the conceptions of children living in a city with those of children living in country areas.

3. investigate the affect of increasing maturity by comparing the alternate concepts of a science concept held by standard 4 pupils with those held by standard 9 pupils not doing science.

4. investigate the effect of studying science by comparing the science concepts of standard 9 science pupils with those of standard 7 pupils and std.9 pupils who do not do science in school.

Requirements of a data collecting instrument:

Since we wished to determine the frequency with which alternate conceptions of a number of science conceptions were held by a fairly large number of sub-populations, a numerically large sample was required. This in turn meant that a tremendous amount of data would be collected and processed. As we were going to be:

(a) working in schools and

(b) using many unsophisticated subjects, e.g. primary school pupils and pupils from rural schools in Transkei, some important constraints were placed on the data collecting instrument.

From our point of view the instrument had to:

(a) be easy to administer;

(b) elicit responses which were easy to prepare for analysis;

(c) take about 30 to 35 minutes to complete, as this is the average length of a South African school period.

From the point of view of the pupils the instrument had to be:

(a) interesting enough to hold their attention;

(b) as simple as possible in meaning i.e. clear and unambiguous ("Child proof" in other words);

(c) simple to complete.

It soon became clear that our requirements would best be met by a multiple choice questionnaire with an accompanying well designed answer sheet.

To meet the requirements of the pupils we decided to use:

* interesting situations;
* as few words as possible in our distractors, i.e. no complicated, wordy distractors;
* no difficult words;
* no emotionally charged words;
* simple and clear instructions;
* a prepared, simple answer sheet.

As entering a classroom and administering a test is in a sense an invasion of the teacher's domain we decided to compensate for this by taking over a whole period so that the teacher would be free. To enable us to do this the time required to complete our questionnaire had to be the length of a period, which on the average is 30 to 35 minutes

As a result of a comprehensive literature survey we decided to investigate the ideas of our pupils in the areas of:

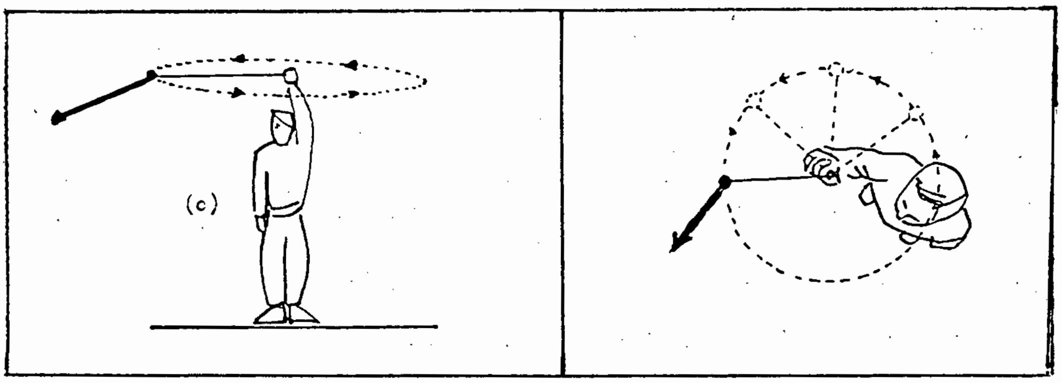
(a) forces acting on bodies at rest but, with the added refinement of comparing the effect of the presence of a human in the situation with that of the situation in which a human is absent (Minstrell);
(b) forces acting on moving bodies (Viennot);
(c) forces acting in a tug-of-war situation, with and without motion (Watts and Zylberstajn);
(d) the effect of height above ground on the force of gravity (Watts);
(e) speed of falling bodies (Whitaker,Maloney);
(f) the relative speeds of bodies during overtaking (McDermott);

(g) the paths along which bodies will fall in various situations (McCloskey);

(h) and to act as our buffer against pupils completing the questionnaire with a lot of time to spare as well as an insurance against periods of differing duration, some questions on the relative temperatures of bodies under certain conditions (Driver,Osborne).

We decided to set our problems in simple situations which would be familiar to virtually all the pupils. In this way we hoped to present them with a question paper which they might find interesting to read and fun to answer. To depict the situation being used and to focus the attention of the pupils, we decided to use simple sketches with a simple description of what the sketch was attempting to show. Furthermore, we would also use sketches for our distractors with a very simple explanation of what the sketches were meant to show. We decided to use a standard multiple choice answer sheet as most children are familiar with such sheets. To minimize transcribing errors, the number of options on the answer sheet were to be exactly the same as the number of options of the corresponding question. As we wished to know the pupil's sex, home language, age, as well as the standard he or she was in and whether he or she did Physical or General Science as a school subject, the answer sheet was organised in such a way that this information was also requested.

A questionnaire covering the area selected was drawn up and the language carefully checked. In order to see whether the information, instructions and sketches were clearly understood by children, a trial run was carried out at a local private school with a group of standard 4 and standard 5 pupils, i.e. on the average 11 to 12 year old pupils. They were told that they should ask for help at any time if the instructions or questions were not clear to them. After the children had completed the paper, they were asked to talk about areas of difficulty which they had experienced. They indicated that they had had some difficulty interpreting the distractors on two circular motion questions and as a result of this the method of presentation on these questions was changed. The following two sketches include an example of a distractor which was not understood and the sketch with which it was replaced:



A : not understood. B : replacement.

Furthermore, it became clear to us that there was a very big difference in the the speed with which different primary school children read. Some of them had no difficulty in completing the paper but a substantial number had difficulty finishing it in the prescribed time. To overcome this problem with the primary school pupils, we decided to present the problems to them orally with one of us reading the questions to them. To us it was important to see that the children really enjoyed doing the paper. They were quietly but intently dropping pencils and erasers, swinging imaginary balls around their heads and in general communicating interest and excitement while doing it. We might add that it was our experience throughout that the children in all of the different standards reacted in this way.

Having satisfied ourselves that the questionnaire met with the requirements which we had set for it both from our and from the the pupils' points of view, it was translated into Afrikaans and the translation was checked for scientific correctness by Mr Faan Jordaan of the Education Faculty at the University of Stellenbosch. A Xhosa translation was done by a local teacher who is Xhosa-speaking and checked by a lecturer in the African Languages Department at the University of Cape Town. Permission to work in schools under the jurisdiction of the Cape Education Department was requested and duly received.

Final instrument:

The final test paper (Appendix A.) consisted of four sections:

Section A consisted of twelve questions dealing with forces acting in different situations. Questions 1,4,8 and 10 dealt with the notion of force required for motion, but added to this was what we hoped would be an answer to the question of what forces are seen as acting, their direction as well as their relative magnitudes. Also present in questions 1 and 2 is the concept of gravitational force, while in question 4 the idea of frictional force acting on moving bodies is added. In question 8 we wanted to see what children understand about the magnitude of the frictional force in static situations. Question 10 looked at the understanding of forces involved in circular motion. Questions 3,7,9 and 11 dealt with the ideas which children have about the forces acting on bodies at rest but added to this was an attempt to discover whether they see the same forces acting on a body if a human is present as part of the system. Questions 6 and 12 dealt with the forces involved in a tug-of-war equilibrium system. In question 6 we added the fact that one of the contestants was noticeably smaller than the other while in question 12 we had one of the contestants winning the contest. Question 5 from this section and question 5 from section B dealt with the idea children have that gravitational force increases with height above the ground.

Section B dealt with the relative magnitudes of the same quantity when possessed by two bodies which differ from each other in some other property. Questions 1 and 3 involved the notion of bodies with different mass falling at different speeds, while question 2 deals with the idea that bodies of different mass will reach different heights when projected upwards with the same initial speed. These three questions obviously deal with free fall and childrens' ideas about this concept. We have not found any reference to the idea tested in question 2 in the literature and we therefore believe that the results of this question will constitute an original contribution to work in this field. Question 4 dealt with the idea which children have about relative speeds during overtaking. As mentioned earlier, question 5 tested the idea that the force of gravitational attraction increases with height above the ground.

Section C asked children to identify the path along which objects would be seen to fall under certain conditions. Questions 1, 4 and 6 asked for the path of a freely falling object which had an initial horizontal velocity, as seen by a stationary observer. Question 2 asked for the observer's perception of the path along which an object would fall while he or she is moving with the object. In questions 3,5 and 7 an observer is asked to identify the path along which a projectile which initially travelled in a circle would travel when it is released. We looked at this in three different situations, one of which involved a child as the projectile, to see to what extent the response is situation-specific.

Section D was, as mentioned earlier, our buffer section and tested some ideas which children have about the relative temperatures of boiling liquids, the temperatures of different materials under the same conditions, as well as an identification of the products formed when water boils. Questions 1 asked the pupils to compare the temperature of a liquid which is boiling in two different containers. One container contained double the volume of liquid in the other one. Question 2 asked the pupils to compare the temperature of the liquid in two containers which differed from one another in that one container was warmed by two flames while the other only had one flame warming it. In question 3 the pupils were asked to compare the readings on two thermometers which are placed in different positions in the same beaker of boiling water. Question 4 asked the pupils to compare the temperatures of plastic and metal under the same conditions, while question 5 dealt with the products of boiling water.

Validity and Reliability:

According to Magnusson (1966,p.59.) data collected should be meaningful and reproducible. The test instrument must measure what it is intended to measure and on repeated measurements it must yield the same results. To ensure that the test did indeed test for the presence of alternate ideas it was shown to some of our colleagues. They agreed that the distractors presented were indeed different ways of responding to the task which was set. In this way the **face validity** of the test was established. Our colleagues were also invited to check the wording of the questions for ambiguities.

With the exception of Doran (1972) no other researchers in this field have published reliability estimates for their instruments. There are very good reasons to accept that the usual statistical tests for test reproducibility are not appropriate in tests of this kind. As Helm (1978) points out:

1. the test was not designed to discriminate between pupils but rather to find out whether they could carry out certain tasks;
2. the tasks consisted of the pupil indicating his choice out of a number of alternate possibilities.

Furthermore, in our case the test covered concepts which some of the pupils would have dealt with to some extent while others would not have dealt with it at all. We were in a real sense interested in their "intuitive" ideas about the situations presented.

There can be no doubt that this test covers a number of domains of knowledge and not just a single one. The concept of internal consistency cannot apply to it. In any case, the real interest lies in the distractors selected and the intention of the test was to find out how widely some of the alternatives presented are held. Helm (1978) is of the opinion that the concept of internal consistency is inappropriate to this kind of test.

However, while it is true that the traditional methods of reliability testing such as split-half or Kuder-Richardson methods are inappropriate in our test, this does not mean that some estimate of reliability is impossible. We were anxious to retest a number of pupils on the same test within a short while after they had written the test and then compare their answers. However, this was impossible to do because of the time factor. We are of the opinion that the results will show that the frequency with which some of the alternatives were selected will indicate consistency in responses across quite divergent groups and that this may be taken as an indication of the reliability of the instrument.

Sample:

To allow us to investigate the problems which were of particular interest to us, we selected to work in:

* what we considered to be schools catering for the middle income group;

* the middle ability class in each standard;
* four English medium co-educational primary schools in Cape Town;
* four Afrikaans medium co-educational primary schools in Cape Town;
* four Afrikaans medium co-educational primary schools in the Western Cape area. These will be referred to as country schools as they are well out of Cape Town.
* four English medium co-educational high schools in Cape Town;
* four Afrikaans medium co-educational high schools in Cape Town;
* four Afrikaans medium co-educational high schools in the Western Cape area to be part of the country schools sample;
* four co-educational primary schools in Transkei
* four co-educational high schools in Transkei.

The principals of the schools selected in the Cape were visited personally and permission to work in their school requested. They were all very helpful and testing started towards the second week in September 1986. Due to the fact that the Department of Education in the Cape Province does not allow data collection in its schools in the fourth term of the school year, i.e. October-December, one of the Afrikaans schools selected had to be omitted

With regards to Transkei schools, a formal request to work in these schools was granted without hindrance. The schools concerned were visited in person. Again we were most cordially received. Unfortunately we could not work in any high schools in the Transkei as their public examinations had started and so we had to be satisfied working with standards 4, 5 and 6 only. In the Cape the selection of the middle ability class in each standard in each school was left up to the Head of the Science department. In Transkei this was not possible as all the pupils in a particular standard are in the same class.

Statistics of the sample:

The final sample was made up as follows:

Number of pupils tested in the Cape = 1834
Number of pupils tested in Transkei = 492
Total number of pupils tested = 2326
This grand total of 2326 is broken down as follows:

STANDARD	ORIGIN	AREA	LANGUAGE	SEX			
				Boys	Girls	Total	Std.Total
4	Cape	Town	Afr.	33	56	89	
			Eng.	43	54	97	
			Other	2	0	2	
			Total	78	111	189	
		Country	Afr.	37	44	81	
			Eng.	7	3	10	
			Other	1	0	1	
			Total	45	47	92	281
	Transkei		Xhosa	74	78	152	
5	Cape	Town	Afr.	45	62	107	
			Eng.	50	48	98	
			Other	2	1	3	
			Totals	97	111	208	
		Country	Afr.	33	42	75	
			Eng.	4	5	9	
			Other	1	1	2	
			Totals	38	48	86	294
	Transkei		Xhosa	67	99	166	

6	Cape	Town	Afr	45	42	87	
			Eng.	41	58	99	
			Other	0	1	1	
			Total	86	101	187	
		Country	Afr.	31	45	76	
			Eng.	5	3	8	
			Other	2	1	3	
			Total	38	49	87	274
	Transkei		Xhosa	72	77	149	
7	Cape	Town	Afr.	41	41	82	
			Eng.	69	58	127	
			Other	0	3	3	
			Total	110	102	212	
		Country	Afr.	50	47	97	
			Eng.	1	0	1	
			Other	0	0	0	
			Total	51	47	98	310
8	Cape	Town	Afr.	47	28	75	
			Eng.	63	34	97	
			Other	6	1	7	
			Total	116	63	179	
		Country	Afr.	48	34	82	
			Eng.	0	0	0	
			Other	0	0	0	
			Total	48	34	82	261
9	Cape	Town	Afr.	77	73	150	
			Eng.	62	55	117	
			Other	1	0	1	
			Total	140	128	268	
		Country	Afr.	72	61	133	
			Eng.	6	4	10	
			Other	0	3	3	
			Total	78	68	146	414
	Transkei		Xhosa	8	17	25	
9	Cape	Science		142	93	235	
		No Sci.		75	104	179	414

Testing procedure:

At the start of the test the children were told that they were part of an investigation designed to look into why children find it difficult to learn Science. "Some teachers think that children are like buckets and that all that they have to do is to pour water into the bucket and that it will get full, but as you know, the buckets have got lots of holes in them and no matter how hard we try, we just cannot get the bucket full. Now we think that some of the holes are ideas which you already have about Science and what we want to do is to find out what these ideas are so that we can tell the teachers: Hey,your kids aren't empty before you start working with them. Take time and find out from them what they already know about the topic that you are teaching". The test and answer sheet was then handed out and the answer sheet completed.

With the primary school groups some time was now spent explaining to them what the different arrows on the diagrams meant - especially those which indicated a size relationship. A small boy or girl was called up to the front of the class and an arrow was drawn on the board to represent his or her height. The pupils were then asked what the arrow which we should use to show my height should look like and they would respond by saying "longer".They were then asked what I should do to show that someone was twice as tall as the little boy or girl being used in the demonstration. It was clear to them that the arrow should be twice as long as the one on the board. They were then told how we had shown this in the test. The test was then read to them, question by question while they followed it on their paper.

Whenever the word force was used, we would read it as such and then refer to it as a push or a pull whose presence, size or direction was asked for. Initially the meaning of the different distractors was explained to them until we were sure that they understood it perfectly. For the first few questions they were also told how to use the answer sheet. This presented no problem with the children in Cape schools but was a major problem in Transkei schools. The pupils in these schools quite clearly had difficulty in understanding the instructions about completing the answer sheet. While the teacher read the questions to them, we spent a considerable amount of time ensuring that the pupils were using the answer sheet correctly. Some of the children took a very long time to get the idea, but by and large they did after much effort from the teacher. It was very clear that they are not used to multiple choice tests. The result was that while all of the children in the primary schools in the Cape finished the paper in about 35 minutes, it took a lot longer in Transkei schools.

In the high schools the children were told to ask me if at any time they did not understand something on the paper. The children did the test by themselves. This provided a small problem as in standard 6 some of the children did not finish the test in the allotted time. In Transkei the problem was a bigger one as they had the added problem of the answer sheet. However most of the paper was done by most of the children. The next problem group was, strangely enough, the standard 9 science group most of whom really struggled to finish in time. Perhaps they looked for catches in the answers. As we have mentioned above, we could not help noticing how the great majority of the children really enjoyed doing the test. As an example of their interest I would like to mention an incident which occurred when we were working with a particular class of primary school children: the bell went for break but they insisted that we finish. We suppose that it would have been hoping for the impossible to think that a project involving such a large number of schools would go off without a hitch and in this respect we were not disappointed: we had a bomb scare at one school and at another a sudden change in the length of the periods for that day caused an unexpected crisis.

The information required about each child as well as the answers to the questions were now transcribed onto a form to be used for the punching of computer cards, a repetitive and boringly tedious task. The data was analysed using the Biomedical Data Processing programe on the University of Cape Town Sperry 1100 mainframe computer.

CHAPTER 4

FORCE AND MOTION

Overview

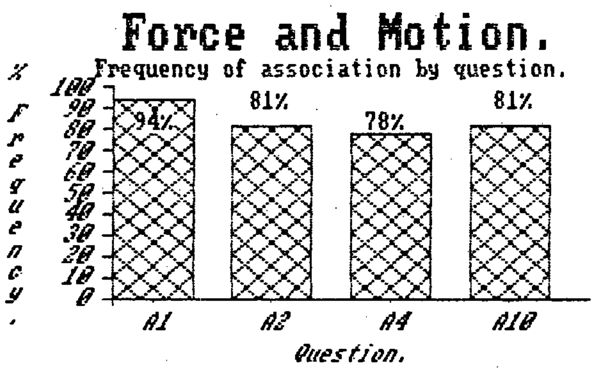
Introduction:

We used questions A1, A2, A4 and A 10 to investigate the beliefs our pupils have about the presence of a force acting in the direction of motion of a body. Furthermore, questions A1, A2 and A4 contain options which indicate the presence of the gravitational force. This may enable us to discover something about the beliefs pupils have about the presence of this force in the situations presented to them. The general area of interest covered by the questions is that between force and motion, i.e. it is an investigation into the belief that pupils have that for a body to move there must be force acting on it in the direction of motion. Each of the questions contains a number of options which include a force in the direction of motion.

In a comparable study by Watts and Zylberstajn (1981) (see p.70) the authors find that about 85% of their sample associate force with motion. Osborne (1985) (see p.72) finds that 46% of 13 year old pupils, 53% of 14 year olds and 66% of 15 year olds consistently hold the view that motion implies a force in the direction of motion. He further finds that 55% of 16 year old pupils hold the same idea. 22% of his sample select the correct option. McCloskey *et al* (see p.69) find that 93% of the high school pupils in their sample hold the view that motion implies a force in the direction of motion before instruction in physics while 80% of postcourse pupils still have this idea.

Results:

If we add the frequencies with which options which indicate a force in the direction of motion of the object are selected for each of the questions, we get the total frequency of pupils who exhibit the belief that motion implies a force in the direction of motion for that particular situation. The following graph compares the frequency with which options which include a force in the direction of motion are selected by pupils for the different situations presented in these four questions:

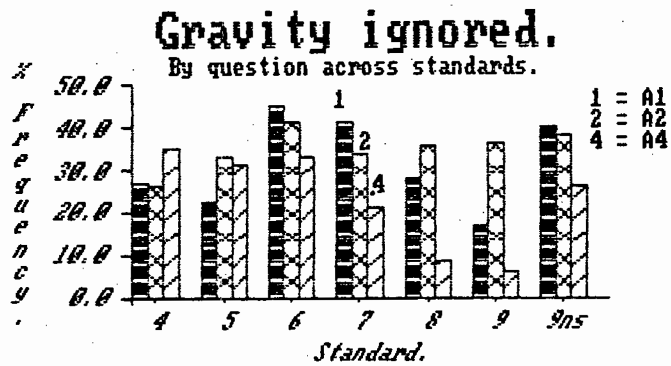


From the graph it is clear that this idea is very popular with pupils. At the same time it also appears that the extent to which it is exhibited depends on the context or the situation in which it is presented.

Our results compare very well with those reported by Watts and Zylberstajn and McCloskey *et al.*, but is in sharp contrast to that reported by Osborne. While he finds that 22% of his sample select the correct options, we find on questions A1, A2 and A10 that only between 6% and 9% of the total sample select the correct answer. Furthermore, on these questions there is very little difference in the frequency with which the correct answer is selected by pupils in the different standards. In these questions the object is depicted as actually moving while in question A2 a ball which has been thrown upwards is actually standing still at the top of its flight. In this question the correct option is selected by 18% of the total sample and again there is very little variation in the frequencies with which this option is selected by pupils in the different standards. The main difference between our study and that of Osborne is that he only used three distractors while we use five and by so doing we probably catere for more beliefs about the nature of the interaction between force and motion.

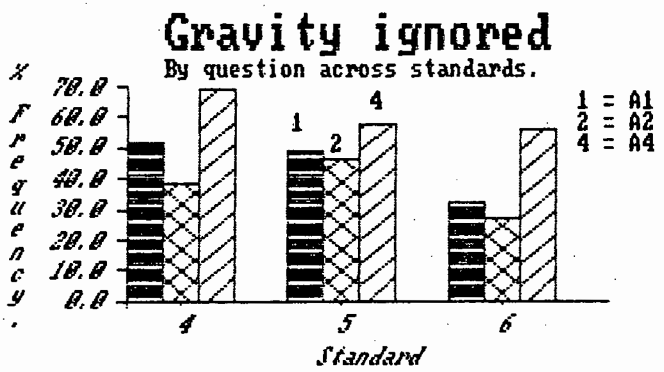
Furthermore, questions A1 and A4 contain options which suggest that the force in the direction of motion is larger than the retarding force. 67% of the pupils tested exhibit this belief on question A1 while 78% of the pupils do so on question A4. That so many of them select these options on A4 may be something of an artefact as they were not presented with options which include a force smaller than the retarding force. Nevertheless it is clear that a sizeable number of the pupils are of the opinion that the force in the direction of motion is larger than any retarding forces.

Questions A1, A2 and A4 also include options which allow pupils to provide evidence of knowledge of the presence of gravitational forces. The following graph compares the frequency with which options which did not include gravitational force are selected by pupils in the different standards in the Cape:

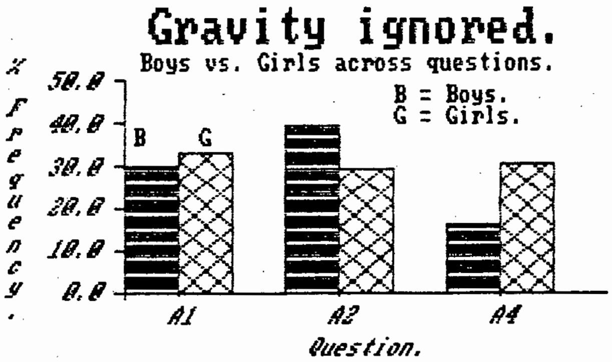


From the graph it is quite clear that knowledge of the presence of gravitational force depends heavily on the situation presented. This is especially clear in the case of standards 8 and 9. It also appears that for any one of the situations presented to them the standard 6 pupils ignore the presence of the gravitational force to a larger extent than any of the other groups.

The same general picture of the situation-dependence of the knowledge of the presence of gravitational forces is present in the selection of options which ignore gravity by pupils in Transkei, as the following graph shows:

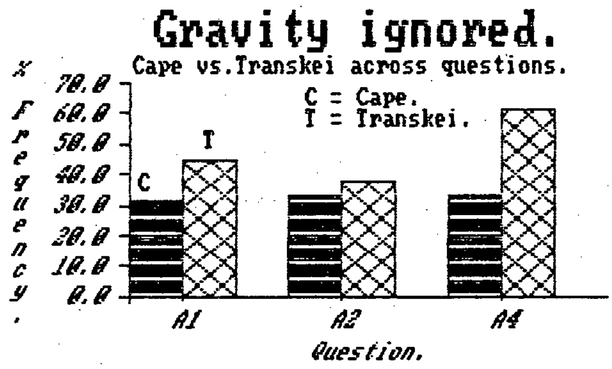


The following graph compares the frequency with which boys and girls in Cape schools select options which ignore gravity.



This graph again demonstrates that the situation presented is important in recognising the presence of the gravitational force. On A2 and A4 there are fairly large difference between boys and girls. Boys and girls respond differently to the same options.

The following graph compares the frequency with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei ignore the presence of the gravitational force:



While it is clear that the Cape pupils as a group respond fairly consistently across the different questions, the Transkei pupils again show the affect of the situation on recognising the presence of the gravitational force. In general pupils in Cape schools are more aware of the presence of this force than their counterparts in Transkei.

Question A10 deals with some of the ideas about circular motion. It is quite clear that pupils are of the opinion that there must be a force pushing the ball around in a circle. This force is seen to act in conjunction with both outward and inward acting forces.

We find that while the pupils overwhelmingly select options which indicate a belief in a link between force and motion, different options are preferred by the different standards. The frequency of selection of the different options changes with the standards but the general picture remains remarkably the same as far as the pupils' fundamental belief of force in the direction of motion is concerned.

We find that pupils in standards 4, 5 and 6 in Cape and Transkei schools share a belief that force is necessary for motion, but this belief is not quite as firmly held by the Transkei pupils. Furthermore, Transkei pupils tend to ignore the presence of gravitational force to a greater extent than Cape pupils. Transkei pupils also select the correct option more often than Cape pupils. On A 10, the question which deals with the forces involved in circular motion, the two groups differ in that more Transkei pupils select the correct option and in that Cape pupils prefer a force in the direction of motion linked to centrifugal and centripetal forces while options linking the force in the direction of motion with a centrifugal force is not as popular with Transkei pupils.

We find that only on A1 do Afrikaans-and-English-speaking pupils differ to any extent in the frequency with which they select the different options. On this question Afrikaans-speaking pupils are more aware of the presence of the gravitational force and more of them select a force larger than the gravitational force in the direction of motion than the English-speaking pupils. On the other questions there are no noteworthy differences in the frequencies with which Afrikaans and English pupils select the different options.

We find that while boys and girls in the Cape do not differ in the frequency with which they select the correct options, they do differ in the options which they prefer. Girls tend to ignore the presence of the gravitational force more than boys do. On A 10 girls are more aware of the presence of centripetal force than boys.

We find no noteworthy differences in the frequencies with which boys and girls in Transkei select the different options on all of the questions.

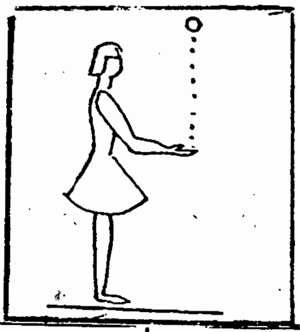
We find no noteworthy differences in the frequencies with which Afrikaans-speaking pupils from town and country areas select the different options on all of the questions.

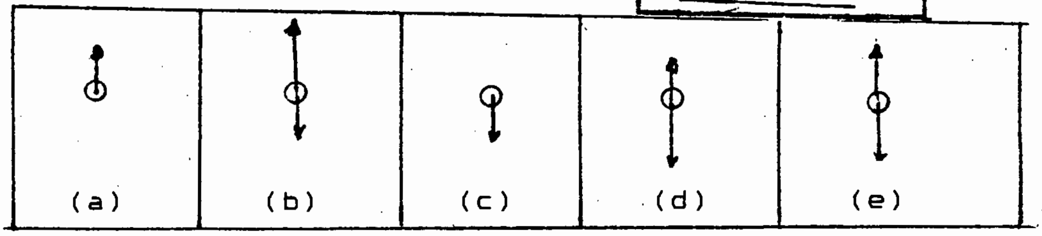
We find no noteworthy difference in the frequencies with which the correct options are selected by standard 4 and standard 9 pupils who do not do science. The two groups do differ though in the selection of the other options.

We find no noteworthy difference in the frequencies with which the correct options are selected by pupils in standard 9 who do science and who do not do science. The two groups differ though in the frequencies of selection of their preferred options.

Question A 1

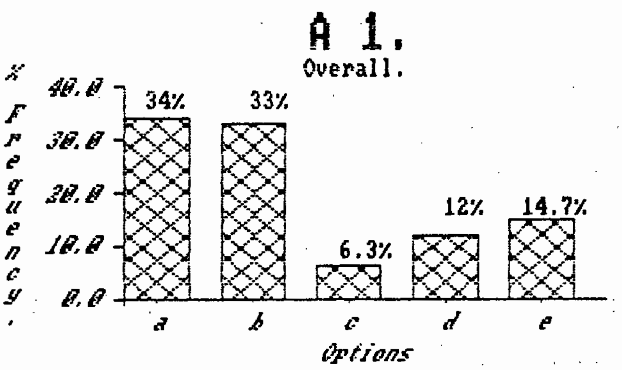
The sketch shows a girl throwing a ball vertically upwards. The sketch which best shows the forces acting on the ball immediately after it has left the girl's hand, is:





(a) The overall picture:

The following graph shows the frequencies with which the different options are selected by the whole sample (N = 2323).



Note:

1. Only 6.3% of the pupils select c, the correct option.

2. 34% select a, the option which excludes the force acting against the motion of the ball; i.e. the gravitational force.

3. 33% select b, the option which includes gravitational force

but with a force larger than gravity in the direction of motion.

4. 12% select d, the option which includes gravitational force but with a force smaller than gravity in the direction of motion.

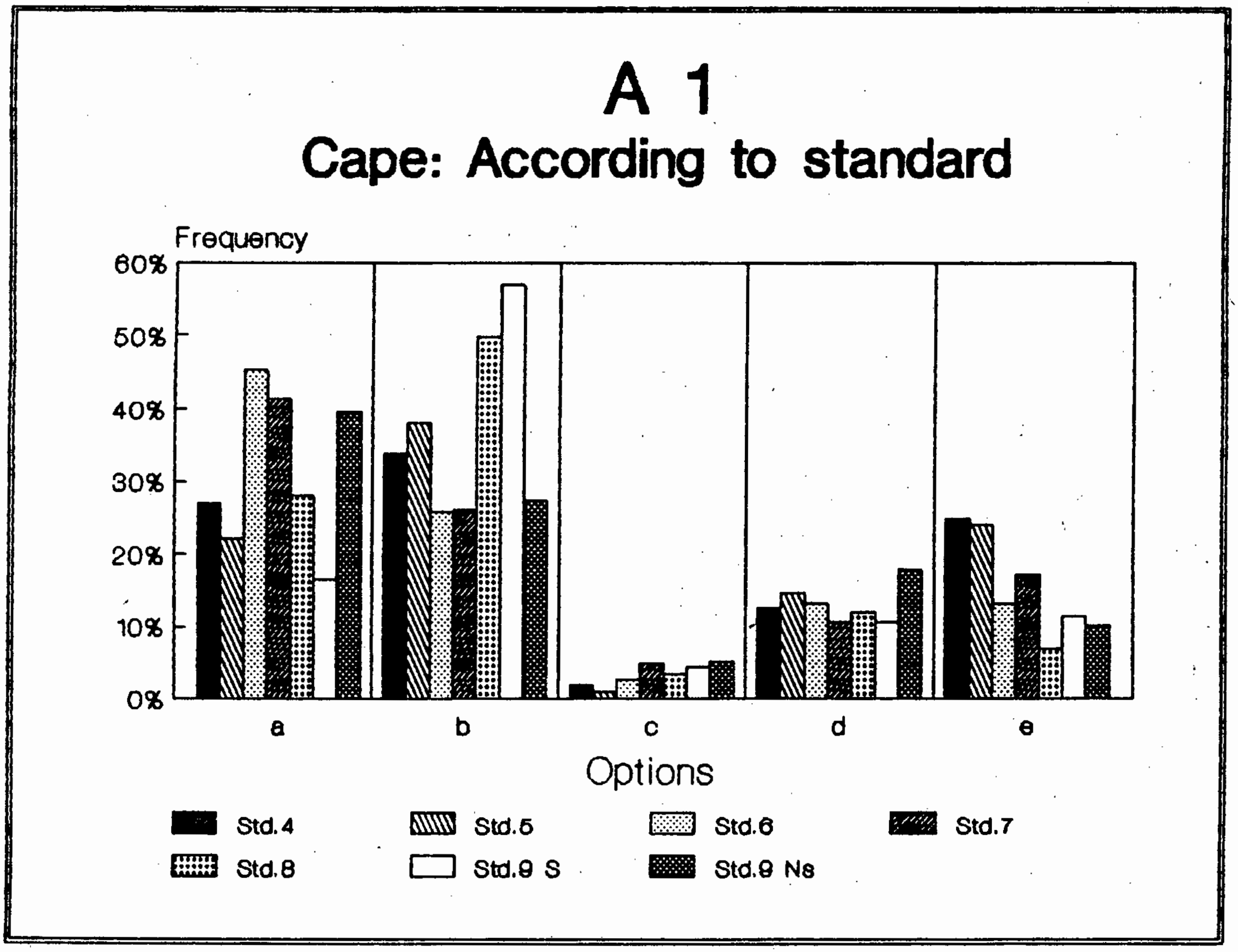
5. 14,7% select e, the option which suggests that the force acting in the direction of motion is as large as the gravitational force.

Thus, overall 93,7% of the pupils select options which indicate a belief in a force acting in the direction of motion of the ball. Furthermore, 34% of the pupils do not consider the force of gravity to be acting on the ball. What is interesting from the data is that although a large number of the pupils select the option which indicates that the force in the direction of motion is larger than gravity, 12% considered it to be smaller and about 15% considered it to be as large.

(b) **According to standard:**

1. <u>In the Cape</u>:

The following graph compares the frequencies with which the different options are selected by pupils in the different standards in schools in the Cape.



<u>Note</u>:

1. The frequencies with which the different options are selected are very similar for:

   (i) standards 4 and 5

   (ii) standards 6 and 7 and the standard 9 no science group.

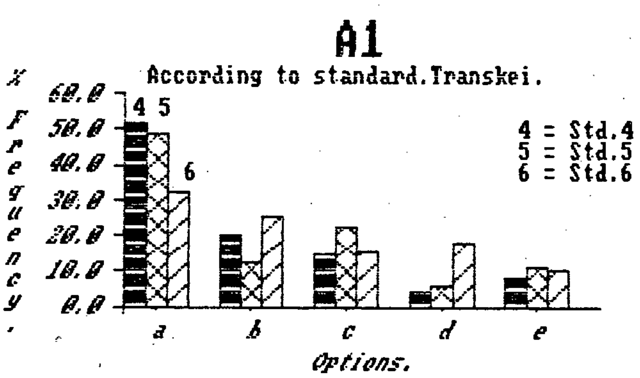
2. Standards 6 and 7 differ markedly from standards 4 and 5 in their selection of option a, the option which ignores the

presence of gravity. The standards 6 and 7 pupils select this option in preference to the others. The reason for this is unclear.

3. The standard 9 group who do not do science also ignore gravity
4. The standard 8 and standard 9 science group overwhelmingly select option b, the option which includes gravity with a force larger than gravity acting in the direction of motion.
5. The frequencies with which c, the correct option, is selected is very similar for all the groups and ranges from only 1% to 5%.

(2) <u>In Transkei:</u>

The following graph compares the frequencies with which the different options are selected by pupils in the different standards in Transkei.



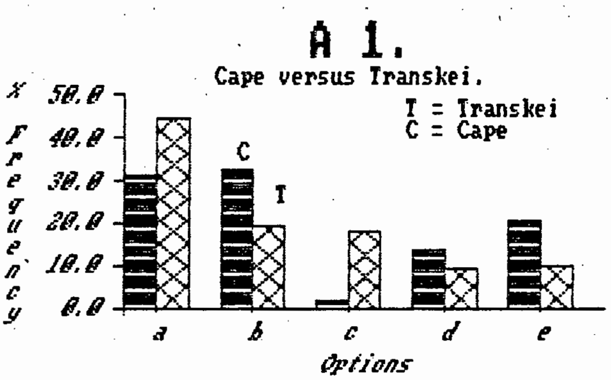
<u>Note</u>:

1. Option a receives overwhelming support from standards 4 and 5

and to a lesser extent from standard 6. It is clearly the most popular option. This may indicate an increased awareness of the presence of the gravitational force from standard 4 through to standard 6.

(c) **Comparison between the Cape and Transkei**:

The following graph compares the frequencies with which the different options are selected by standards 4, 5 and 6 pupils in the Cape and Transkei.



Note:

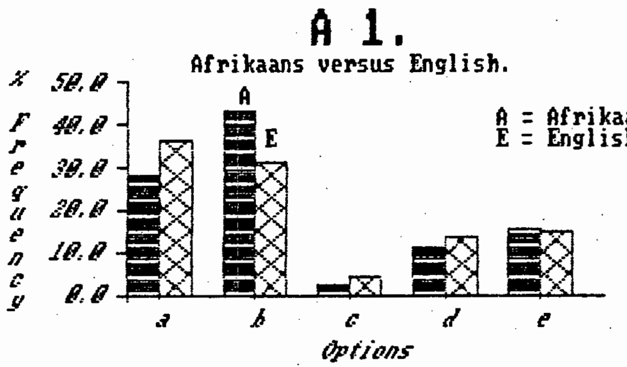
1. There is a very large difference in the frequencies with which option a is selected by the two groups: 44,4% by Transkei pupils against 31.2% of Cape pupils.
2. The correct option, c, is selected by 18% of Transkei pupils as opposed to 1,8% Cape pupils. As we have mentioned before (p.130) the pupils in Transkei had great difficulty in using the multiple choice answer sheet and it may well be that what we are seeing here is the effect of guessing by some of the

pupils especially as this is the first question on the questionnaire.

3. The two groups have different preferences for the options presented to them.

(d) **Comparing language groups in the Cape**:

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in the Cape select the different options.



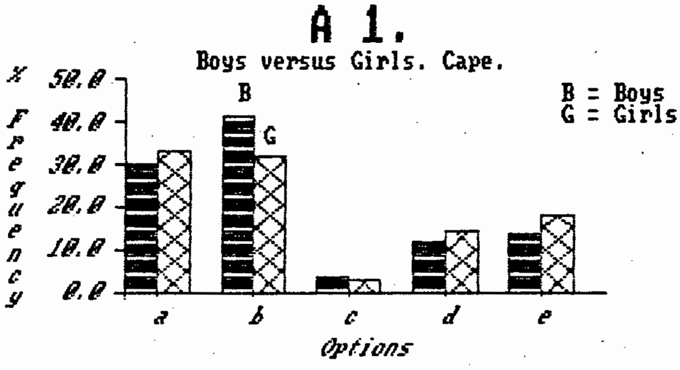
Note:

1. The only noteworthy difference between the groups lies in the selection of options a and b. 36% of English-speakers ignore the presence of gravity as opposed to 28% of Afrikaans-speakers. 43% Afrikaans-speakers select a force larger than gravity in the direction of motion as opposed to 31% of English-speakers.

(e) **Comparing the sexes:**

1. In the Cape:

The following graph compares the frequencies with which boys and girls in Cape schools select the different options.



Note:

1. It is only on option b that there is a noteworthy difference between the selections of boys and girls with 41% of boys selecting this option as opposed to 32% of girls.

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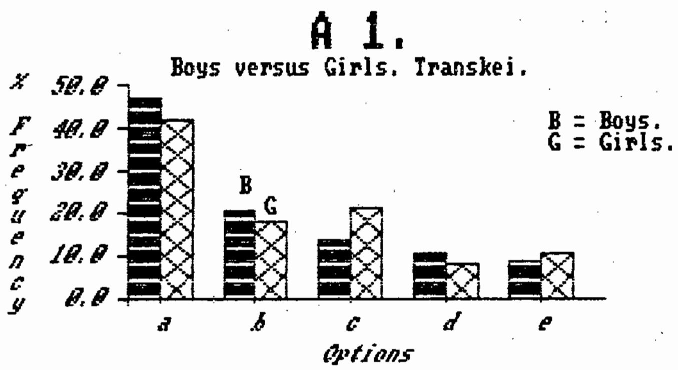
2. <u>In Transkei</u>:

The following graph compares the frequencies with which boys and girls in Transkei schools select the different options:



Note:

1. The only real difference between boys and girls in this group appears to be in the frequencies with which option c is selected; 14% of the boys select this option as opposed to 21% of the girls. It is very possible that the girls are guessing.

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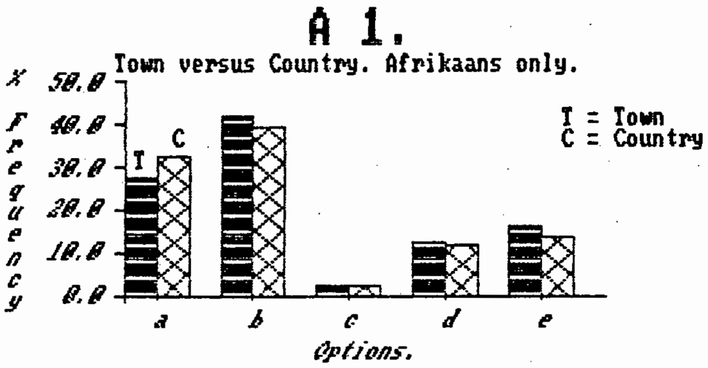
(f) **Comparing pupils from Town and Country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and country towns select the different options.



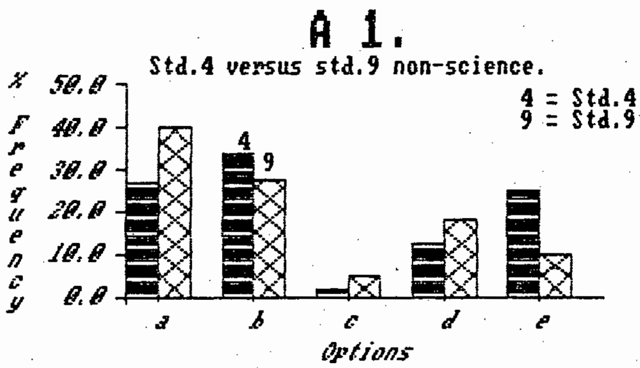
Note:

1. The distribution of the frequencies with which the two groups select the various options is very similar.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 " no science " group.

The following graph compares the frequencies with which Cape standard 4 pupils and standard 9 pupils who do not do science select the different options.

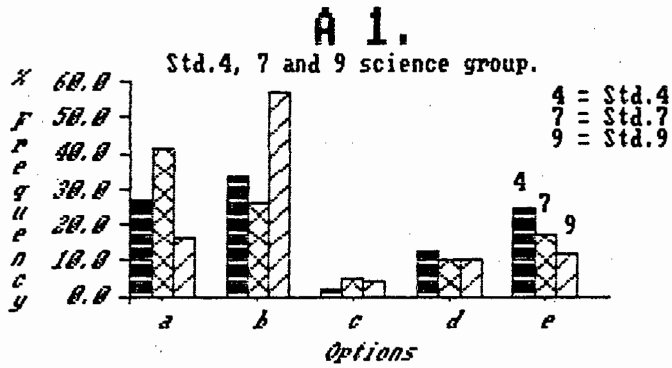


Note:

1. 40% of the standard 9 group select a, the option which excludes gravity as opposed to 27% of the standard 4 group.
2. 25% of the standard 4 group select e, the option which suggests that the force upward and the force downward are equally large while only 10% of the standard 9 group select this option.
3. 5% of the standard 9 group select c, the correct option as opposed to 2% of the standard 4 group.
4. 18% of the standard 9 group select d, the option which suggests that the force upwards is smaller than gravity while only 12% of the standard 4 group select this option.

2. <u>Standards 4 , 7 and 9 "science group "</u>

The following graph compares the frequencies with which standard 4,7 and 9 science pupils select the different options

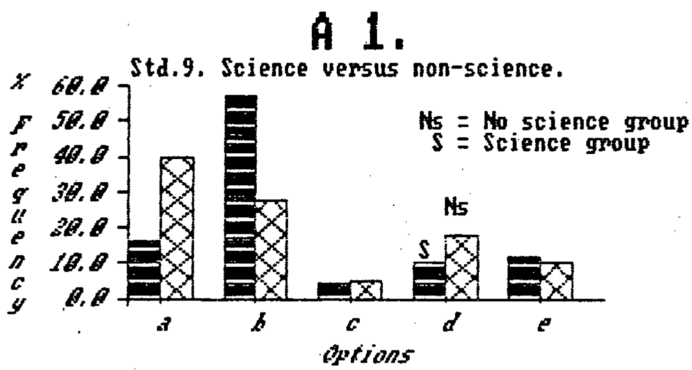


Note:

1. A clear majority of the standard 9 group select b, the option which includes gravity acting in conjunction with a larger force in the direction of motion, while the majority of standard 7 select a, the option which excludes gravity. Interestingly, the standard 4 group are about evenly divided between a and b, with 27% and 34% respectively selecting the options. Only 26% of the standard 7 group select option b.
2. Option c, the correct option, is selected by 4% of the standard 9 group, 5% of the standard 7 group and 2% of the standard 4 group.

3. Standard 9 science pupils and standard 9 pupils who do not do science :

The following graph compares the frequencies with which standard 9 pupils doing science and standard 9 pupils not doing science select the various options.

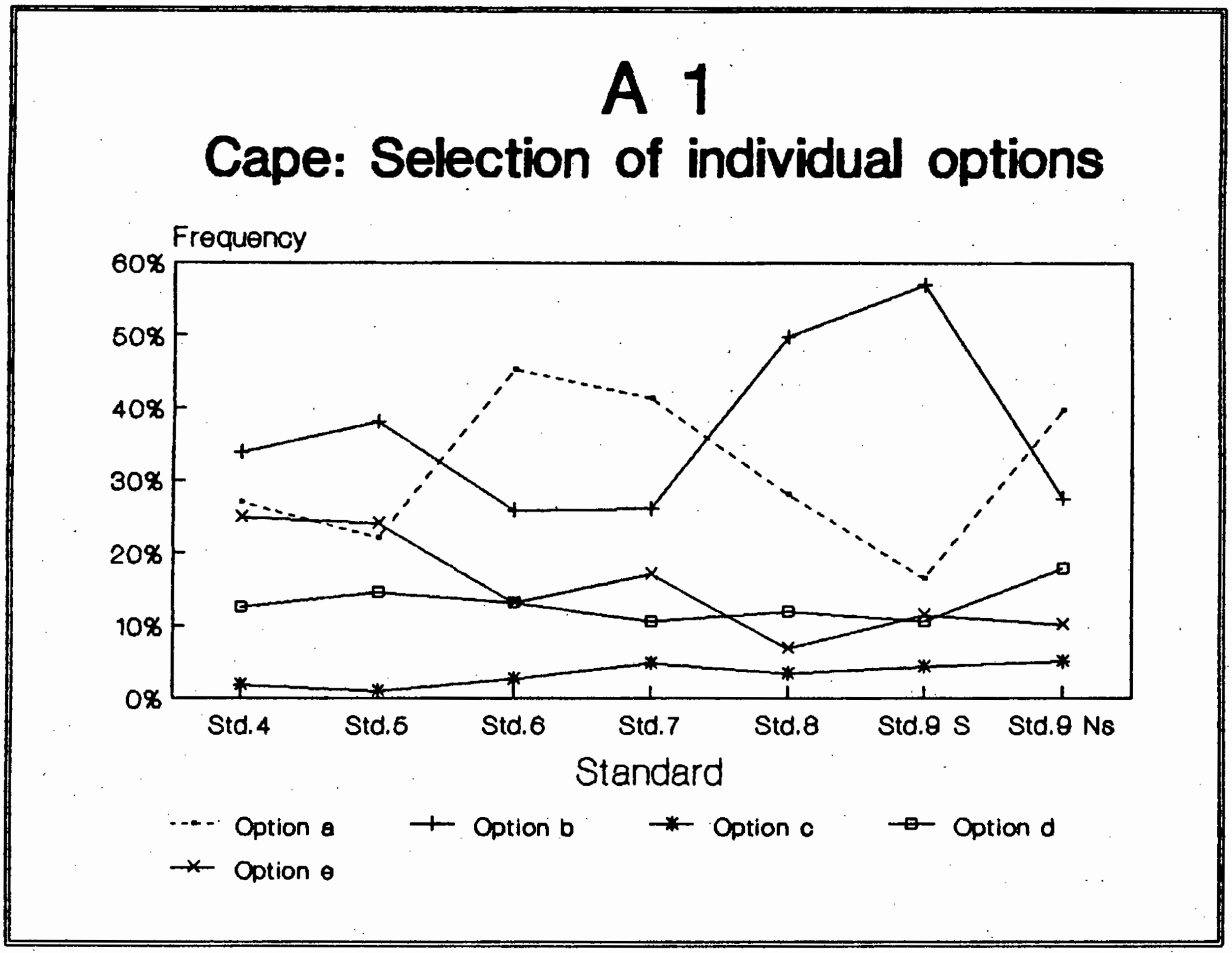


Note:

1. The main difference between the two groups lies in the frequencies with which options a and b are selected. The majority of the science group select b, indicating that they are aware of the presence of the gravitational force to a larger extent than the non - science group.
2. There is no noteworthy difference in the frequencies with which c, the correct option, is chosen by the two groups.

(h) **Selection of individual options:**

The following graph shows how the individual options are selected by the different standards in the Cape.



Note:

1. The popularity of option b reaches a sharp peak with the standard 9 science pupils.
2. Option a is a popular choice with standard 6, 7 and 9 no science pupils.
3. Option c is unpopular with pupils in all of the standards.

Summary:

1. As far as the overall picture is concerned we find that:

   93.7% of the pupils select options which indicate a belief that a force is acting in the direction of motion of the ball;

   the correct option is selected by only 6.3% of the pupils;

   34% of the pupils select option a, the option which excludes the presence of the force acting against the direction of motion of the ball; the gravitational force.

2. When we compare the frequencies with which the different options are selected by pupils in the different standards in schools in the Cape, we find that:

   the different standards select the different options with differing frequencies. Of interest is the comparison between Cape standard 4 and 5 pupils on the one hand and standard 6 and 7 pupils on the other hand, in their ideas concerning the presence of a force opposing motion in this case. We also find that there is little difference in the frequencies with which the correct option is selected by the different groups.

   In Transkei we find that a sizeable fraction of the standard 4 and 5 pupils do not consider the presence of a force acting against the motion of the ball in this situation. We also find that considerably more Transkei pupils select the correct option than their counterparts from the Cape. This may be due to guessing.

3. We find that English-and-Afrikaans-speaking pupils differ slightly in their choice of options a and b, with slightly more Afrikaans-speaking pupils selecting the options which include gravity.

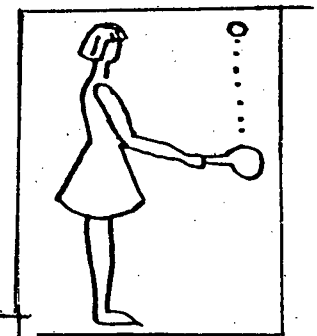
4. We find that boys and girls in Cape schools differ slightly in their choice of options. More boys select options which include gravity. In Transkei this trend appears to be the other way around as fewer boys appear to select options which include gravity.

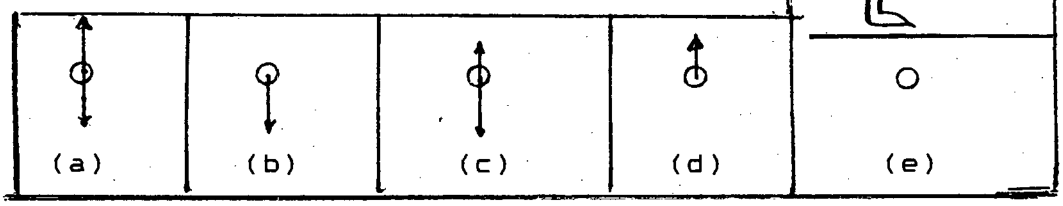
5. We find that there is no real difference in frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options.

6. We find that standard 4 pupils differ from standard 7 and standard 9 pupils who do not do science in that the standard 4 group seem to be more aware of gravity. The standard 9 science group select options including gravity more frequently than any of the mentioned groups with the standard 8 group finding options containing gravity a little less attractive.

Question A 2

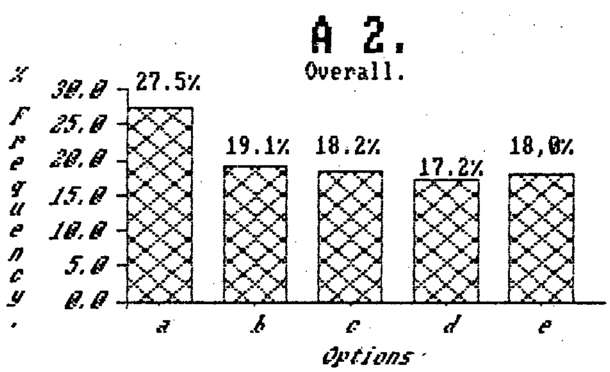
The following sketch shows a girl who has used a bat to hit a ball vertically upwards. The sketch which best shows the forces acting on the ball when it has reached its highest point and just before it starts to fall back to the ground, is :





(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample. (N = 2320)



Note:

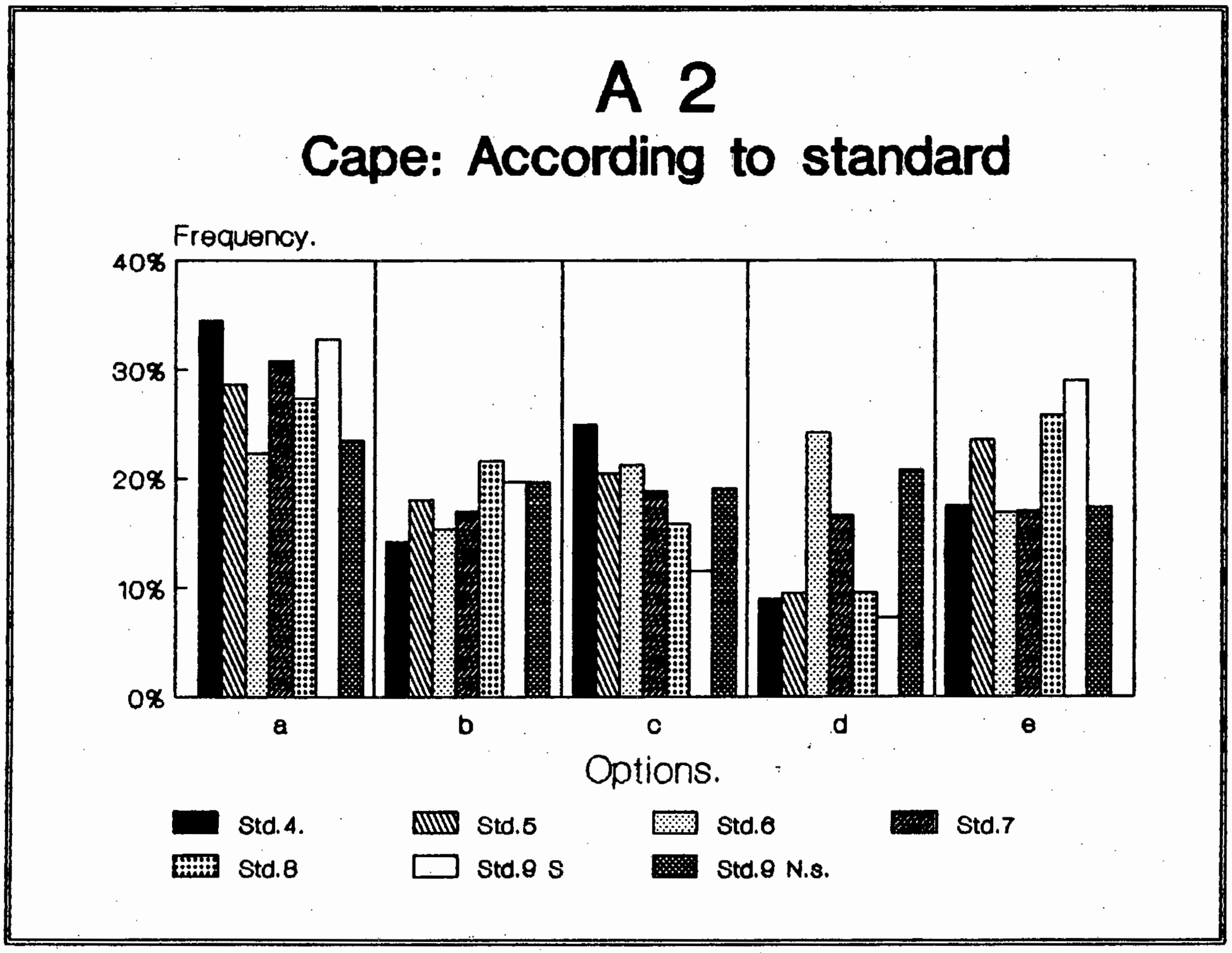
1. Although the selection of options is fairly evenly distributed, option a, the option which suggests that two forces of equal magnitude are acting on the ball, is selected appreciably more often than any other option. (27%)

2. Option b, the correct option is selected by 19% of the pupils.
3. Option c which suggests that the upwards force is smaller than the downwards force is selected by 18% of the pupils.
4. Options d and e, which both ignore the presence of gravity, are selected by a total of 35% of the pupils.
5. Options a,c,d and e all suggest a force in the direction of motion of the ball and are selected by 81% of the pupils.
6. Options a, b and c suggest the presence of gravity and are selected by 65% of the pupils.

(b) **According to standard:**

1. <u>In the Cape</u>:

The following graph compares the frequencies with which the different options are selected by the different standards in schools in the Cape.



Note:

1. There is a reasonable amount of variation in the frequencies with which the different groups select option a. The frequencies with which standard 4, 7 and standard 9 science pupils select option a is very similar and in the region of 33% of each of the groups. About 23% of the standard 6 pupils and the standard 9 pupils who do not do science select option

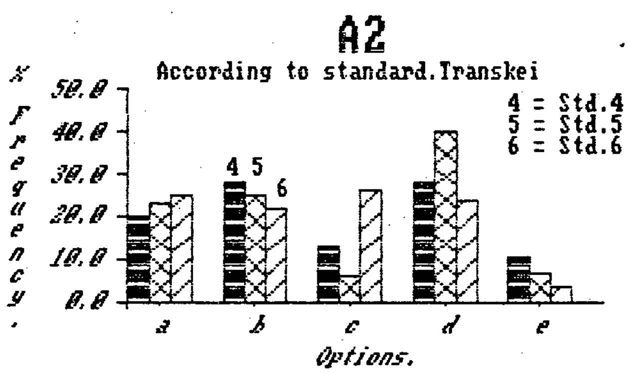
a while about 27% of the standard 5 and standard 8 pupils select this option.

2. The variation in the frequencies of selection of option b, the correct option, is less than that for option a. It is least popular with the standard 4, 5 and 6 and 7 pupils and in the region of 17% while with the standard 8 and both the standard 9 groups it is selected by about 20% of the pupils.
3. Option c, the option which suggests that there are two forces acting on the ball, a force acting against the direction of its motion and a smaller one in the direction of its motion, is the next most popular choice of the standard 4 pupils with 25% of them selecting it. About 20% of the standard 5, 6, 7 and standard 9 "no science" pupils select this option. 16% of the standard 8 pupils and 11% of the standard 9 science pupils select this option.
4. There is a big variation in the frequencies with which the different groups select option d, the option which suggests that the only force acting on the ball is a small force in the direction of its original motion. It is least popular with the standard 9 science pupils who select it with a frequency of 7%. It is most popular with the standard 6 pupils who select it with a frequency of 24% Pupils in standards 4, 5 and 8 are very similar in their selection of this option. About 10% of these pupils select this option. In the standard 7 group 17% of the pupils select this option while 21% of the standard 9 "no science" group select this option.
5. Option e which suggests that no force acts on the ball when it is standing still, is selected by about 17% of the pupils in

standards 4, 6, 7 and the standard 9 "no science" group. About 25% of standards 5 and 8 pupils select this option while 29% of the standard 9 science pupils do.

2. In Transkei:

The following graph compares the frequencies with which the different options are selected by pupils in the different standards in Transkei.



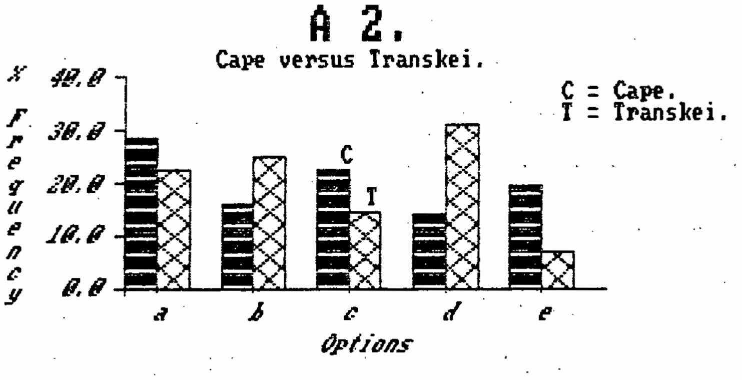
Note:
1. There is a reasonable amount of variation in the frequencies with which the different groups select the different options.
2. Option e, the "no force" option, is the least popular with the groups, the frequencies of selection being 4% for standard 6 pupils and 10% for standard 4 pupils.
3. Option d is a popular option with 40% of standard 5 pupils selecting it. This is their preferred option.
4. The selection of option c shows the largest difference in the frequencies of selection by the pupils in the different standards. The standard 6 group select this option with a frequency of 26% while the standard 5 group select it with a

frequency of 6% and the standard 4 pupils with a frequency of 13%

5. There is very little difference between standards in the selection of option b. A fairly large group of pupils in each of the standards, ranging from 28% for standard 4 to 22% in standard 6, select this option.
6. As in the case of option b, the pupils in the different standards differ very slightly in their selection of option a, ranging from 20% for standard 4 through to 25% for standard 6.
7. The responses of the standard 6 group is evenly spread across options a, b, c and d while there is a large degree of variation in the frequencies with which these options are selected by the standard 4 and standard 5 groups.

(c) **Comparison between the Cape and Transkei:**

The following graph compares the frequencies with which the different options are selected by standard 4, 5 and 6 pupils in the Cape and Transkei.

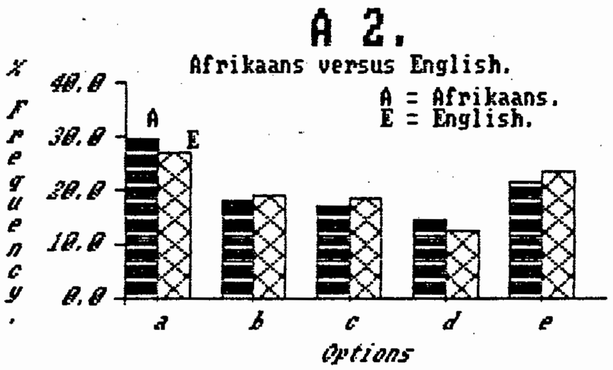


Note:

1. There is a large difference in the frequencies with which pupils from the two groups select the different options. While 25% of Transkei pupils select b, the correct option in this case, only 16% of Cape pupils select it. Option d, the option which suggests that the only force acting on the ball is a small force upwards, is selected by 31% of Transkei pupils while only 14% of the pupils in the Cape select it. On the other hand, option e, which suggests that when the ball is standing still at the top of its flight there are no forces acting on it, is selected by 19% of the Cape pupils and by only 7% of Transkei pupils.
2. The presence of the force of gravity is ignored by 38% of Transkei pupils and 33% of Cape pupils.
3. Force is thought to act in the direction of motion by 84% of Cape pupils and 75% of Transkei pupils.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in the Cape select the different options.



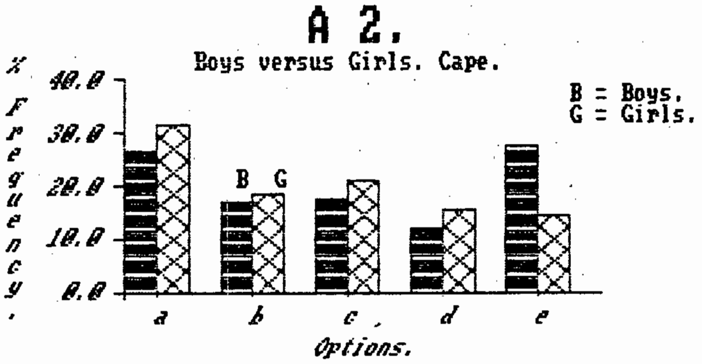
Note:

1. There are no noteworthy differences in the frequencies with which the pupils in the two groups select the different options.

(e) **Comparing the sexes:**

1. In the Cape:

The following graph compares the frequencies with which boys and girls in Cape schools select the different options.

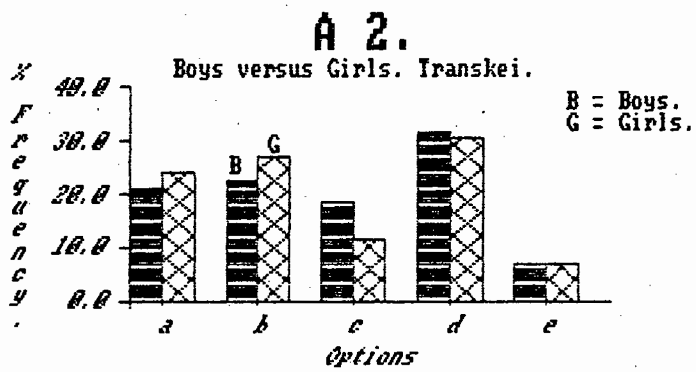


Note:

1. There are small differences in the preference which boys and girls have for options a through to d, but there is a very substantial difference in the selection of option e, the "no force" option. This is selected by only 14% of the girls while 27% of the boys select it.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in Transkei schools select the different options.

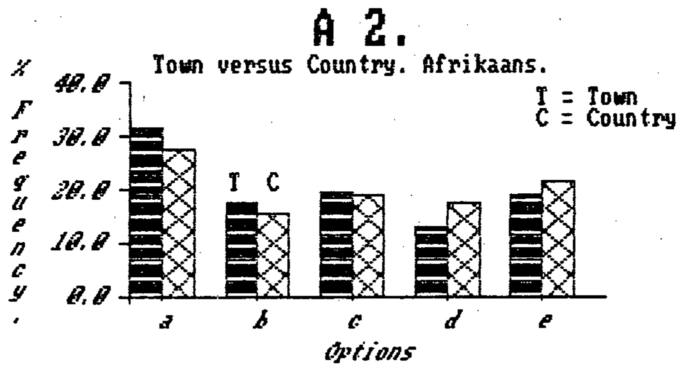


Note:

1. While the frequencies with which the pupils from the two groups select options a, b, d and e do not differ very greatly, this is not true for option c. This option is selected by 18% of the boys and 11% of the girls.

(f) Comparing pupils from Town and Country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options.



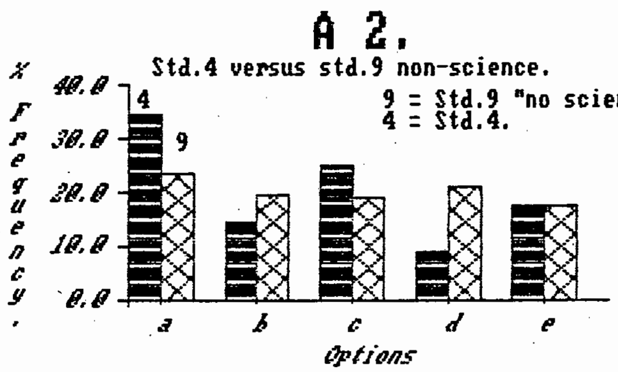
Note:

1. The frequencies of selection of the different options is very similar for the two groups.

(g) Comparing some standards:

1. Standard 4 and standard 9 " no science " group.

The following graph compares the frequencies with which Cape standard 4 pupils and standard 9 pupils who do not do science select the different options



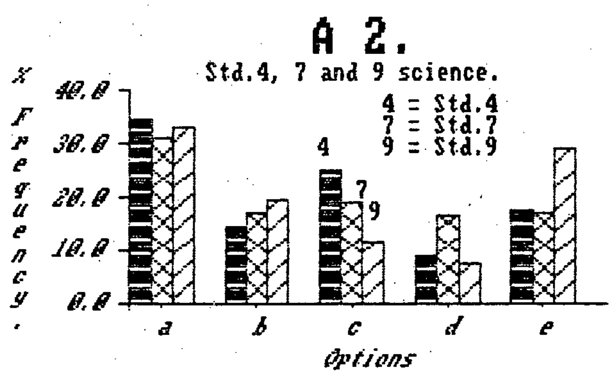
Note:

1. With the exception of option e, there is considerable difference in the frequencies with which the different groups of pupils select the different options.
2. While the frequency with which each of the different options are selected are fairly evenly spread across the options for the standard 9 pupils, this is not true for the standard 4 pupils who prefer option a and find option d unattractive.
3. Although more of the standard 9 group select the correct option, the standard 4 group appear to be more aware of the presence of gravity, with options a,b and c being select by 73% of this group as opposed to 62% of the standard 9 group.
4. 91% of the standard 4 pupils select options which suggest a belief in the presence of a force in the direction of motion

as opposed to 79% of the standard 9 group.

2. <u>Standards 4, 7 and 9 " science group".</u>

The following graph compares the frequencies with which Cape standard 4, 7 and 9 science pupils select the different options.



Note:

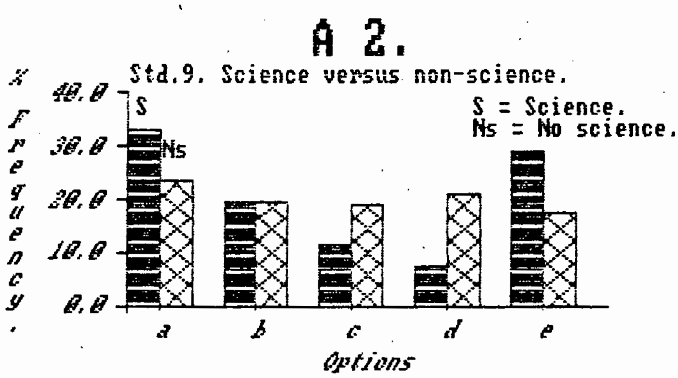
1. Option a is selected with very similar frequencies by the different groups of pupils.
2. There is a steady increase from standard 4 through to standard 9 in the frequency with which pupils in the different groups select option b.
3. There is an equally steady decrease from standard 4 through to standard 9 in the frequency with which the pupils in the different groups select option c
4. Pupils from the standard 4 and standard 9 groups find option d unattractive, while about 17% of the standard 7 pupils select this option.
5. About 17% of the pupils in the standard 4 and standard 7

groups select option e, while this option is selected by 29% of the pupils in the standard 9 group.

6. The presence of gravity is ignored by 26% of the standard 4 pupils, 34% of the standard 7 pupils and 36% of the standard 9 pupils.

3. <u>Standard 9 science pupils and standard 9 pupils who do not do science:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and standard 9 pupils who do not do science select the different options.



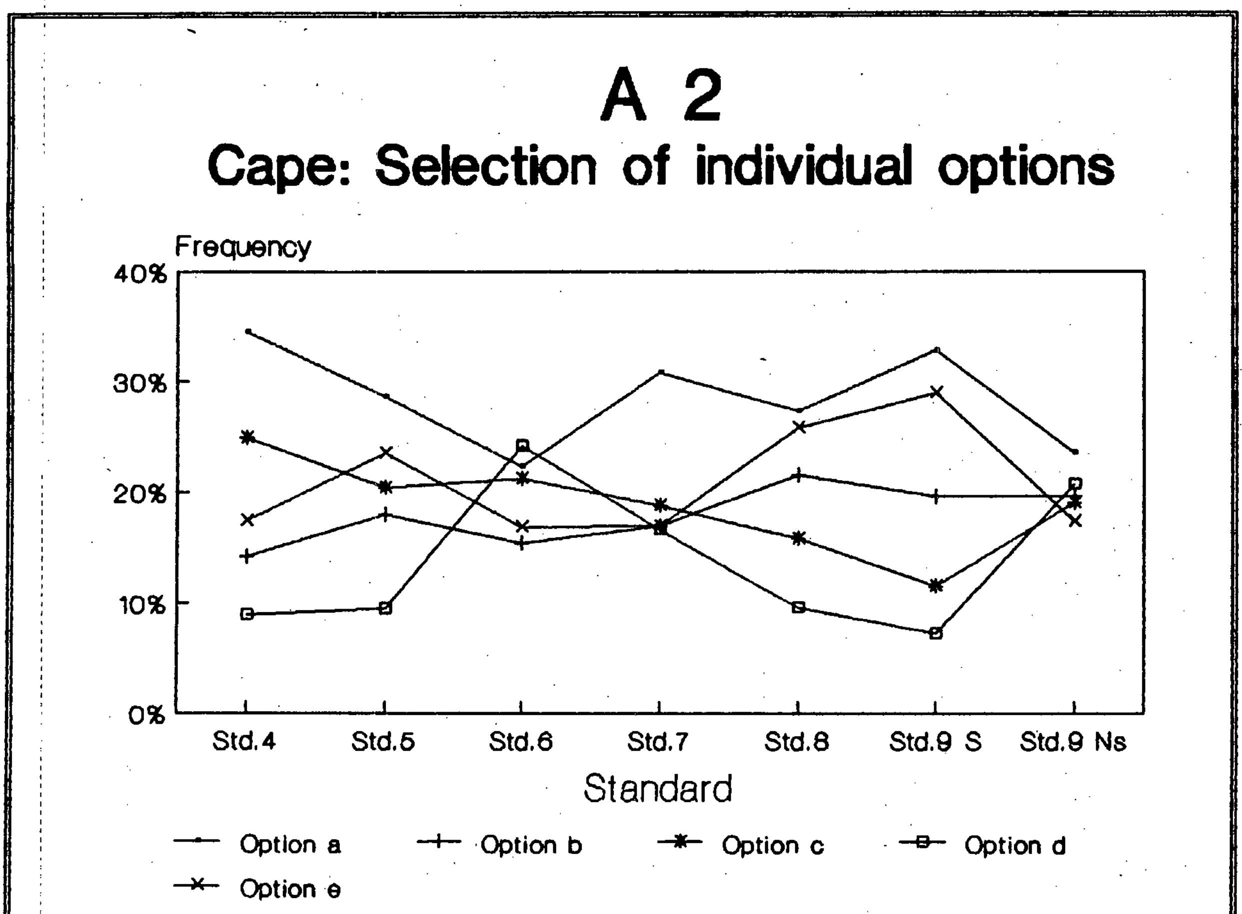
Note:

1. It is quite clear that with the exception of option b, pupils from the two groups select the different options with very different frequencies.

2. Options a and e are very popular with pupils in the science group.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by pupils across the standards.



Note:

1. Option a is popular with all of the standards.
2. Option d is very popular with standard 6 pupils but decreases gradually in popularity down to the standard 9 science group
3. There is a gradual increase in popularity of option e from standard 7 through to the standard 9 science pupils.

Summary:

1. As far as the overall picture is concerned we find that:

   there is a preference for option a, with 27% of the pupils selecting it;

   the frequencies with which the other options are selected are very similar and in the region of 18%;

   81% of the pupils select options which suggest a force acting in the direction of motion;

   35% of the pupils select options which ignore the presence of gravity.

2. When we compare the frequencies with which the different standards in Cape schools select the different options we find that:

   there is a fair amount of variation in the frequencies with which the different standards select the different options;

   option b shows a gradual increase in popularity across the standards;

   option c shows a gradual decrease in popularity across the standards;

   the standard 9 science pupils select options a and e in preference to the others.

3. When we compare the frequencies with which the different standards in Transkei select the different options we find that:

   there is a fair amount of variation in the frequencies with which the different standards select the different options;

there is a gradual increase in the popularity of option a across the standards;
there is a gradual decrease in the popularity of option b across the standards;
option e is very unpopular with all the standards;
option d is very popular with the standard 5 group.

4. When we compare the pupils in the Cape with their counterparts in Transkei we find that:

   there is a very big difference in the frequencies with which the different options are selected by the two different groups;
   this difference is especially large in the frequencies of selection of options d and e;
   the preferred option in Cape schools is a, the option which suggests that at the top of its flight the ball experiences two forces of equal magnitude, but opposite in direction, acting on it;
   the preferred option in Transkei schools is d, the option which suggests that there is a small force acting on the ball at the top of its flight, in the direction of the original motion.

5. When we compare Afrikaans-and-English-speaking pupils we find that there is no noteworthy difference in the frequencies with which the two groups select the different options.

6. When we compare the frequencies with which boys and girls in Cape schools select the different options we find that there

are small differences on most of the items except e, which is the second most popular item with the boys (27%) and the least popular with the girls.(14%)

In Transkei schools we find that there are small differences in the frequencies with which the different options are selected by boys and girls, with the exception of option c, in which there is a fairly large difference, with 18% of the boys selecting it as opposed to 11,5% of the girls.

7. When we compare the frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options, we find no noteworthy difference.

8. When we compare some of the standards we find that:

the frequencies with which the standard 4 pupils select the different options to be very different from that of the standard 9 pupils who do not do science. Furthermore, we find that 29% of the standard 4 group neglect gravity as opposed to 38% of the standard 9 group. 91% of the standard 4 group link force and motion while 79% of the standard 9 group do.
Option a is selected with similar frequencies by standard 4, 7 and 9 science pupils, the frequencies of selection being about 32%.
On the other options there is fairly large variation in the frequencies with which the different groups select the options.
Standard 9 science pupils and standard 9 pupils who do not do science select option b, the correct option, with the same

frequencies. However, the groups differ markedly in their selection of the other options.

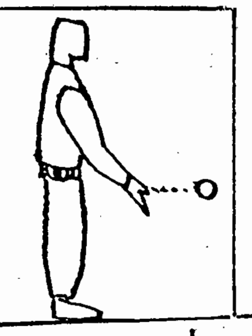
9. When we compare the frequencies with which the individual options are selected by the different standards, we find that:

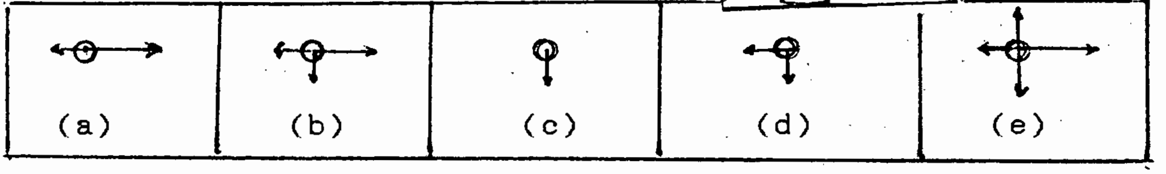
the different options have different popularities with the different standards;

options a and e are the two most popular options.

Question A 4

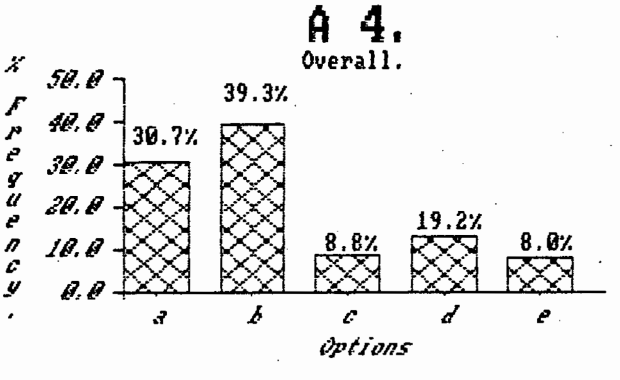
The sketch shows a boy who has thrown a ball horizontally away from him. The sketch which best shows the forces (including friction or resistance) acting on the ball immediately after it has left the boy's hand, is:





(a) **The overall picture:**

The following graph shows the frequency with which the different options are selected by the whole sample.



Note:

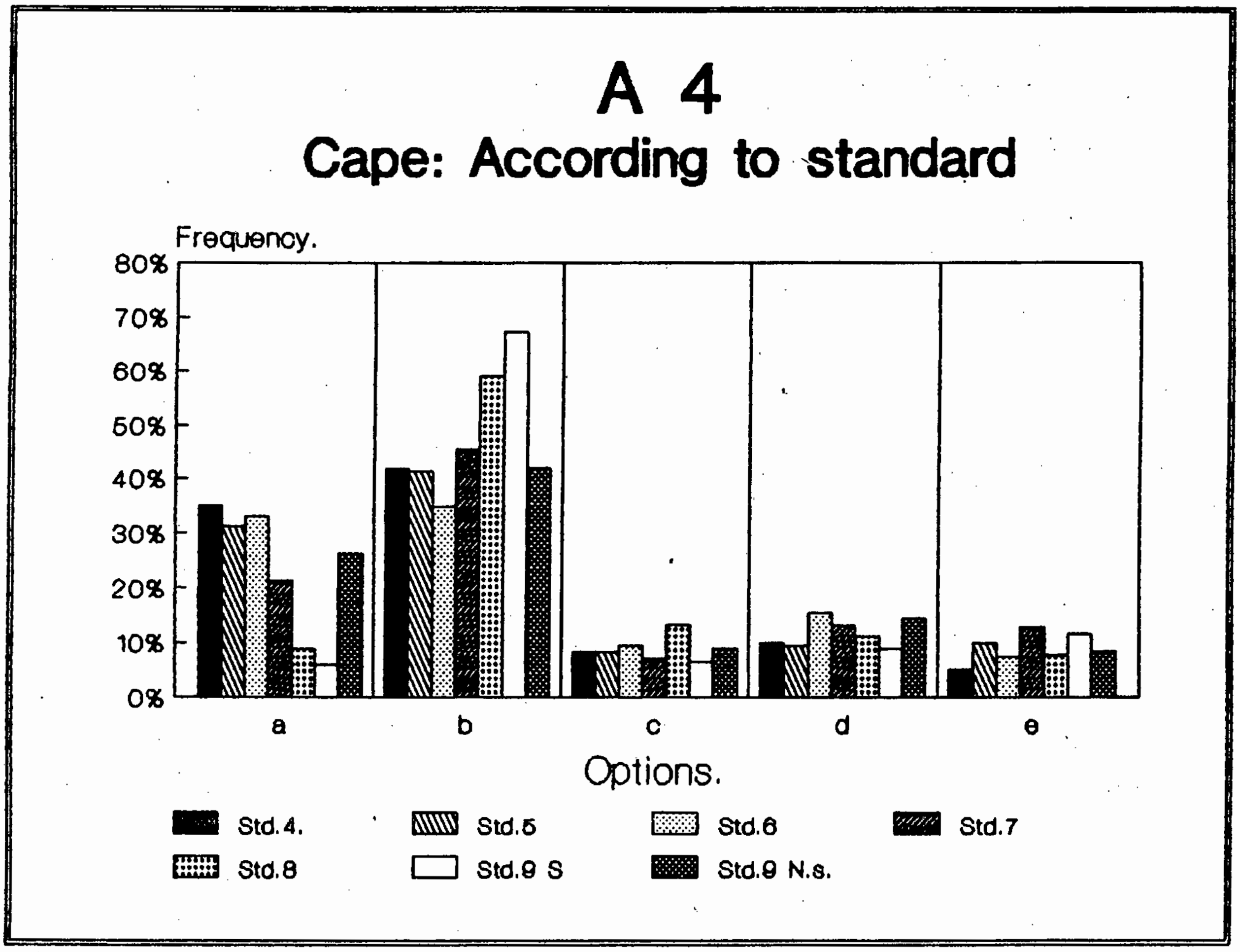
1. Options a and b are by far the most popular options. These options imply a force acting in the direction of motion of the ball and a force acting against the direction of motion of the ball, but the "driving" force is larger than the resisting force.

2. Options a, b and c which all imply a force in the direction of motion, is selected by 78% of the pupils.
3. Option c, the correct option, is selected by 19% of the pupils.
4. Only option a excludes the force of gravity and is selected by 31% of the pupils.
5. 8% of the pupils select option e which suggests the presence of a force, as large as gravity, acting upwards.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequency with which the different options are selected by pupils in the different standards in schools in the Cape.



Note:

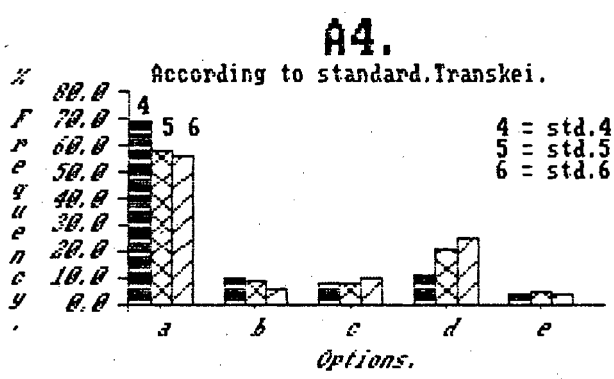
1. Although pupils from the different standards select the options with differing fequencies, options a and b are by far the most popular. However standard 8 and 9 science pupils do not find option a very popular but overwhelmingly select option b, which overall is the most popular option with all the standards.

2. There is very little support for option d, the correct option.

3. The frequency of selection of the different options is very similar for standards 4 and 5.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



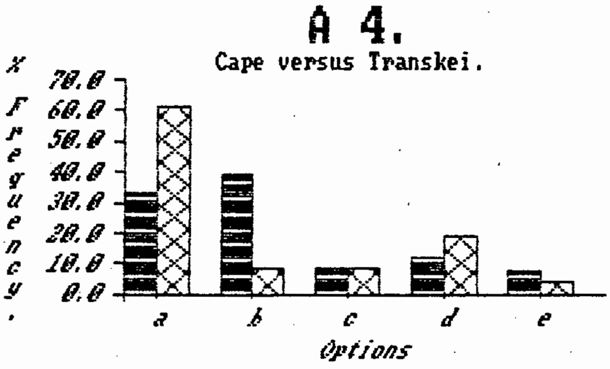
Note:

1. Option a receives overwhelming support from all of the standards. This is the option which excludes a downward force acting on the ball.

2. The next most popular option is the correct option, option d.

(c) **Comparison between the Cape and Tanskei:**

The following graph compares the frequency with which the different options are selected by pupils is standards 4, 5 and 6 in the Cape and Transkei.

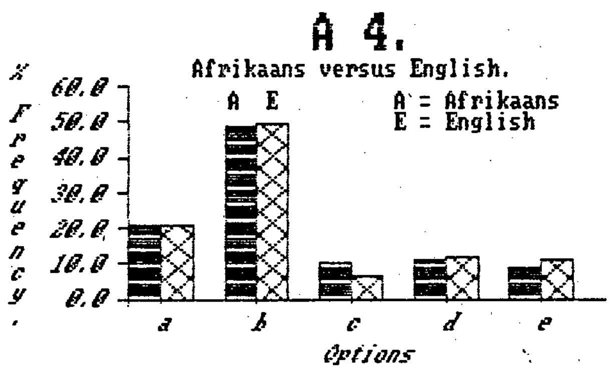


Note:

1. There is very large differences in the frequencies with which pupils from the two areas select option a, the option which excludes gravity. This option is selected by 61% of Transkei pupils as opposed to 33% of Cape pupils.
2. While only 8% of Transkei pupils select option b, the option which includes gravity with a force in the direction of motion of the ball, this option is selected by 39% of the Cape pupils.
3. About 19% of Transkei pupils select the correct option as opposed to 12% of the pupils in Cape schools.

(d) **Comparison of the language groups in the Cape:**

The following graph compares the frequency with which Afrikaans-and-English-speaking pupils in the Cape select the different options.



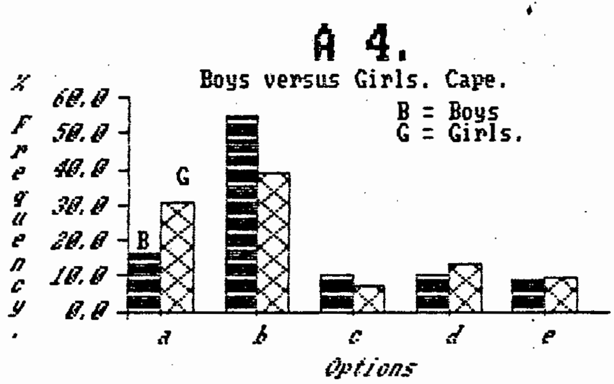
Note:

1. There is no noteworthy differences in the frequencies with which the two language groups select the options for this question.

(e) **Comparing the sexes:**

1. In the Cape:

The following gaph compares the frequencies with which boys and girls in Cape schools select the different options.

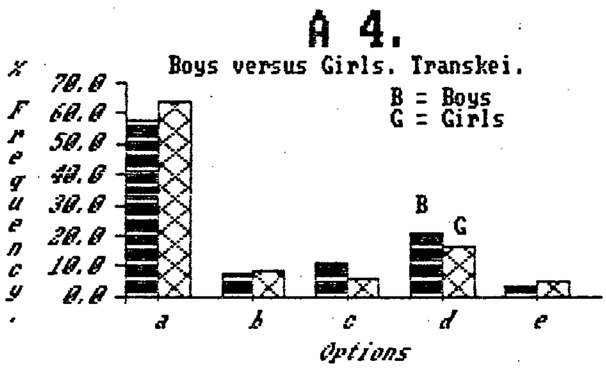


Note:

1. The major difference lies in the selection of options a and b. Both boys and girls find option b the most popular, but boys find it much more so than girls who find it a little more popular than a. Boys appear to be more aware of the presence of a downwards acting force on the ball.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in Transkei select the different options.

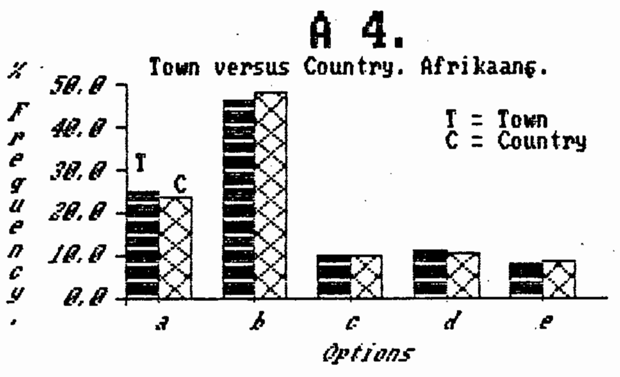


Note:

1. There are only small differences in the frequencies with which the different options are selected by boys and girls. Option a is overwhelmingly the most popular with both boys and girls.

(f) **Comparing pupils from Town and Country areas in the Cape:**

The following graph comapres the frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options.



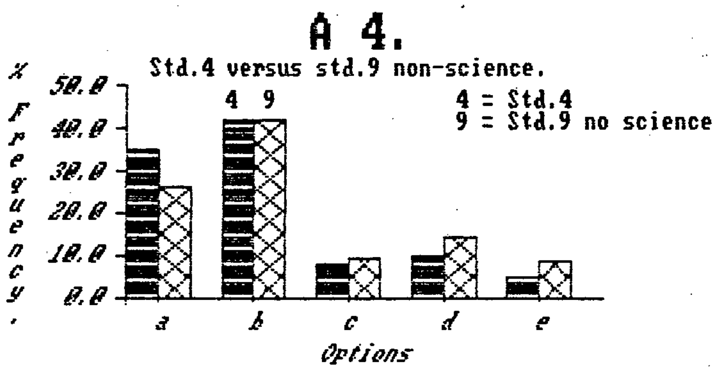
Note:

1. The frequencies with which the two groups select the different options are amazingly similar.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 "no science" group.

The following graph compares the frequencies with which pupils in standard 4 and standard 9 who do not do science select the different options.

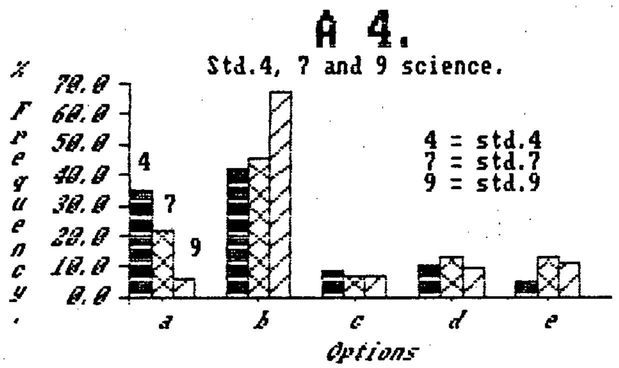


Note:

1. The major difference between the two groups lie in the frequencies with which option a is selected. This is the option which ignores the presence of gravity and is selected by 35% of the standard 4 group and only by 26% of the standard 9 group.

2. <u>Standards 4, 7 and 9 "science group":</u>

The following graph compares the frequencies with which standard 4, 7 and 9 pupils who do science select the different options.

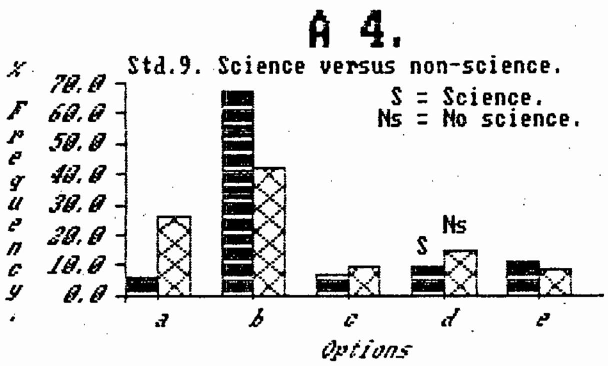


Note:

1. There are only small differences in the frequencies of selection of options c, d and e.
2. The correct option, d, is selected with about the same frequency by the three different groups.
3. Option a, the option which ignores gravity, becomes progressively less popular from standard 4 through to standard 9.
4. Option b, the option which includes gravity in combination with a force in the direction of motion which is bigger than the retarding force, increases in popularity from standard 4 through to standard 9.

3. <u>Standard 9 science pupils and standard 9 pupils who do not do science:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and standard 9 pupils who do not do science select the different options.



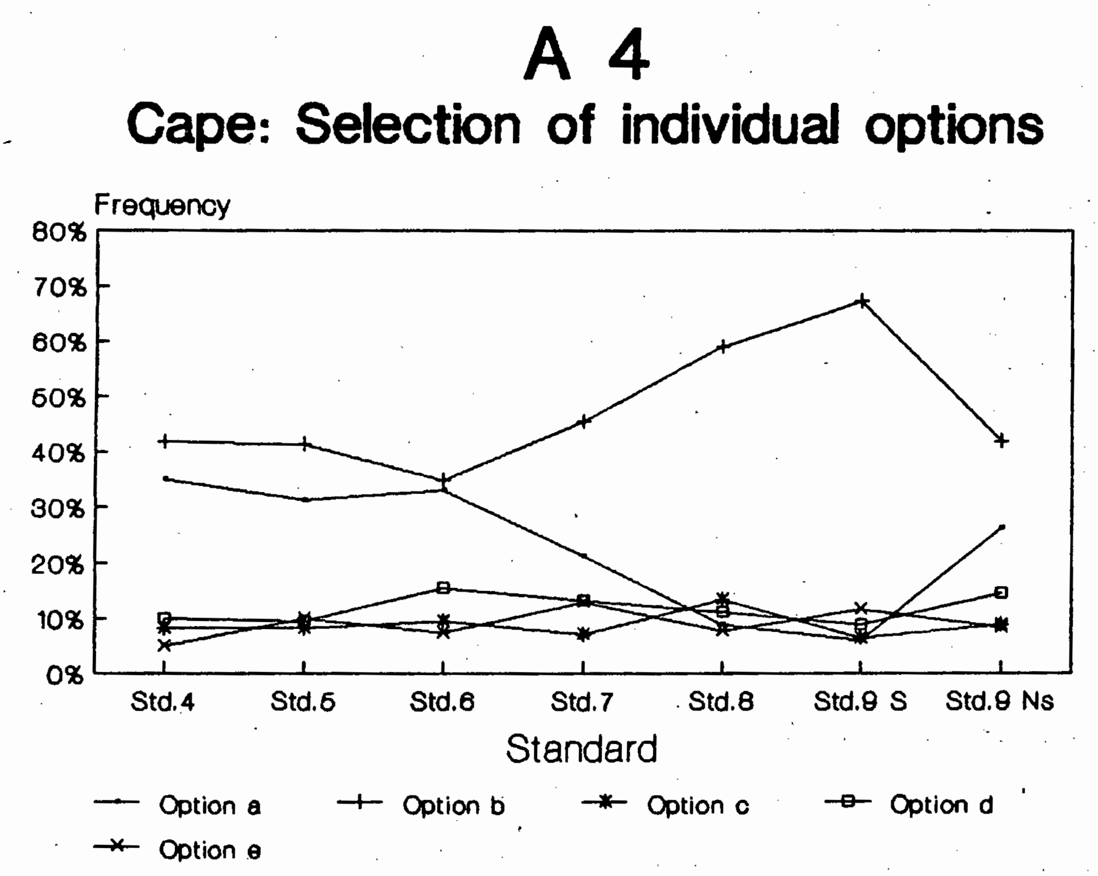
Note:

1. There is very little difference in the frequencies with which the different groups select options c, d and e. More of the no science group actually select the correct option.

2. There is very large differences in the frequencies of selection of options a and b. The science pupils select the option which includes gravity in combination with a force in the direction of motion which is larger than the retarding force and, while this option is also the most popular with the pupils who do not do science, the difference in the frequencies with which options a and b are selected is not nearly as large as for the science group.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the different options are selected by the pupils in the different standards.



Note:

1. Option b increases in popularity to a maximum with the standard 9 science group.
2. Option a decreases in popularity from a maximum with the standard 4 group to a minimum with the standard 9 science group.
3. Options c, d and e are selected with very similar frequencies.

Summary:

1. As far as the overall picture is concerned we find that:

   there is a preference for option b with 39% of the pupils selecting it;

   that option a is the next most popular with 31% of the pupils selecting it;

   78% of the pupils select options which suggest a force acting in the direction of motion;

   31% of the pupils select the option which ignores the presence of gravity.

2. When we compare the frequencies with which the different standards in Cape schools select the different options we find that:

   there is very little variation in the frequencies with which the different standards select options c, d and e;

   option b is by for the most popular option with all of the groups especially with the standard 9 and 8 science pupils;

   standards 4, 5 and 6 show similarity in the frequencies with which they select the different options.

3. When we compare the frequencies with which the different standards in Transkei select the different options we find that:

   option a is overwhelmingly selected by all of the groups;

   the next most popular option is option d, the correct option.

4. When we compare the pupils in the Cape with their counterparts in Transkei we find that :

   There are large differences in the frequencies with which the two groups select options a and b. Option a is very popular with Transkei pupils with some 61% of the pupils selecting that option as opposed to 30% of the pupils in the Cape who find option b more attractive with 39% of them selecting it as opposed to 8% of the Transkei pupils.
   73% of the pupils in Transkei select options which indicate force in the direction of motion of the ball while 80% of the Cape pupils select similar options.

5. When we compare Afrikaans-and-English-speaking pupils we find that there is no noteworthy differences in the frequencies with which they select the different options.

6. When we compare the frequencies with which boys and girls in Cape schools select the different options we find that both boys and girls select option b most frequently but that it is much more popular with the boys. Girls select option a much more frequently than boys.

   In Transkei we find vey little difference between boys and girls in the frequencies with which they select the different options. Both boys and girls overwhelmingly select option a.

7. When we compare the frequencies with which Afrikaans-speaking pupils who live in Cape Town and in country towns select the different options, we find that there are no noteworthy

differences.

8. When we compare some of the standards we find that:

the frequencies with which standard 4 pupils and standard 9 pupils who do not do science select the different options, differ slightly, except on option a where 35% of the standard 4 group select the option as opposed to 26% of the standard 9 group;

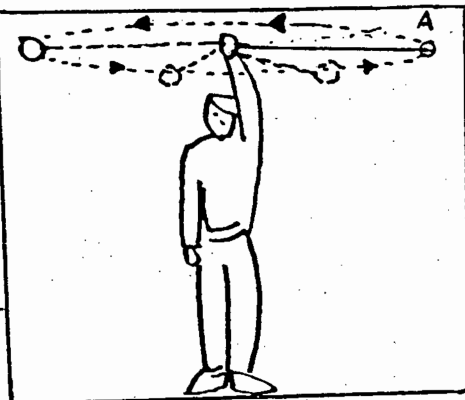
the frequencies with which standard 4, 7 and 9 pupils who do science select options c, d and e are fairly similar. Option a decreases in popularity from standard 4 through to standard 9 while option b increases in popularity from standard 4 through to standard 9;

the standard 9 science pupils and the standard 9 pupils who do not do science differ markedly on their selection of options a and b. The standard 9 science group overwhelmingly select option b which is also the most popular option with the pupils who do not do science. Only 6% of the science pupils ignore the presence of gravity as opposed to 26% of the pupils who do not do science.

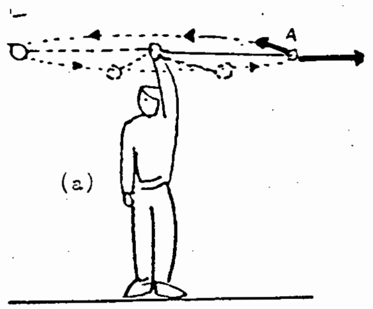
9. When we compare the frequency with which the individual options are selected by the different standards, we find that the popularity of option b increases to a maximum with the standard 9 science pupils while option b declines in popularity to a minimum with the standard 9 science pupils.

Question A 10

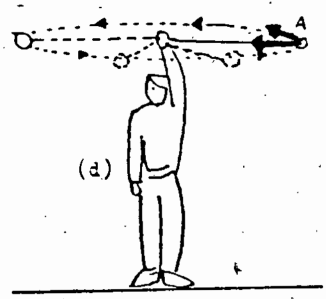
The sketch shows a boy who is swinging a ball, which is tied to a string, horizontally around his head. The force or forces acting on the ball at A because of its motion (not gravity and friction):



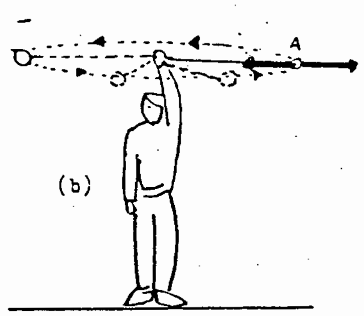
(a)



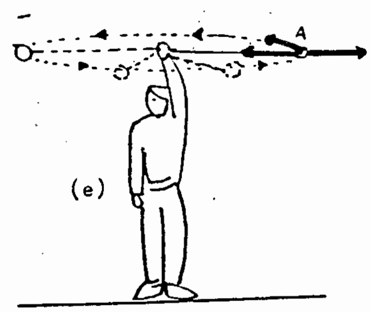
(d)



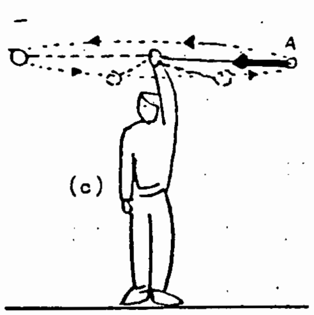
(b)



(e)

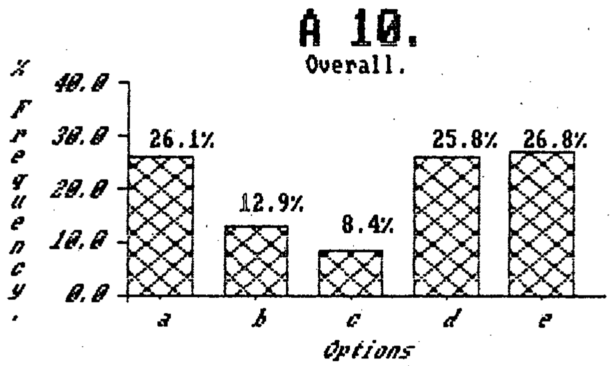


(c)



(a) **The overall picture**:

The following graph shows the frequencies with which the different options are selected by the whole sample.



Note:

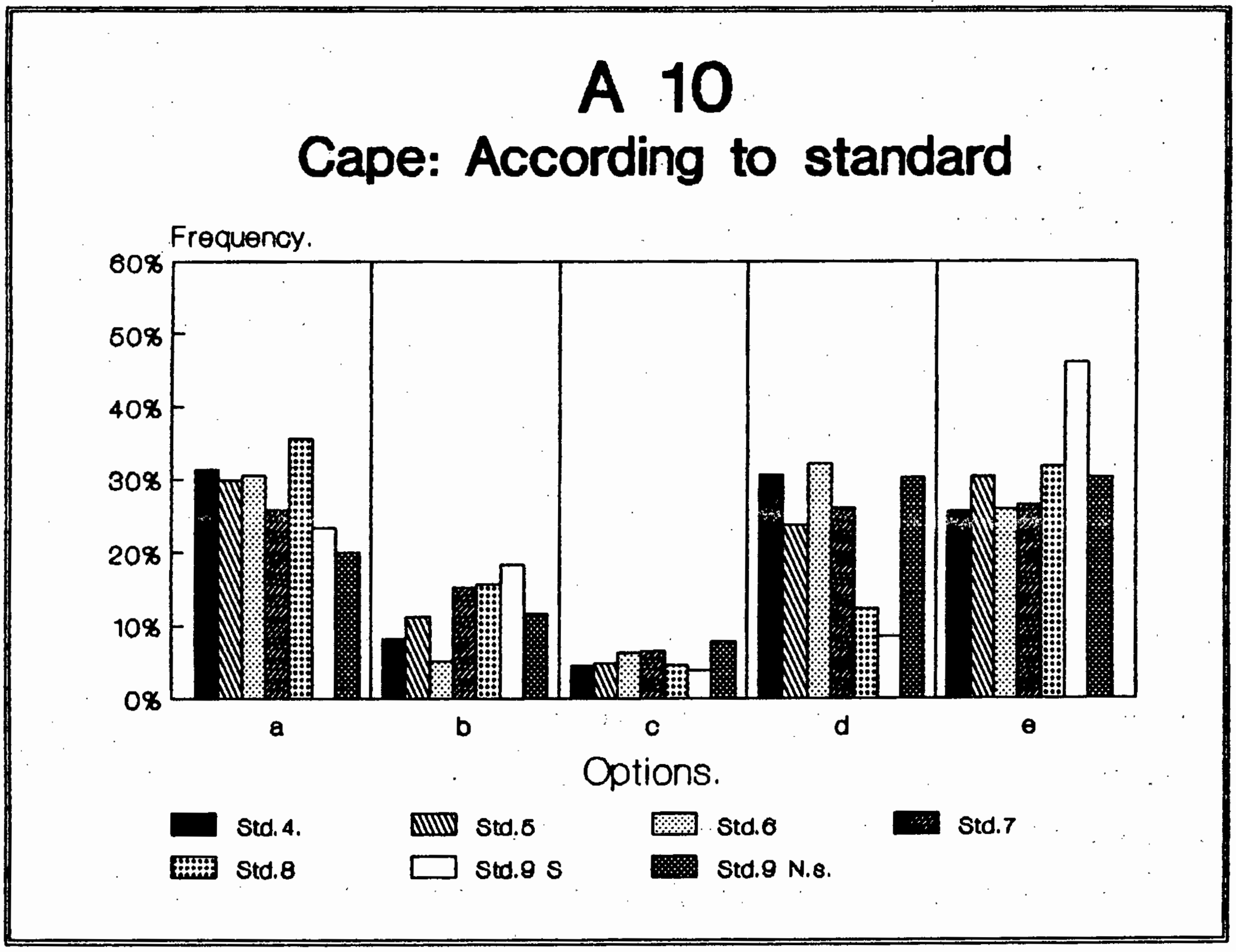
1. Options a, d and e are about equally popular. These options all involve a force acting in the direction of motion of the ball. That means that 78% of the pupils select options indicating a force acting in the direction of motion.
2. Option c, the correct option, is selected by only 8% of the sample.
3. Option b which involves only an inward force (centripetal) and an outwards force (centrifugal) is selected by about 13% of the sample.

•

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which the different options are selected by pupils in the different standards in the Cape.



Note:

1. With the exception of option c, the correct option, there is a fair amount of variation in the frequencies with which the different standards select the options. While the frequencies of selection of the options by standards 4, 5, 6 and 7 are fairly evenly distributed over options a, c and e, the same is not true for the remaining groups.

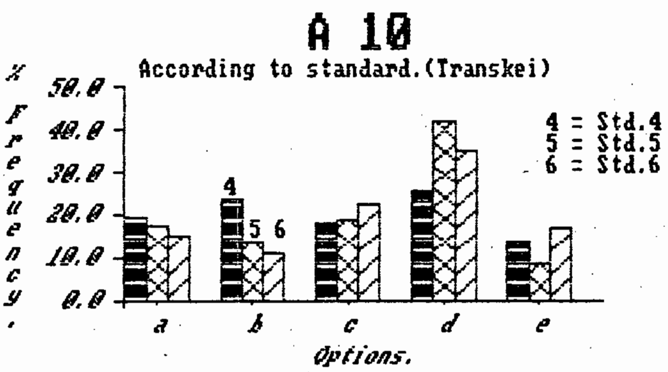
The standard 9 science group selects option e at the expense of most of the other options while the standard 8 group is evenly spread over options a and e. The standard 9 pupils who do not do science favour options d and e and to a lesser extent a.

2. It is quite clear from the results that the vast majority of the pupils associate force and motion.

3. Selection of options which suggest the presence of centripetal force, centrifugal force and a combination of these with a force in the direction of motion predominate, and the frequencies with which these are selected are evenly spread.

2. In Transkei:

The following graph compares the frequencies with which the different options are selected by pupils in the different standards in Transkei.



Note:

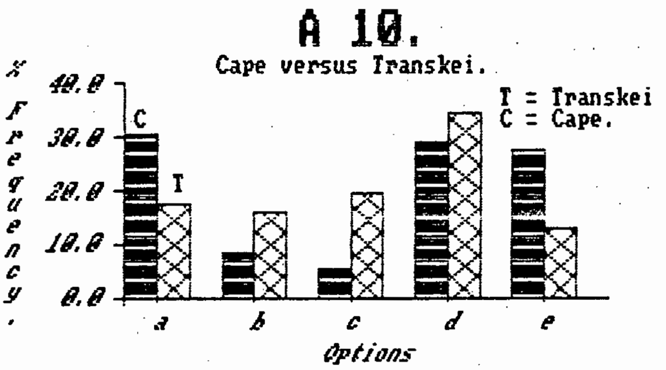
1. There is a reasonable amount of variation in the frequencies

with which the different options are selected by pupils in the different standards.

2. Option d, which combines centripetal force with a "driving force", is the most popular option for all of the groups.
3. The standard 4 group shows the least variation across the options.

(c) Comparison between the Cape and Transkei:

The following graph compares the frequencies with which the different options are selected by pupils in standards 4, 5 and 6 in the Cape and Transkei



Note:

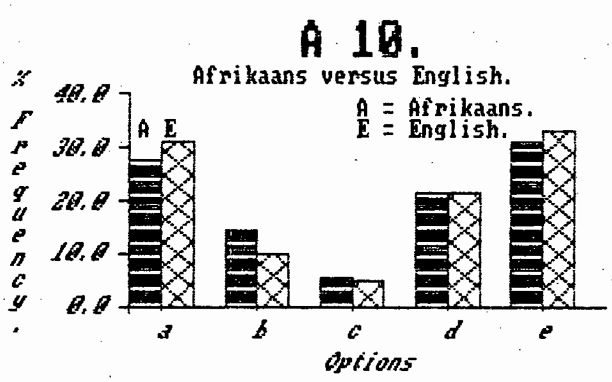
1. There is a big difference in the selection of the options between the two groups. Pupils in the Cape found options a, d and e about equally attractive while options b and c receive very little support. In Transkei the frequencies of selection is spread more evenly over the different options although option d is the most popular.
2. There is a big difference in the frequencies with which the two groups select c, the correct option. This option is

selected by about 20% of Transkei pupils as opposed to only 5% of the pupils in the Cape.

3. Pupils in the Cape overwhelmingly select options which indicate the belief in a force acting in the direction of motion. This force is seen to act in conjunction with centripetal and centrifugal force. The majority of Transkei pupils also select a force in the direction of motion but options which link this force to a centrifugal force are not popular

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in the Cape select the different options.



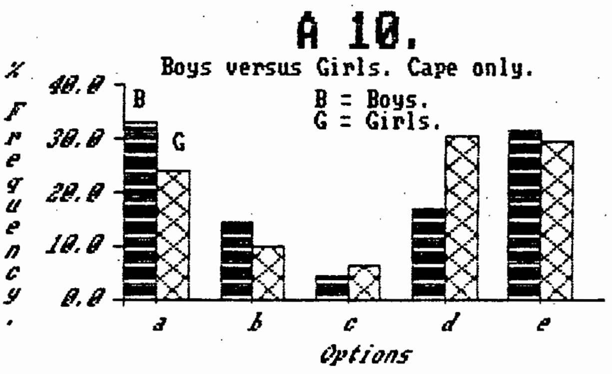
Note:

1. There are only small differences in the frequencies with which the different options are selected by the two groups. It is only on options a and b where the differences are relatively large.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which the different options are selected by boys and girls in schools in the Cape.

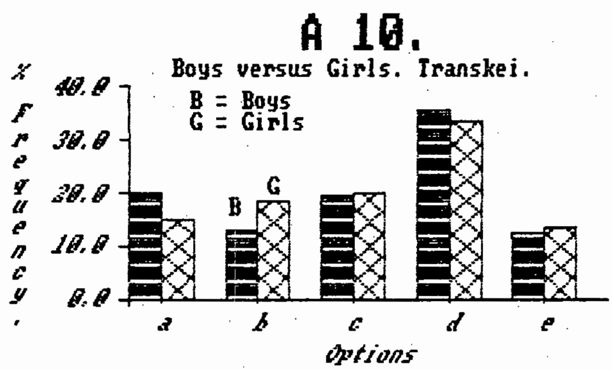


Note:

1. There is a fair amount of difference in the frequencies with which boys and girls select options a, b, and d. Option a combines a "driving force" with a centrifugal force. This option is selected by 33% of the boys as opposed to 24% of the girls. Option d combines a "driving force" with a centripetal force and is selected by 30% of the girls as opposed to 16% of the boys.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options

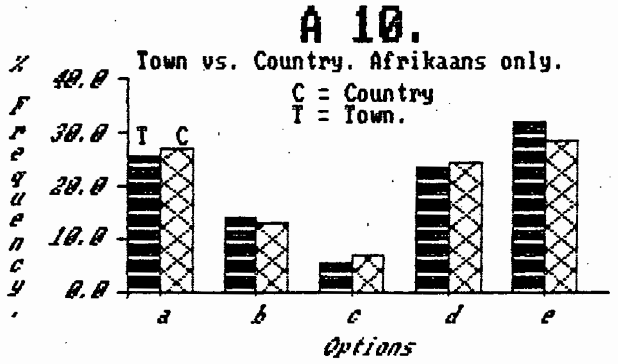


Note:

1. There are only small differences in the frequencies with which the different options are selected by the two groups. Only on options a and b do the groups differ slightly.

(f)Comparing pupils from Town and Country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options.



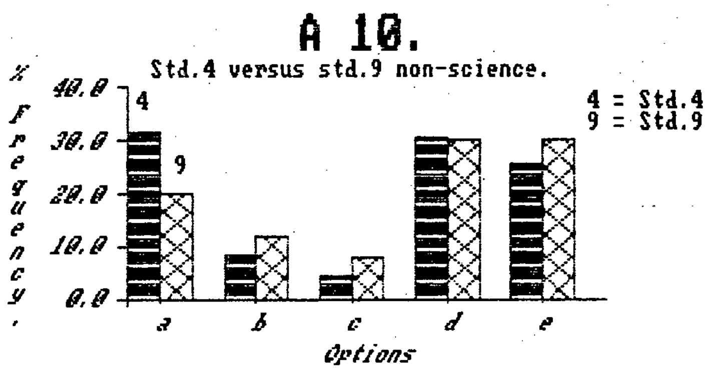
Note:

1. There are virtually no differences in the frequencies with which the two groups select the different options.

(g) Comparison of different standards:

1. <u>Standards 4 and standard 9 "no science" group.</u>

The following graph compares the frequencies with which Cape standard 4 pupils and standard 9 pupils who do not do science select the different options.

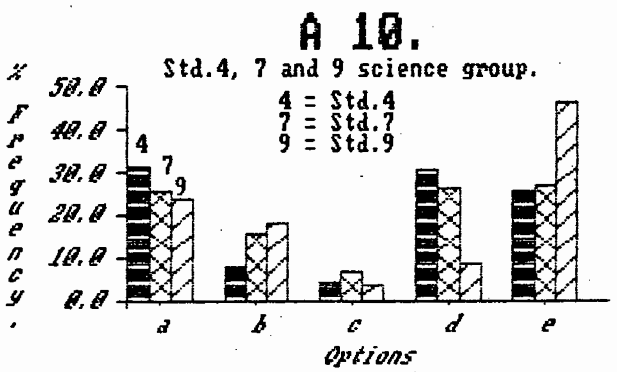


Note:

1. With the exception of option d, there are differences in the frequencies with which the two groups select the different options. This difference is especially large in the case of option a which is selected by 31% of the standard 4 group as opposed to 20% of the standard 9 group. The standard 4 group select options which include centrifugal force in combination with a "driving force" in preference to other options whereas the standard 9 group prefer options which include centripetal force in combination with a "driving force".

2. Standard 4, 7 and 9 "science group".

The following graph compares the frequencies with which Cape pupils in standards 4, 7 and 9 science classes select the different options.

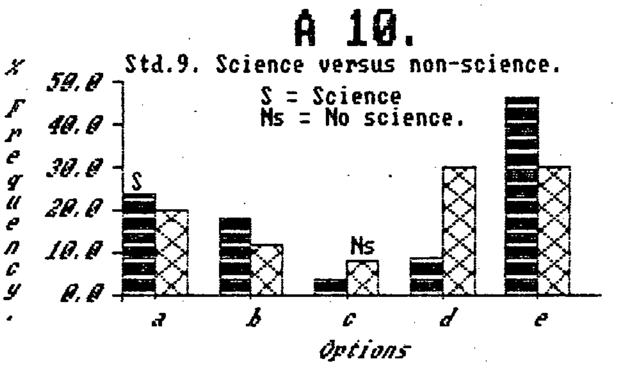


Note:

1. The groups differ quite markedly in their selection of the different options with the biggest difference being between the standard 4 and 7 groups on one hand and the standard 9 group on the other.
2. The standard 4 and 7 groups select options which indicate a belief in the presence of centrifugal force in preference to other options while the standard 9 group select options which indicate a preference for the presence of a centripetal force. These two forces are selected in combination with other forces by the three groups but the main difference is that while the standard 4 and 7 groups select options which include centrifugal force, the standard 9 group select options which include centripetal force as one of the forces.

3. <u>Standard 9 science pupils and standard 9 pupils who do not do science</u>.

The following graph compares the frequencies with which standard 9 pupils doing science and standard 9 pupils not doing science select the different options

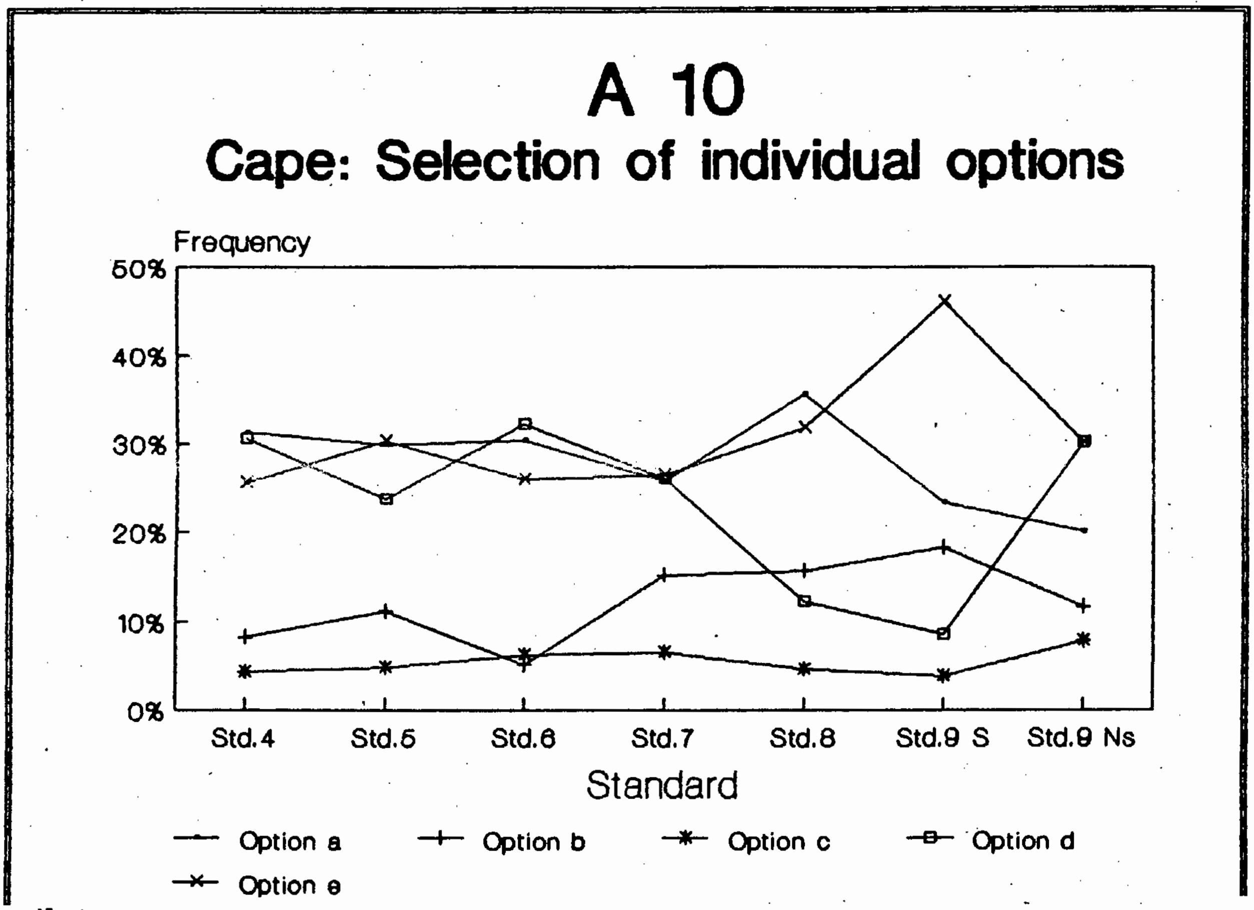


Note:

1. There are clearly differences in the frequencies with which the two groups select the different options. This difference is most marked in the case of options d and e. Standard 9 science pupils are in favour of the presence of a centrifugal force.

(h) **Selection of individual options:**

The following graph compares the frequencies of selection of the different options across the different groups.



Note:

1. Options b and c are very unpopular. These are the options which exclude a force in the direction of motion of the ball.
2. Option e increases in popularity from standard 7 through to the standard 9 science group coupled with a decrease in the popularity of option d over these groups. This reflects an increasing awareness of the presence of both centrifugal and centripetal force across these standards.

Summary:

1. As far as the overall picture is concerned we find that:

options a, d and e are selected with frequencies of about 26% each. These options all include a force acting in the direction of motion of the ball. This means that about 78% of the sample associate force with motion in this situation.

2. When we compare the frequencies with which the different standards in the Cape select the different options we find that:

although there is a fair amount of variation in the frequencies with which the options are selected by the different groups, in general standards 4, 5, 6 and 7 preferred options a, d and e. The standard 8 group preferred option a and e while the 9 science group select option e as its prefered option.

3. When we compare the frequencies with which the different standards in Transkei select the different options we find that:

there is a small difference between the frequencies with which the different groups select the different options but in general option d is the preferred option of all of the standards.

4. When we compare the pupils in the Cape with their counterparts in Transkei we find that:

   the two groups differ greatly in their selection of the different options;

   the correct option is selected by 20% of Transkei pupils while only about 5% of the pupils in the Cape select it;

   pupils in the Cape select options which indicate a belief in a force in the direction of motion in combination with centrifugal force, centripetal force, or both, about equally frequently. Pupils in Transkei preferred a force in direction of motion in combination with a centripetal force. Options including centrifugal force are not very popular with the pupils in Transkei.

5. When we compare Afrikaans-and-English-speaking pupils we find that there are small differences in the frequencies with which the two groups select options a and b. In general the frequencies with which the options are selected is very similar.

6. When we compare the frequencies with which boys and girls in Cape schools select the different options we find that boys and girls differ in their selection of options a, b and d. Boys favour options which include centrifugal force while girls favour options which include centripetal force.

   In Transkei schools we find that boys and girls differ very slightly in the frequencies with which they select options a and b.

7. When we compare the frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options we find that there were really no differences worth mentioning between the two groups.

8. When we compare the frequencies with which some of the standards select the different options we find that:

standard 4 pupils select options which include centrifugal force in combination with a "driving force" while the standard 9 pupils who do not do science select options which include centripetal force in combination with a " driving force". It appears that the standard 4 group are more aware of an "outwards" acting force on the ball.

standard 4 , 7 and 9 pupils who do science differ markedly in their selection of option e. This option is overwhelmingly selected by the standard 9 pupils. This group seems to prefer the presence of centripetal force in combination with centrifugal and "driving force". However, inspite of the fact that there are marked differences in the frequencies with which the groups select the different options, no one group shows much less of a belief in the need for a force to act in the direction of motion of the ball. The differences observed are associated with the forces acting in conjunction with this force.

9. When we compare the frequencies with which the individual options are selected by the different standards we find that:

options a, d and e are about equally popular with pupils in standard 4, 5, 6, 7, and the standard 9 no science group; option e increases in popularity from standard 7 through to the standard 9 science pupils while option d decreases in popularity across the same standards.

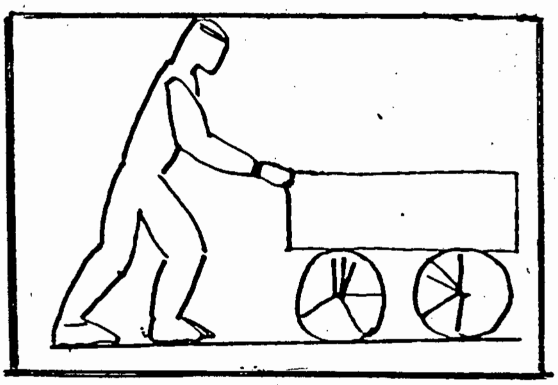
Chapter 5

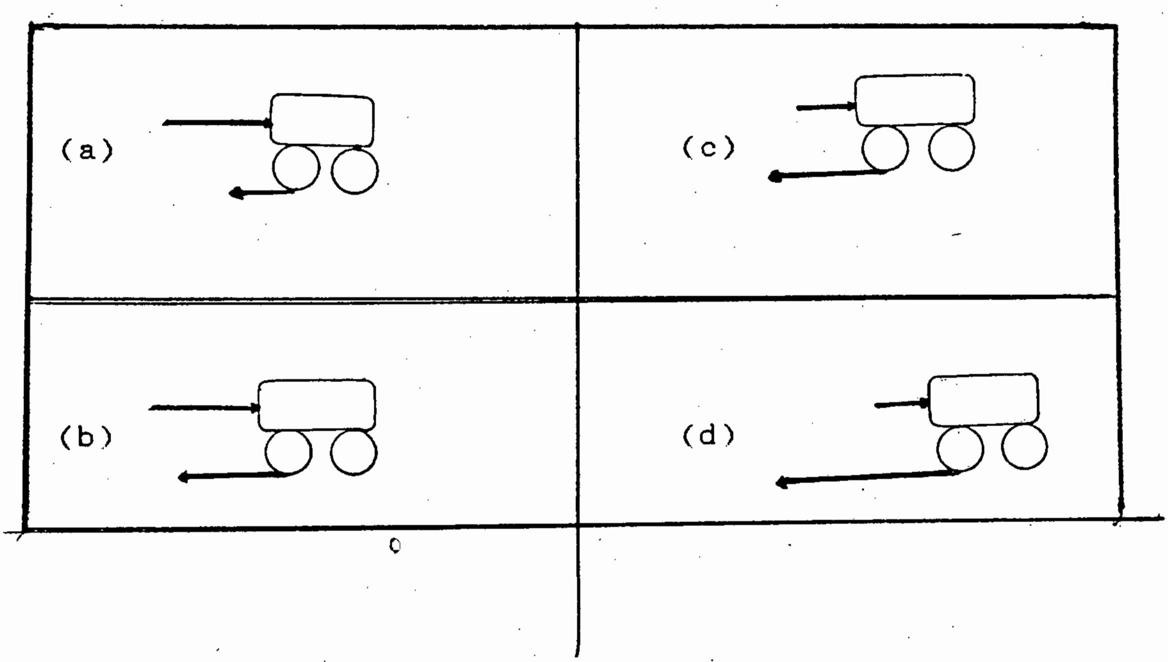
Relative magnitude of frictional force

We are interested in the beliefs our pupils hold about the relative magnitude of the frictional force and the force used to move a cart which is stuck in the sand, a fairly common experience for most of the pupils. It is our experience that pupils often consider the frictional force to be larger than the applied force in this case. If pupils select the options which indicate that the frictional force is greater than the applied force while the cart is stationary, then this indicates that they are acting contrary to the widely held idea that obects move in the direction of the larger force.

Question A 8:

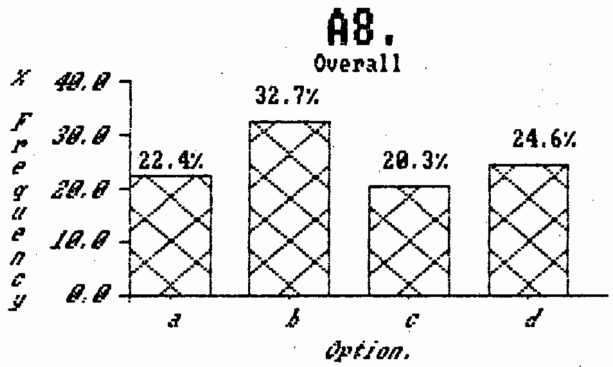
The sketch shows a boy who is pushing a cart. The cart is not moving because it is stuck in sand. The sketch which best shows the relative sizes of the force with which the boy is pushing compared to the frictional force or force of resistance, is:





(a)The overall picture:

The following graph shows the frequencies with which the whole sample selects the different options.



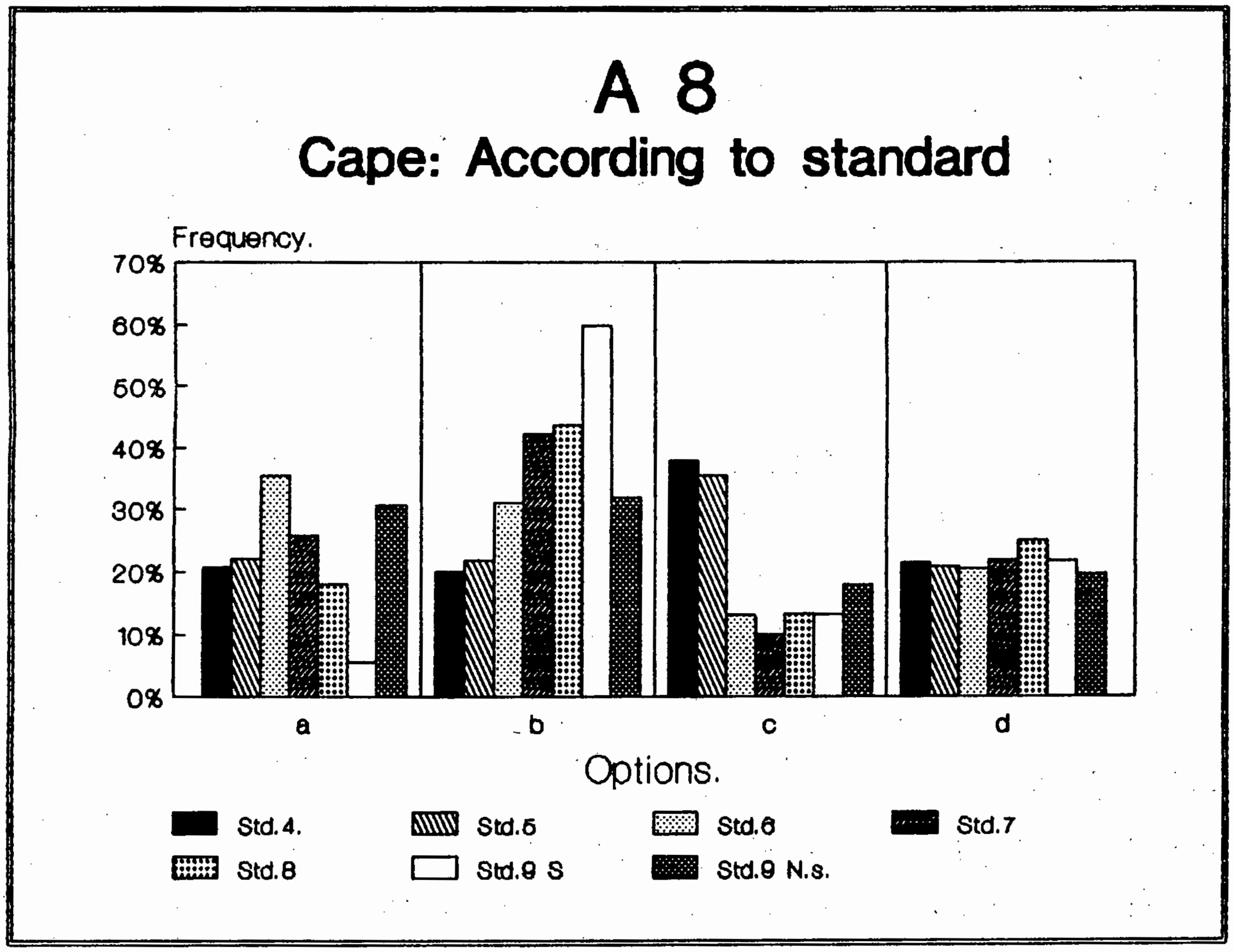
Note:

1. 22% of the sample select option a, the option which suggests that the frictional force is less than the force with which the man is pushing.
2. 33% of the sample select option b, the option which suggests that the two forces are equal and opposite to each other.
3. 20% select option c, the option which suggests that the frictional force is a little larger than the applied force.
4. 25% of the sample select option d, the option which suggests that the frictional force is much larger than the applied force.
5. thus 45% of the sample select options which suggest that the frictional force is larger than the applied force.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.

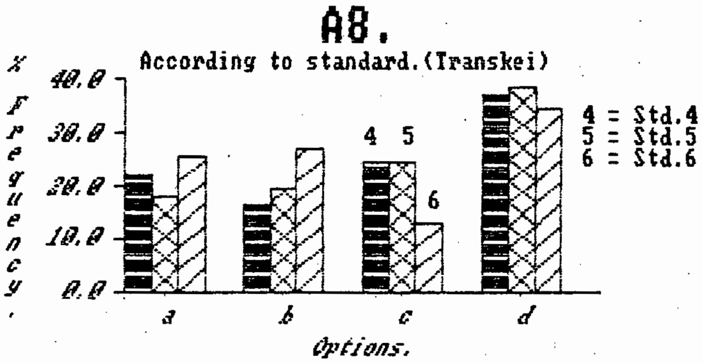


Note:

1. While option a is relatively popular with the standard 6 and standard 9 non-science pupils, it is very unpopular with the standard 9 science pupils.
2. There is an increase in the popularity of option b to a maximum with the standard 9 science pupils. This may be the effect of learning at school, but it is also possible that the pupils who after standard 7 select to do science have a better

2. In Transkei:

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.

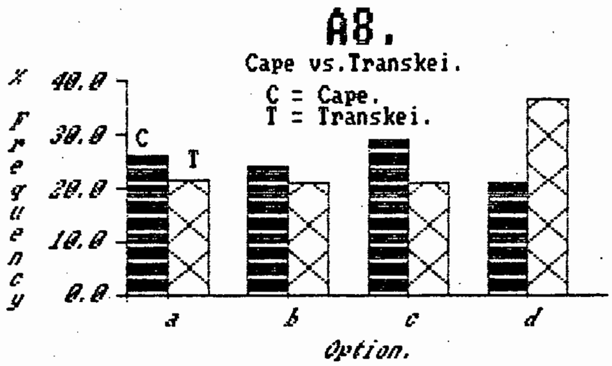


Note:

1. Option d is the most popular option with the pupils in all of the standards and there is very little difference in the frequencies with which pupils in the different standards select this option.
2. There is an increase in the frequencies with which option b is selected.
3. There are small variations in the frequencies with which pupils in the different standards select option a.
4. The standard 6 pupils do not find option c very attractive.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.



Note:

1. There are comparatively small differences in the frequencies with which the two groups select options a and b.

   26% of the pupils in Cape and 22% of the pupils in Transkei schools select option a.

   24% of the pupils in Cape and 21% of the pupils in Transkei schools select option b.

2. There is a fairly large difference in the frequencies with which the two groups select option c.

   29% of the pupils in Cape and 21% of the pupils in Transkei schools select this option.

3. There is a large difference in the frequencies with which the two groups select option d.

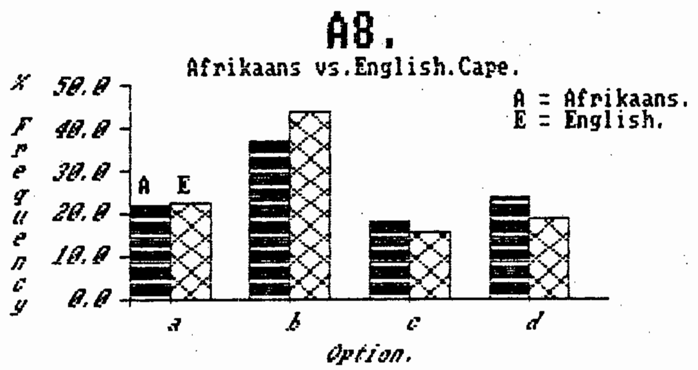
   21% of the pupils in Cape and 37% of the pupils in Transkei schools select this option.

•

4. 50% of the pupils in the Cape and 58% of the pupils in Transkei select options which suggest that the frictional force is larger than the applied force.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



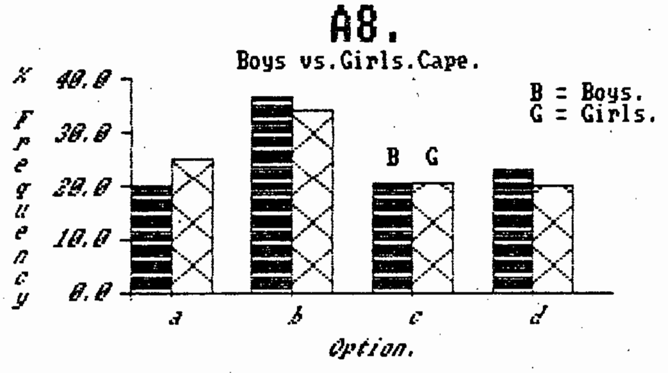
Note:

1. There are only small differences in the frequencies with which the two groups select option b and d.
2. 37% of Afrikaans-and 44% of English-speaking pupils select option b.
3. 24% of Afrikaans-and 19% of English-speaking pupils select option d.
4. Option a is selected by about 22% of the pupils of each of the two groups.
5. Option c is selected by about 17% of the pupils each of the two groups.
6. 42% of Afrikaans-and 34% of English-speaking pupils select options which suggest that the frictional force is larger than the applied force.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

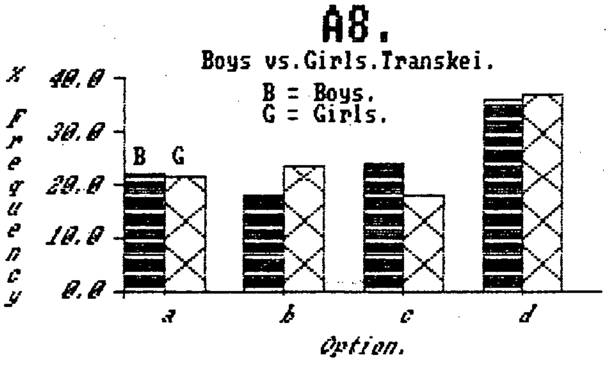


Note:

1. There are only very small differences in the frequencies with which the two groups select options a and d.
2. 20% of the boys and 25% of the girls select option a.
3. 23% of the boys and 20% of the girls select option d.
4. Option b is selected by about 35% of both groups.
5. Option c is selected by 20% of both groups.
6. 44% of the boys and 41% of the girls select options which suggest that the frictional force was larger than the applied force.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

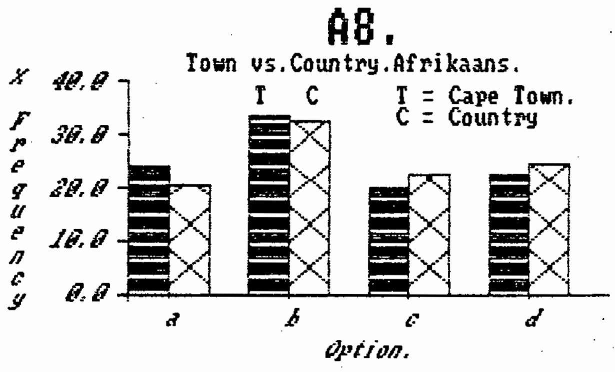


Note:

1. There are only small differences in the frequencies with which boys and girls select options a and d.
2. 18% of the boys and 24% of the girls select option b.
3. 24% of the boys and 18% of the girls select option c.
4. Option a is selected by about 22% of both groups.
5. About 36% of both groups select option d.
6. 60% of the boys and 55% of the girls select options which suggest that the force of friction is larger than the applied force.

(f) **Comparing Town and Country:**

The following graph compares the frequencies with which Afrikaans-speaking pupils who attend schools in Cape Town and country towns select the different options.



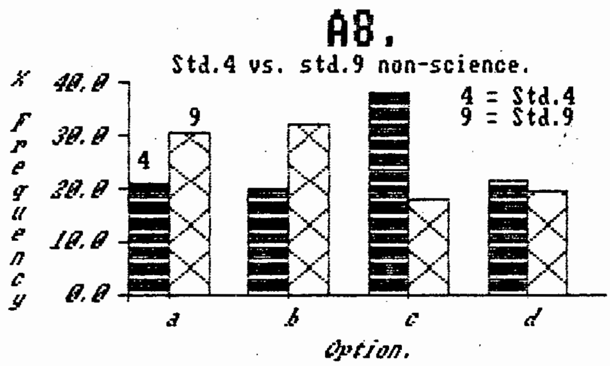
Note:

1. There is a small difference in the frequencies with which the two groups select option a.
2. 24% of the pupils living in Cape Town and 21% of pupils living in country towns select option a.
3. 42% of pupils living in Cape Town and 47% of pupils living in country towns select options which suggest that the frictional force was larger than the applied force.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science in school select the different options.



Note:

1. There are large differences in the frequencies with which the two groups select options a, b and c.

2. 21% of the standard 4 and 31% of the standard 9 pupils select option a. The reason for this is unclear.

3. 20% of the standard 4 and 32% of the standard 9 pupils select option b. It is possible that an awareness of the situation involved develops with increasing age or that the older pupils have a firmer commitment to a belief which involves force in the direction of motion.

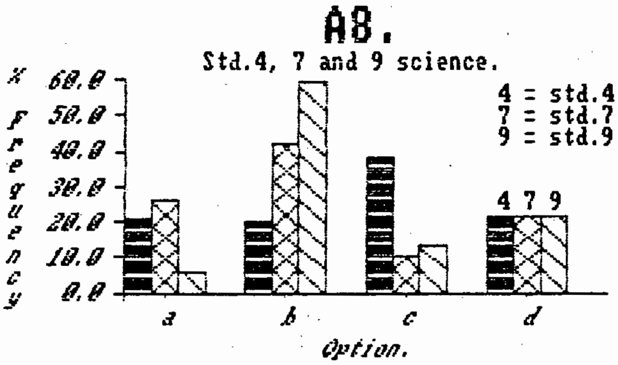
4. 38% of the standard 4 and 18% of the standard 9 group select option c.

5. 59% of the standard 4 and 38% of the standard 9 group select

options which suggest that the frictional force was larger than the applied force. A possible reason for this difference was dicussed under 3 above.

2. Standards 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.



Note:

1. The frequencies with which the different groups select options a, b and c are notably different.
2. The frequencies with which the different groups select option d is very similar
3. There is an increase in the frequencies with which option b is selected. The differences may be due to increased exposure to learning in school, a firmer commitment to a belief involving force in the direction of motion or a better understanding of the situation involved. The pupils in standard 9 select to do science and may be reasonably expected to be more aware of the forces involved in this situation. However, this is doubtful

as this group certainly did not show any better understanding of the situations involving force and motion.

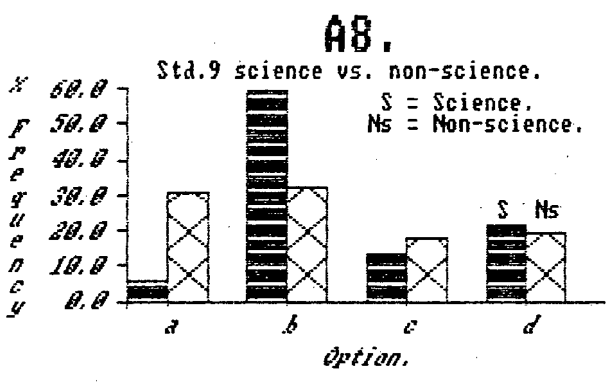
4. Option a is very unpopular with the standard 9 science pupils.

5. Option c is very popular with the standard 4 pupils.

6. 59% of standard 4, 32% of standard 7 and 35% of standard 9 science pupils select options which suggest that the frictional force is larger than the applied force.

3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.



Note:

1. The frequencies with which the two groups select options a, b and c is different.

2. 6% of the science and 31% of the non-science pupils select option a.

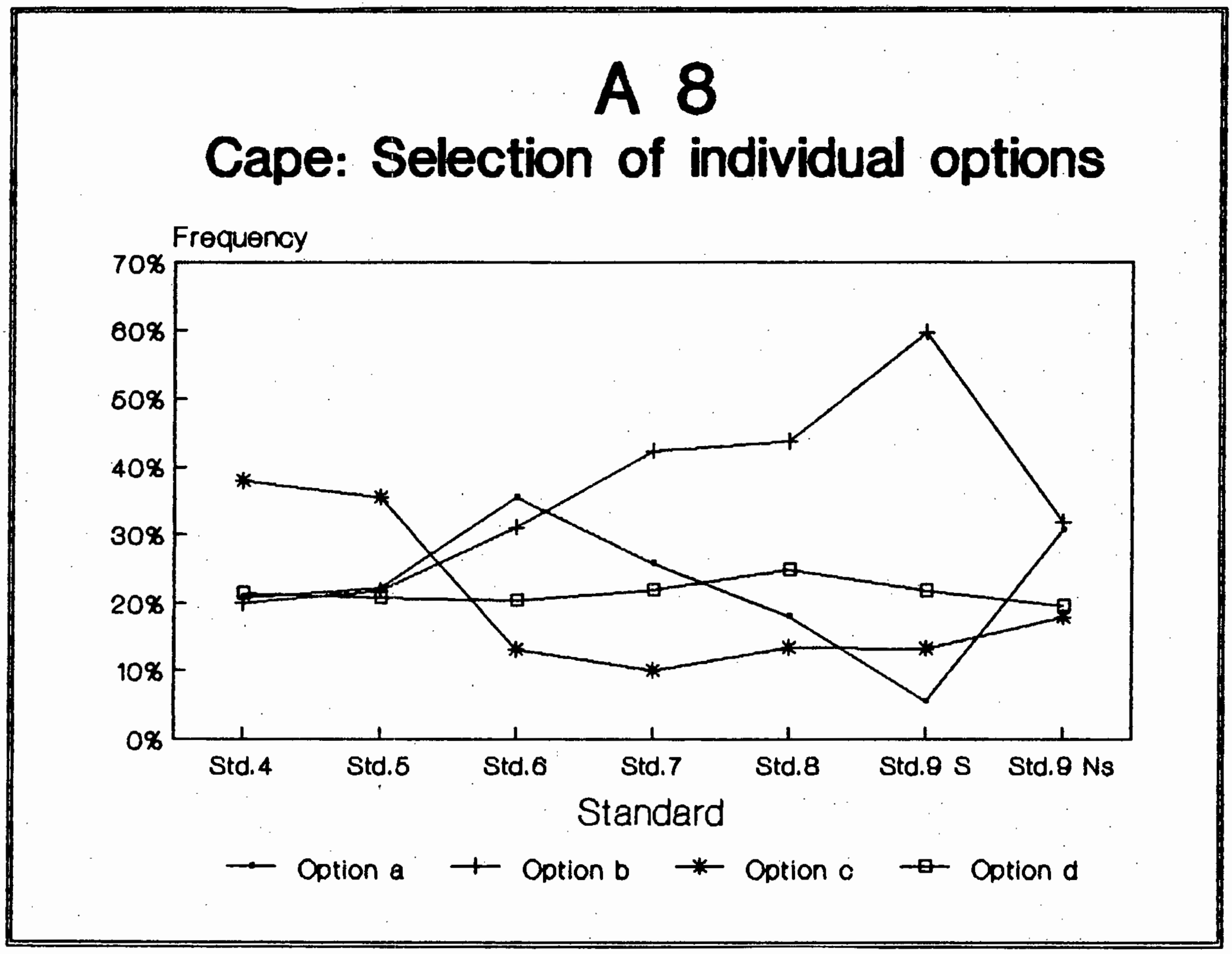
3. 60% of the science and 32% of the non-science group select

option b.

4. 13% of the science and 18% of the non-science pupils select option c.
5. 35% of the science and 38% of the non-science group select options which suggest that the frictional force is larger than the applied force.
6. While the science group select the correct option with a much higher frequency than the non-science group, there is very little difference between the two groups as far as believing that the frictional force is larger than the applied force.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options were select by the different standards.



Note:

1. There is an increase in the popularity of option b to a maximum with the standard 9 science pupils.
2. While option c is very popular with standard 4 and 5 pupils its popularity decreases thereafter.
3. Option a is very popular with standard 6 pupils but its popularity decreases thereafter until it reaches a mimimum with the standard 9 science pupils.

4. Option d is selected by a consistent proportion of pupils in all of the standards.

Summary:

1. When we examine the overall picture we find that:

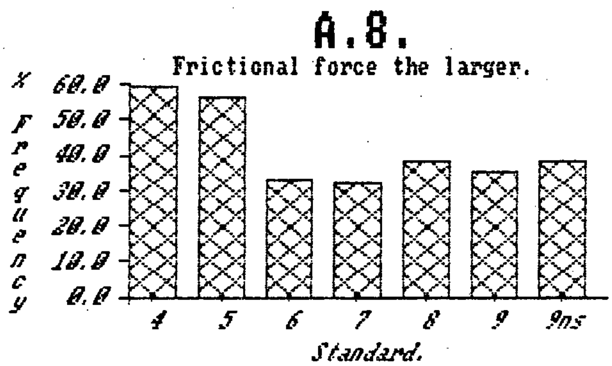
   22% of the sample believe that the frictional force is smaller than the applied force;
   33% of the sample believe that the frictional force is as large as the applied force;
   20% of the sample believe that the frictional force is slightly larger than the applied force while a further 25% believe that it is much larger. This means that 45% of the sample believe that the frictional force is larger than the applied force.

2. When we compare the frequencies with which pupils in the different standards in schools in the Cape select the different options we find that:

   the majority of standard 6 pupils and a substantial proportion of the standard 9 non-science pupils believe that the frictional force is smaller than the applied force;
   the belief that the two forces are equally large increases across the standards to a maximum with the standard 9 science pupils;
   the majority of standards 4 and 5 pupils believe that the frictional force is slightly larger than the applied force;
   about 20% of the pupils in each of the groups believe that the frictional force is much larger than the applied force;

- the belief that the frictional force is larger than the applied force is a persistent one with pupils in all standards.

The following graph compares the frequencies with which pupils in the different standards select options which suggest that the frictional force is larger than the applied force:



The belief that the frictional force is larger than the applied force is held by about 60% of the pupils in standards 4 and 5. The remarkable feature is that in the rest of the standards the options which suggest this belief is selected fairly consistently by about 35% of the pupils. If this result is seen in conjunction with our "force and motion" results, then it is clear that a substantial proportion of pupils are unaware that these two ideas are in conflict with each other. This is probably an example of two different min-theories being used to solve the problems.

In Transkei we find that the pupils in all three the standards prefer option d which suggests that they believe that the frictional force is much larger than the applied force.

There is also some evidence that the belief that the forces are equally large increases across the standards.

3. When we compare pupils in standards 4, 5 and 6 in Cape and Transkei schools we find that:

   29% of Cape and 21% of Transkei pupils believe that the frictional force is slightly larger than the applied force;
   21% of Cape and 37% of Transkei pupils believe that the frictional force is much larger than the applied force;
   50% of Cape and 58% of Transkei pupils believe that the frictional force is larger than the applied force.

It would appear that although there are differences in the way in which the two groups have responded to these two options, that the difference is essentially one of degree only. A slightly higher proportion of Transkei pupils believe that the frictional force is larger than the applied force but a substantial proportion of these pupils believe that the frictional force is much larger than the driving force

4. When we compare the frequencies with which Afrikaans-and English-speaking pupils select the different options we find that:

   37% of Afrikaans-and 44% of English speaking pupils believe that the two forces are equal in size;
   42% of Afrikaans-and 34% of English-speaking pupils believe that the frictional force is larger than the applied force. Of the pupils who held this belief, the proportion of Afrikaans pupils who believe that the frictional force is much larger

than the applied force is a little higher than that of the English-speaking pupils who hold the same belief. Thus the belief that the frictional force is larger than the applied force is somewhat more widely held by Afrikaans-speaking pupils.

5. When we compare boys and girls in Cape schools we find that there is some evidence that the belief that the frictional force is larger than the applied force is held by a slightly higher proportion of the boys.

   In Transkei we also find that a slightly higher proportion of the boys believe that the frictional force is larger than the applied force.

6. When we compare the frequencies with which Afrikaans-speaking pupils who attend schools in Cape Town and in country towns select the different options we find that a slighly higher proportion of pupils in country schools believe that the frictional force is larger than the applied force.

7. When we compare the frequencies with which pupils in some of the standards select the different options we find that:

   20% of standard 4 and 32% of standard 9 pupils who do not do science at school believe that the forces are equal in size. This may suggest that this belief is one which is more widely held by older pupils and therefore that there is some maturation effect involved.

   the belief that the frictional force is larger than the applied force is much more widely held by standard 4 pupils;

the proportion of the pupils who believe that the two forces are equal in magnitude increases across the standards but the proportion who believe that the frictional force is much larger than the applied force is very similar for all of the different standards;

although 60% of science pupils and only 32% of non-science pupils believe that the forces are equal in magnitude, 35% of the science and 38% of the non-science group believe that the frictional force is larger. This belief is very widely held by pupils across all of the standards as we have shown earlier on.

8. When we compare the frequencies with which the individual options are selected by the different standards, we find that:

while the proportion of pupils who select option b and thereby indicating a belief that the forces are equal in magnitude increases at the expense of options a and c, option d, the option whose selection indicates a belief that the frictional force is much larger than the applied force, remained remarkably constant across the different standards.

9. We also find that in all of the groups which we looked at there is some support for the notion that the frictional force is in fact less than the applied force. While it may not be very difficult to understand the reasons for the origin of a belief that the frictional force is larger than the applied force, the same is not true for the belief that the frictional force is smaller than the applied force.

Chapter 6

Static equilibrium

Overview

Introduction:

In the work dealing with "passive force" reviewed in chapter 2 (see p.56) researchers have commonly found that pupils have difficulty identifying the forces acting on bodies at rest. In particular, they have found that if pupils are presented with a situation which involves a body at rest on a surface, then it is the presence of a normal force which is difficult to accept. However, Terry and Hurford (1985) found that when the pupils were asked to indicate the forces acting on a body at rest on a table, then when suspended from a spring and finally when supported by the palm of a hand, then the number of pupils who identified two forces as acting on the body was considerably higher in the last two cases than in the first case.

In this study pupils were presented with four situations which were conceptually identical but differed in that two of the cases involved a suspended body (A3 and A7) while two of the cases involved a body being supported by a surface (A9 and A 11). Furthermore, in A7 the object was suspended from the arm of a man or a woman while in A 11 the object was supported on the palm of a man's hand.

Results:

In all of the graphs which follow, the frequency with which similar options have been selected when attempting the different questions have been compared in the following way:

<u>option 1</u> = the upward and downward forces are equal and opposite, i.e. the correct response.

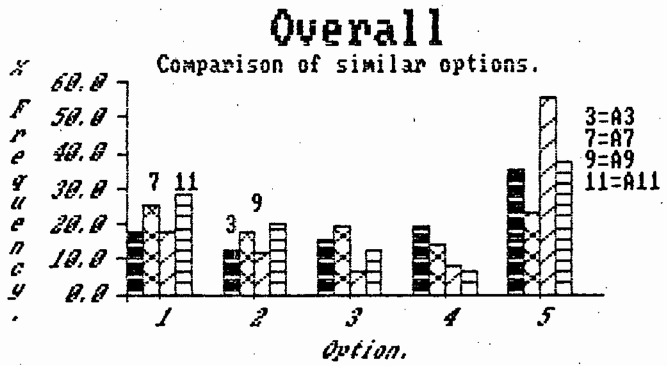
<u>option 2</u> = the downward acting force is larger than the upward acting force.

<u>option 3</u> = the upward acting force is larger than the downward acting force.

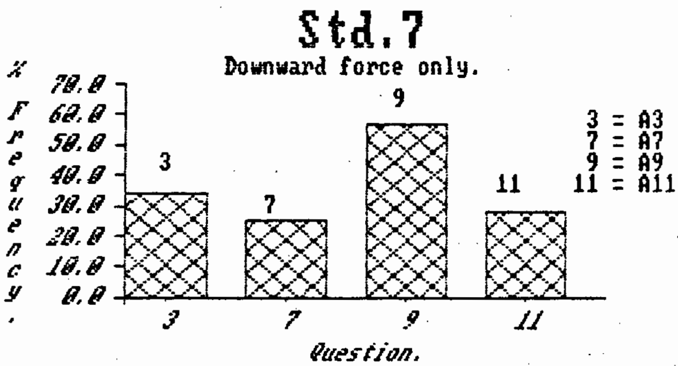
<u>option 4</u> = only an upward acting force is present.

<u>option 5</u> = only a downward acting force is present.

The following graph compares the frequency with which the whole sample selects the different options on all of the questions.



It is quite clear from the graph that the pupils respond differently to the different questions. The frequency with which the correct option, option 1, is selected increases when a human is present as part of the system. It is also quite clear that the frequencies with which all of the options are selected are very strongly influenced by the situation which is depicted in the question. That the presence of a human in the situation has a dramatic effect on the frequencies with which options are selected is further illustrated by an examination of the graphs which show the frequencies with which a single force is selected.



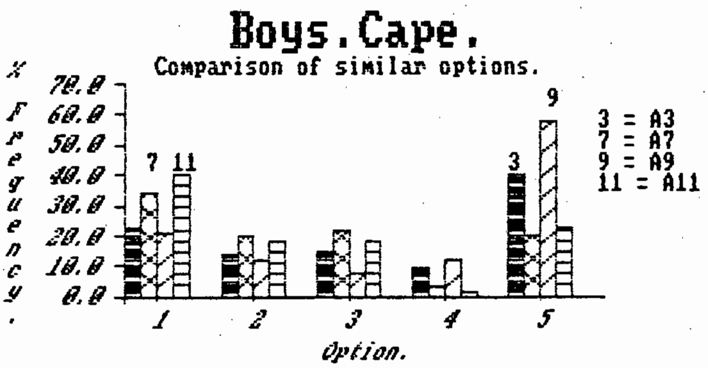
It is clear that in the presence of a human a single downward acting force is not selected as often as it is in the absence of a human. The frequencies with which this force is selected is also dependent on the situation presented.

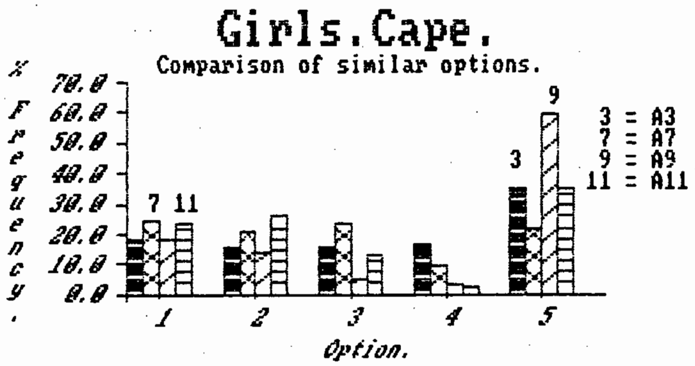
The above graphs which depict the overall situation do not illustrate the variation which exist between groups. Some of this variation is shown by the following graphs.

•

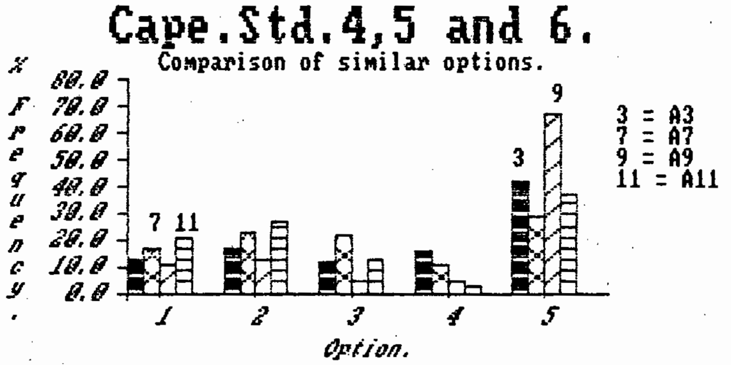
1. <u>Sex and Culture</u>:

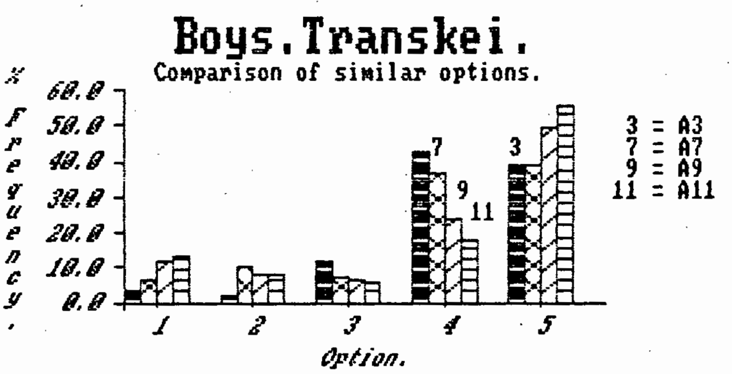
The following graphs show the frequencies with which boys and girls in the Cape and Transkei as well as Cape standards 4, 5 and 6 pupils select the different options on the different questions.

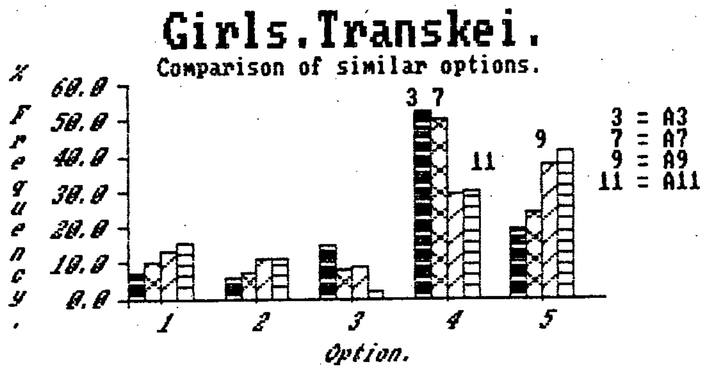




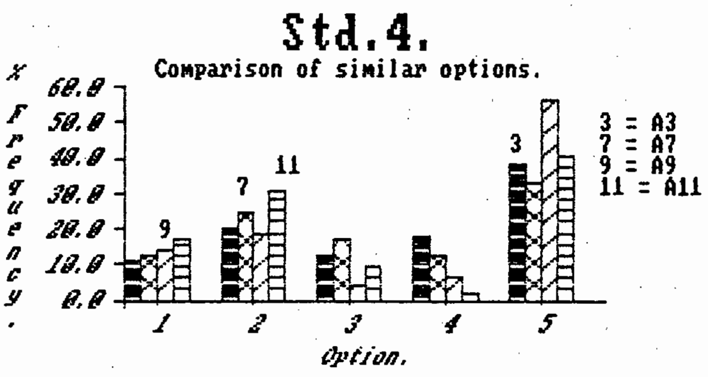
The folowing graph which compares the frequencies with which standards 4, 5 and 6 pupils in Cape schools select the different options is included for easy comparison with the graphs which follow for boys and girls in Transkei schools

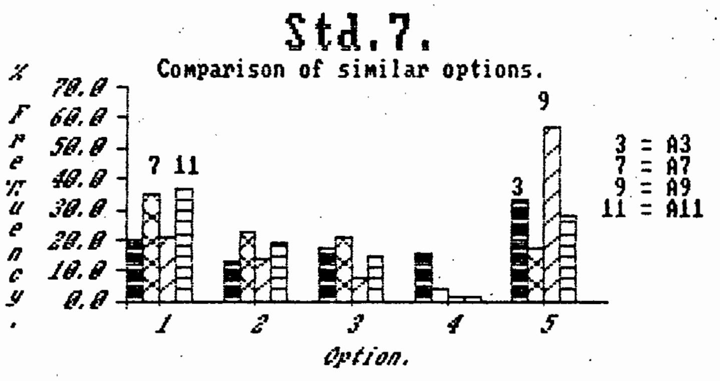


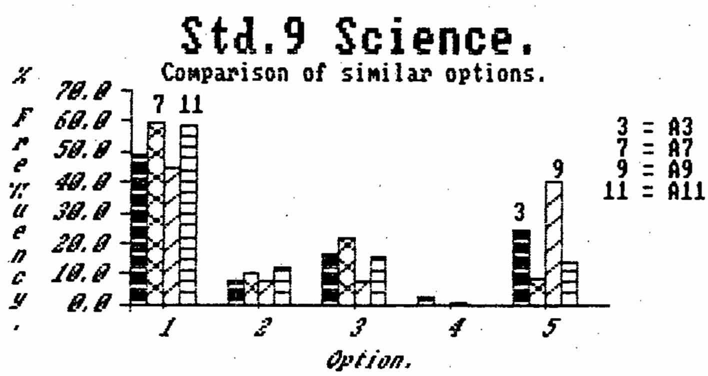




It is clear from the graphs that while fairly large differences exists between the frequencies with which pupils in Cape and Transkei schools select the different options, small differences exist in the frequencies with which boys and girls in the Cape and in Transkei select the different options but that in all cases, there is a strong indication that the frequencies with which any one particular option is selected depends to a large extent on the situation depicted. In Cape schools it is clear that the presence of a human in the situation very clearly effects the selection of options; more pupils select the correct option when a human is seen to be holding an object. What is of particular interest is the tremendous increase in the frequencies with which a single downward acting force is selected when the object is supported on a table. This tendency is present throughout all of the standards in Cape schools as the following graphs show :


Std.4.
Comparison of similar options.
% Frequency.
60.0
50.0
40.0
30.0
20.0
10.0
0.0
9
7
11
3
1
2
3
4
5
Option.
3 = A3
7 = A7
9 = A9
11 = A11


Std.7.
Comparison of similar options.
% Frequency.
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
7 11
3
9
1
2
3
4
5
Option.
3 = A3
7 = A7
9 = A9
11 = A11



It is also clear from the graphs of pupils in Cape schools that a single upward force is not a very popular option and only had a moderate degree of support when a body is suspended by a string.

If we compare the graph which shows the frequencies with which standards 4, 5 and 6 pupils in the Cape select the different options with the two graphs involving boys and girls from Transkei, it is abundantly clear that there are very big differences in the way the pupils from the two areas respond to the questions. While the presence of a single upward force is very unpopular in the Cape, it is remarkably popular in Transkei. Transkei pupils overwhelmingly select options which indicate a single force acting on the body at rest with the preferred option for suspended bodies being a single upward force for girls. Boys are fairly evenly divided in the frequencies with which they select a single upward or downward force in this situation. However, when the body is supported the situation changed dramatically. Both boys and girls now indicate a preference for a single downward force. This option is much more popular with the boys in this situation. It also appears from the graphs that the presence of a human in the situation has a small effect. The major effect with the pupils from Transkei appears to be whether the body is suspended or supported on a surface.

When we compare the frequencies with which Afrikaans-and English-speaking pupils select the different options, it is interesting to observe that more English-speaking pupils select a single downward acting force in all situations, the difference being in the region of 8%.

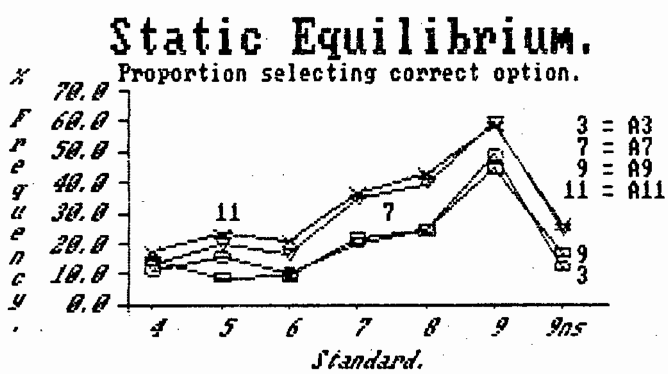
When we compare the frequencies with which boys and girls select the correct option, we find that a higher proportion of boys consistently do so. However, the difference is small. Furthermore, if we look at the frequencies with which the two groups select options which indicate the presence of two forces of unequal magnitude acting on the body at rest in all of the questions, we find that the pattern of distribution is very similar for boys and girls. Girls, however, select these options more frequently.

2. Origin:

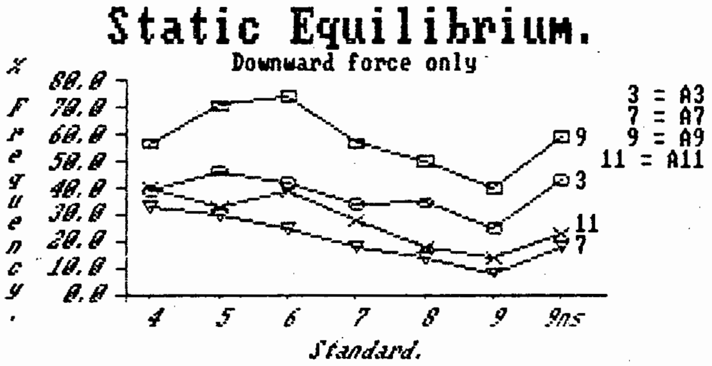
When we compare the frequencies with which Afrikaans-speaking pupils who live in Cape Town and in country towns select different options on the different questions we find no appreciable difference between the two groups. This is an astonishing result and indicates a very strong cultural uniformity between town and country pupils.

3. Standard:

It is clear from the data that the proportion of pupils selecting the correct option on all of the questions increases as we proceed up the standards. This is not completely unexpected as the standard 8 and 9 science groups have selected to do science and will presumably therefore have some interest in the subject. The following graph which compares the frequencies with which the correct option is selected by the pupils in the different standards illustrates this point as well as illustrating the importance of the context of the situation presented.



It is also quite clear that the different standards respond differently to the different options in the different questions. We have mentioned these differences which are either rather small on options which involve the presence of unequal forces or involve a stepwise decrease in the frequencies with which a single downward acting force is selected. The following graph which compares the frequencies with which pupils in the different standards select a single downward acting force in the different situations presented to them illustrates this point clearly.

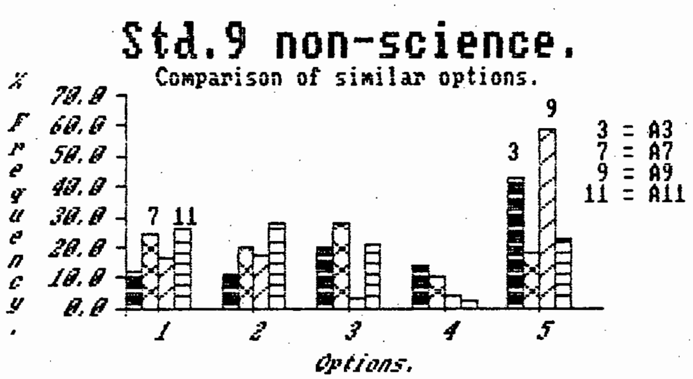


Comparison of the graphs presented for standards 4, 7, and 9 science pupils show that as we proceed up the standards:

1. the proportion of pupils who select option 1, the correct option, increases in all of the questions.
2. the proportion of pupils who select option 2, the option which suggests that the upward acting force is smaller than the downward-acting force, decreases in all the questions.
3. the proportion of pupils who select option 3, the option which suggests that the upward acting force was larger than the downward-acting one, increases slightly.
4. the proportion of the pupils who select option 4, the option which suggests that a single upward-acting force is present, decreases in all questions.

5. the proportion of pupils selecting option 5, the option which suggests a single downward-acting force is present, decreases in all questions.

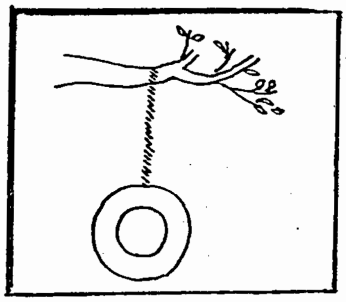
The standard 9 pupils who do not do science at school are an interesting group as they probably represent the scientific thinking of the "man on the street". The following graph compares the frequencies with which this group select the different options on the different questions.

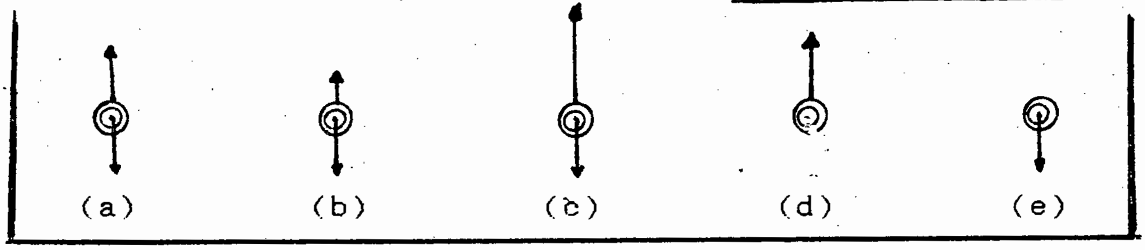


It is quite clear that the presence of a human in the different situations very markedly effect the responses of this group to the questions. The presence of a single downward-acting force is very popular in questions which do not have a human in it. The moment a human is present, however, options which include an upward-acting force in conjunction with downward-acting force increase in popularity.

Question A 3:

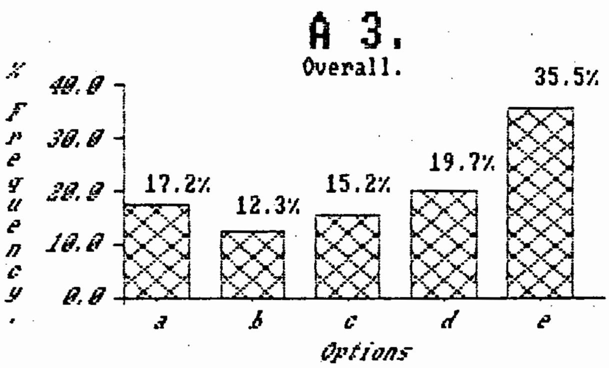
The sketch shows a tyre which is hanging from a rope which has been tied to the branch of a tree. The sketch which best shows and compares the sizes of the forces acting on the tyre is:





(a) **The overall picture:**

The following graph compares the frequencies with which the different options are selected by the whole sample.



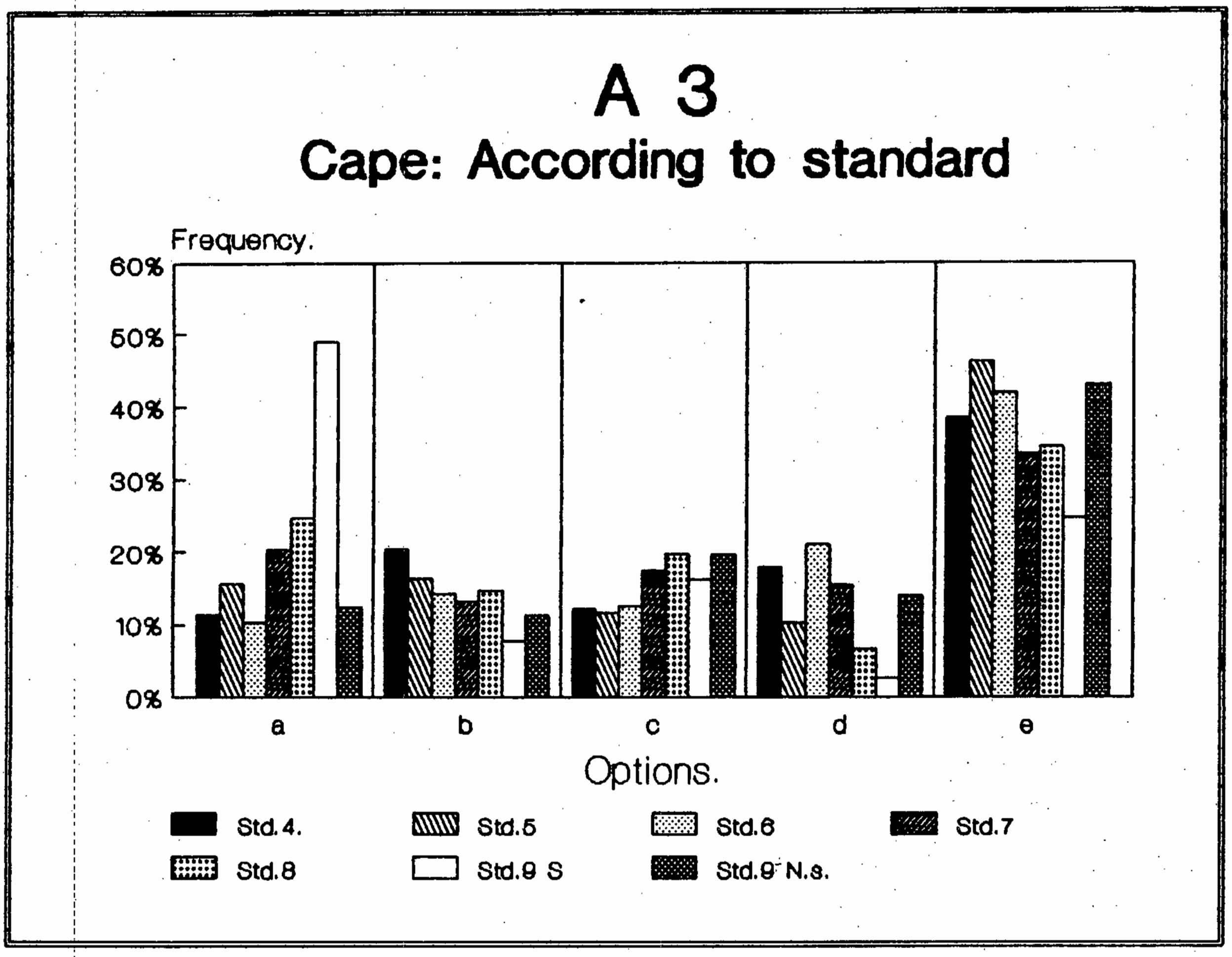
Note:

1. There is a marked preference for option e, the option which suggests that only a downward force acts on the tyre.
2. About 55% of the sample select options d and e, options which suggest that only one force is present.

(b) **According to standard** :

1. <u>In the Cape:</u>

The following graph compares the frequencies with which the different standards in the Cape select the different options.

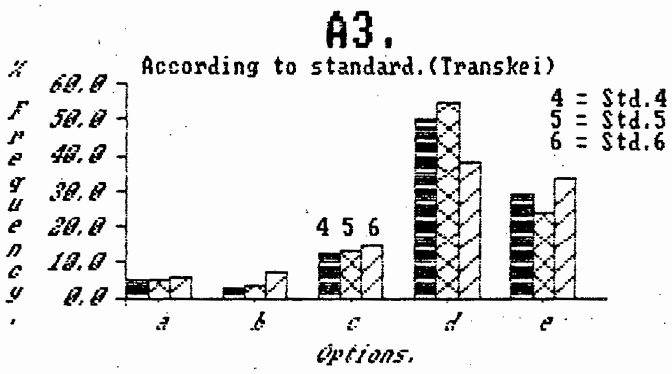


Note:

1. With the exception of the standard 9 science pupils there is a preference for option e by all of the other groups.
2. There is an increase in popularity of option a, the correct one, from standard 6 through to standard 9. This option is the preferred one for the standard 9 science group.
3. In general the standard 9 pupils who do not do science responded to the options in the same way as the standard 4, 5, 6 and 7 groups.

2. In Transkei:

The following graph compares the frequencies with which the different standards in Transkei select the different options.

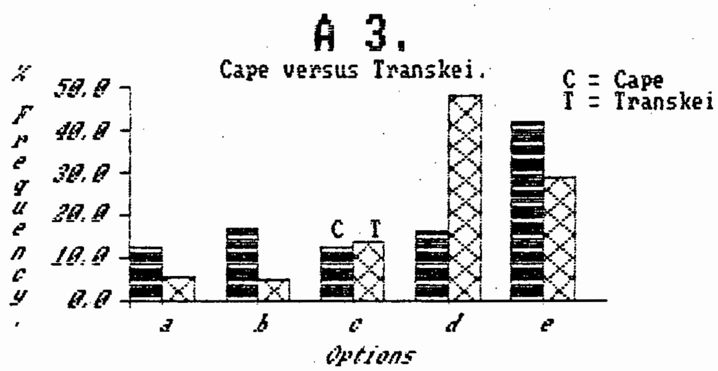


Note:

1. There is a marked preference for option d by all of the standards. Selection of this option indicates a belief in the presence of a single force only. This force acts upwards on the tyre.
2. Option e is the next most popular option. This option shows only a downwards force acting on the tyre.
3. It is clear that the pupils in Transkei favour options which include one force only acting on the object.

(c) Comparison between the Cape and Transkei:

The following graph compares the frequencies with which standard 4, 5 and 6 pupils from the Cape and Transkei select the different options.

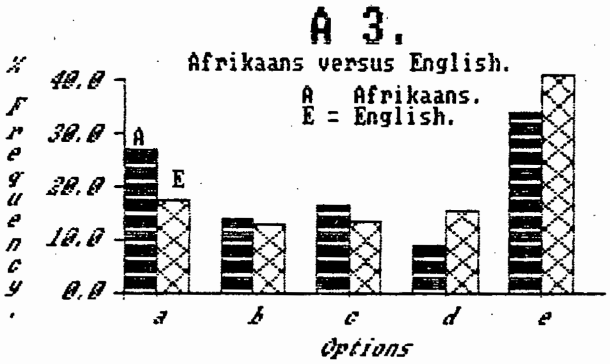


Note:

1. With the exception of option c, there is considerable difference in the frequencies with which the two groups select the different options.
2. While pupils from the Cape select option e, which suggest a belief in a downwards force only acting on the tyre, Transkei pupils select d, which suggests an upward force only acting on the tyre.
3. By selecting options d and e pupils indicate a belief in the presence of one force only acting on the tyre. 58% of Cape pupils select these options compared to 76% of Transkei pupils.
4. 16% of Cape and 48% of Transkei pupils select option d, the option which suggests that only an upward force is acting on the tyre.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in the Cape select the different options.



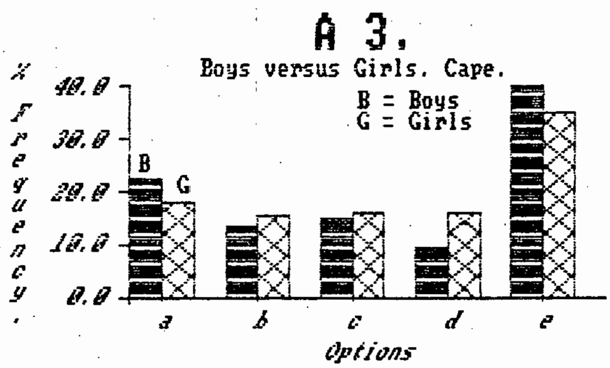
Note:

1. There are marked differences in the frequencies with which the two groups select options a, d and e.
2. 27% of the Afrikaans-speaking group and 18% of the English-speaking group select a, the correct option.
3. The belief in a single force acting on the tyre is held by 43% of the Afrikaans-speaking group and by 56% of the English-speaking group.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in Cape schools select the different options.

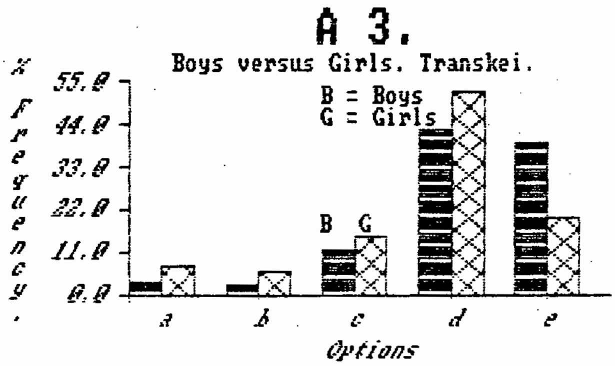


Note:

1. There are small differences in the frequencies with which the two groups select options a, d and e.
2. 50% of the boys and 51% of the girls select options which indicate a belief that only one force is acting on the tyre; the most popular one being a downward force only.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in Transkei select the different options,

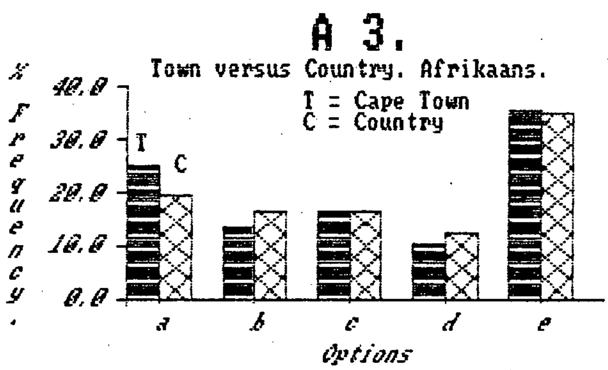


Note:

1. There are appreciable differences in the frequencies with which the two groups select options d and e. 43% of the boys and 52% of the girls select option d, which suggests that there is only an upwards force acting on the tyre. 39% of the boys and 20% of the girls select option e, which suggest that there is only a downward force acting on the tyre.
2. 82% of the boys and 72% of the girls select options which indicate a belief in a single force acting on the tyre; the most popular being an upward force only.

(f) **Comparing pupils from Town and Country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans-speaking pupils who live in Cape Town and in country towns select the different options.



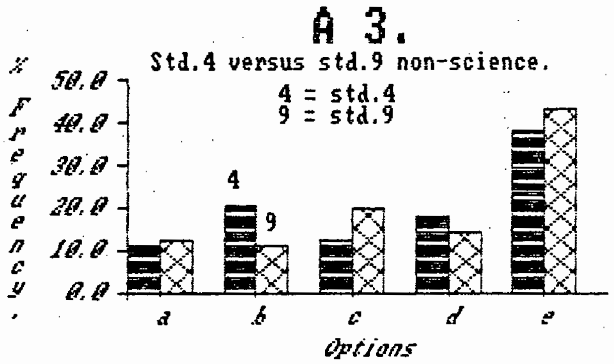
Note:

1. There is a small difference in the frequency of selection of option a. This option is selected by 25% of the Cape Town group and 20% of the country group.
2. 35% of both groups select option e, which suggest a belief in only an upward force acting on the tyre.

(g) **Comparing different standards:**

1. <u>Standard 4 and standard 9 "no science " group.</u>

The following graph compares the frequencies with which Cape standard 4 and standard 9 pupils who do not do science select the different options

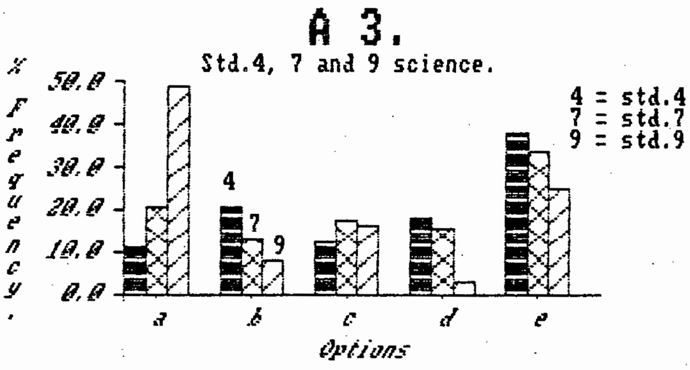


Note:

1. Both groups prefer option e.
2. There are difference in the frequencies with which the groups select option b and c. Option b suggests that the force acting upwards is smaller than the force acting downwards. This is selected by 20% of the standard 4 group and 11% of the standard 9 group. Option c suggests that the force acting upwards is larger than the force acting downwards and is selected by 12% of the standard 4 group and 20% of the standard 9 group.
3. 56% of the standard 4 group and 57% of the standard 9 group select options which show one force only acting on the tyre.

2. Standards 4, 7 and 9 "science" group:

The following graph compares the frequencies with which pupils in standards 4, 7 and 9 who do science select the different options.

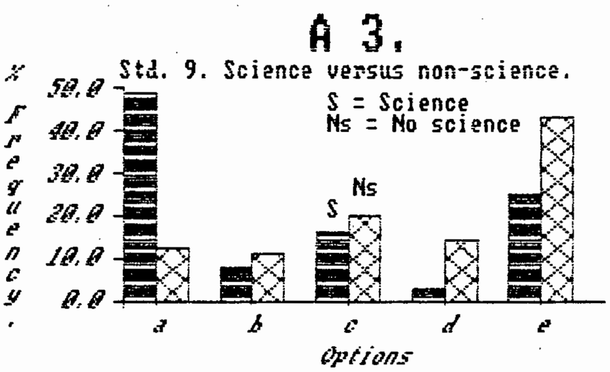


Note:

1. The groups differ on options a, b, d, and e and substantially so on option a.
2. There is an increase in the frequencies of selection of option a from standard 4 through to standard 9.
3. There is a decrease in the frequencies of selection of option e from standard 4 through to standard 9.
4. Option e is the preferred option for the standard 4 and 7 groups while a is the preferred option of the standard 9 group.
5. 56% of the standard 4 group, 49% of the standard 7 group and 27% of the standard 9 group select options which indicate the presence of a single force acting on the tyre; the preferred force being a downward force. Only 3% of the standard 9 group select a single upward force as the preferred option.

3. <u>Standard 9 science pupils and standard 9 pupils who do not do science:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and who do not do science select the different options.



Note:

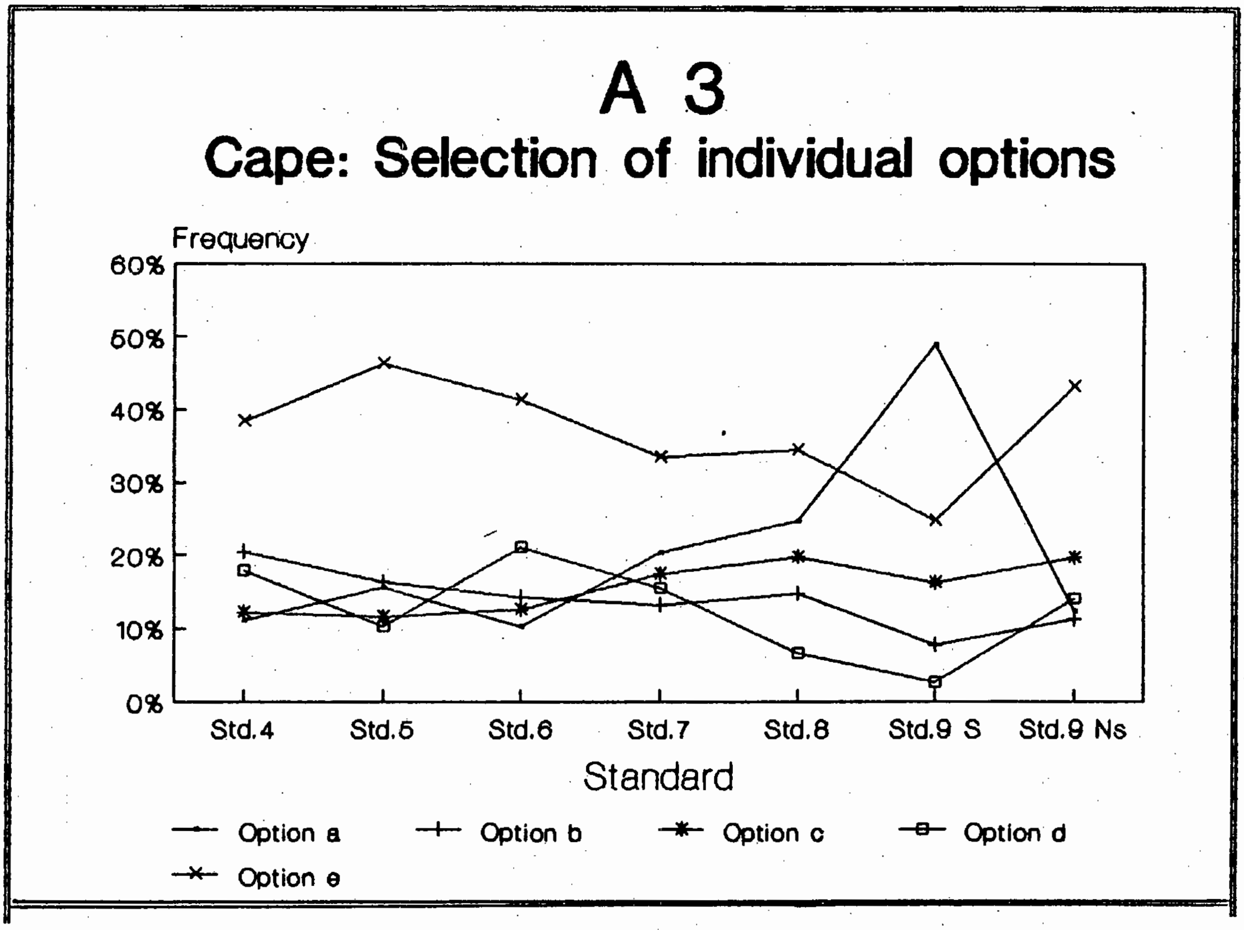
1. There is a very large difference in the frequencies with which options a and e are selected by the two groups. The majority of the science group select the correct option while the majority of the group not doing science select option e, which suggests the presence of a single force acting downwards on the tyre.
2. 24% of the science group select options which indicate the belief that the forces acting on the tyre are not equally large. Another 25% select the option which indicates a downwards force only. The option which suggests that only an upward force is acting on the tyre is very unpopular with this group.
3. Both groups found option c fairly attractive. This option suggests that the upward acting force is larger than the

downward acting one.

4. The correct option is selected by only 49% of the pupils who do science.

(h) **Selection of individual options:**

The following graph compares the frequencies of selection of the different options across the different standards.



Note:

1. There is a gradual increase in popularity of option a to a peak with the standard 9 science pupils.

2. There is a gradual decrease in the popularity of option e reaching a minimum with the standard 9 science pupils.

3. There is a decrease in popularity of option d from standard 6 to standard 9 science pupils.
4. The small but consistent support for options c and d, which suggests that two forces act on the tyre but that these forces are not balanced, range from about 10% to 20% across the standards.

Summary:

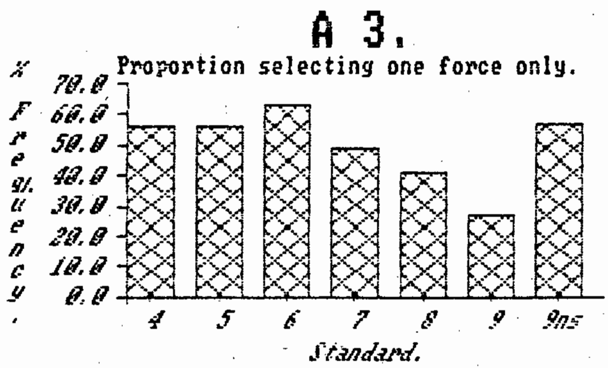
1. As far as the overall picture is concerned we find that:

   there is a marked preference for option e, with 36% of the pupils selecting this option. Option e suggests that only a downward force acts on the tyre.
   55% of the pupils select options which include only one force acting on the tyre.

2. When we compare the frequencies with which the different standards in Cape schools select the different options we find that:

   with the exception of the standard 9 pupils who do science the groups prefer option e;
   the standard 9 science pupils prefer option a, the correct option;
   option a increases in popularity to a maximum with the standard 9 science pupils;
   option a is selected by only 49% of the standard 9 science pupils.

The following graph compares the frequencies with which the different standards select options which include one force acting on the tyre only.



Note:

There is a decrease in the frequencies from standard 6 to standard 9 science pupils.

The standards 4, 5, 6 and the standard 9 non-science group are fairly similar in their selection of these options.

3. When we compare the standards in Transkei we find that:

   there is a marked preference for option d. This option includes a force acting upwards only.

   the majority of pupils select options which include one force acting on the tyre.

4. When we compare the pupils in the Cape with their counterparts in Transkei we find that:

   there is considerable difference in the frequencies with which options d and e were selected;

- Transkei pupils prefer option d while Cape pupils prefer option e;
- 58% of Cape pupils and 76% of Transkei pupils select options which indicate the belief that only one force is acting on the tyre.

5. When we compare Afrikaans-and English-speaking pupils we find that:

   - there are small differences in the frequencies with which options a, d and e were selected;
   - 43% of Afrikaans-speaking pupils and 56% of English-speaking pupils select options which include only one force acting on the tyre.

6. When we compare boys and girls from Cape schools we find that:

   - there are small differences in the frequencies with which the groups select options a, d and e;
   - e is the preferred option for both groups;
   - 50% of the boys and 51% of the girls select options which include only one force acting on the tyre.

   In Transkei we find that:

   - there are big differences in the frequencies with which the two groups select options d and e. Girls prefer option d.
   - 82% of the boys and 76% of the girls select options which include one force only acting on the tyre. The preferred option is an upward force.

7. When we compare Afrikaans-speaking pupils who live in Cape Town with their counterparts living in country towns, we find that there is a small difference in the frequencies with which option a is selected.

8. When we compare the standards we find that:

standard 4. and standard 9 pupils who do not do science both prefer option e;

there are small difference in their preference for options b and c by these two groups;

56% of the standard 4 group and 57% of the standard 9 group select options which include only one force acting on the tyre;

standard 4, 7 and 9 pupils who do science differ in the frequencies with which they select different options. Standard 4 and standard 7 pupils prefer option e while standard 9 pupils who do science prefer option a.

56% of the standard 4 group, 49% of the standard 7 group and 27% of the standard 9 group select options which include only one force acting on the tyre.

the standard 9 science pupils and the standard 9 pupils who do not do science differ very markedly on the frequencies with which they select options a and e. The science pupils prefer option a while the non-science group prefer option e.

9. When we compare the frequencies with which the individual options are selected by the different standards we find that:

option a increases in popularity up to the standard 9 science pupils;

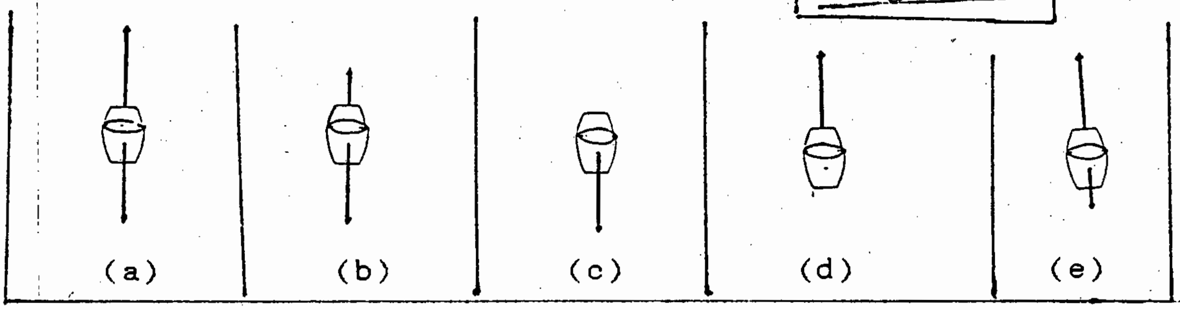
option e decreases in popularity up to the standard 9 science pupils;

option d decreases in popularity from standard 6 to the standard 9 science group;

options b and c are selected with frequencies which fluctuated between 10% and 20%.

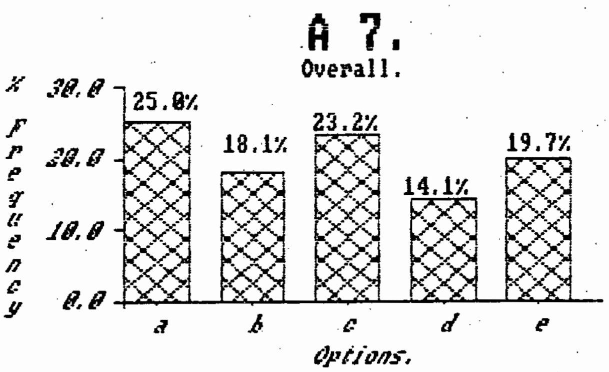
Question A 7:

The sketch shows a man holding a bucket of water in his hand. The sketch which best shows and compares the forces acting on the bucket of water is :



(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



Note:

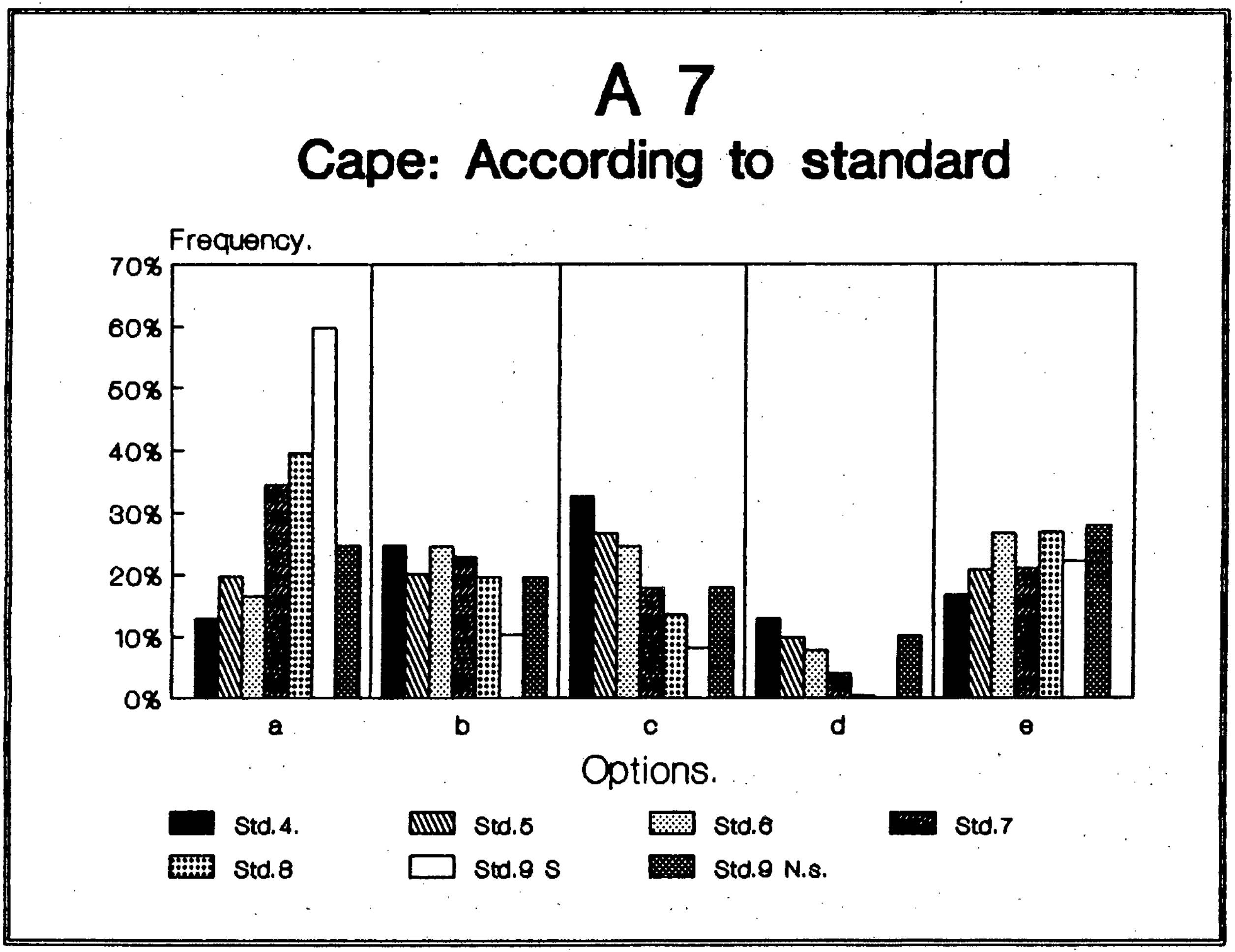
1. Option a, the correct option, is selected by 25% of the sample.
2. 23% of the sample select option c, which indicates that only a downward force acts on the bucket.

3. Options c and d, which suggest that only one force is acting on the bucket, is selected by 37% of the sample.
4. 38% of the sample select options b and e, which indicate that two forces of unequal magnitude act on the bucket.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which the different options are selected by the different standards in the Cape.



Note:

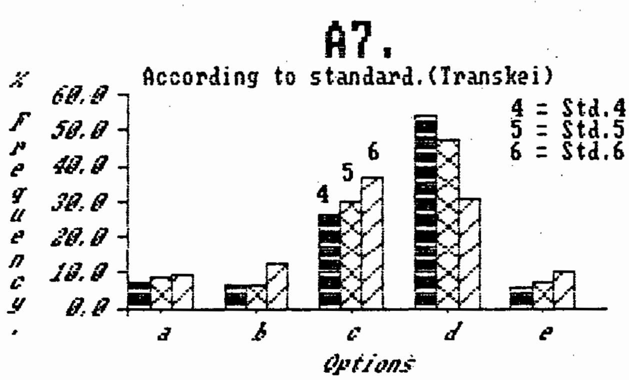
1. There is an increase in popularity of option a, the correct option, from standard 4 through to standard 9 pupils who do

science.

2. There is a decrease in popularity of option c, the option which suggests that only a downward force acts on the bucket, from standard 4 through to standard 9 pupils who do science.
3. Option d, the option which suggests that only an upward force acts on the bucket, is unpopular with all of the groups.
4. Options b and e, which suggest that two forces of unequal magnitude act on the bucket, are selected by between 20% and 30% of the groups. However, option e, the option which suggests that the upwards force is the larger, is the more popular.

2. In Transkei:

The following graph compares the frequencies with which the different standards in Transkei select the different options.



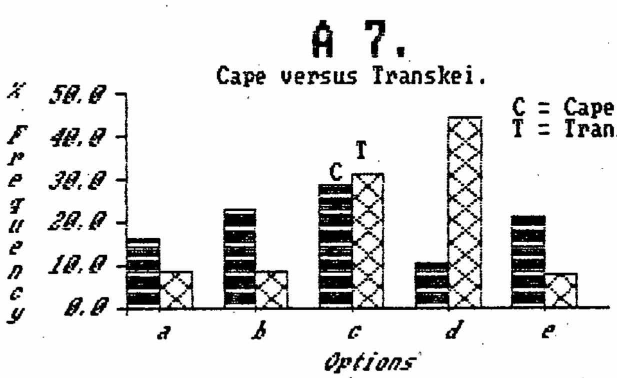
Note:

1. Options a, b,and e are unpopular. These options all suggest that two forces are acting on the bucket.

2. There is a decrease in popularity of option d, the option which suggests that only an upward force is acting on the bucket, from standard 4 through to standard 6.
3. There is an increase in popularity of option c, the option which suggests that only a downward force is acting on the bucket, from standard 4 through to standard 6.
4. Option d is the most popular option with all of the groups except the standard 6 group, which has a small preference for option c.

(c) **Comparison between the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in the Cape and Transkei select the different options.



Note:

1. There are large differences in the frequencies with which most of the options are selected by the two groups except in the case of option c.
2. Although pupils in the Cape prefer option c which suggests a

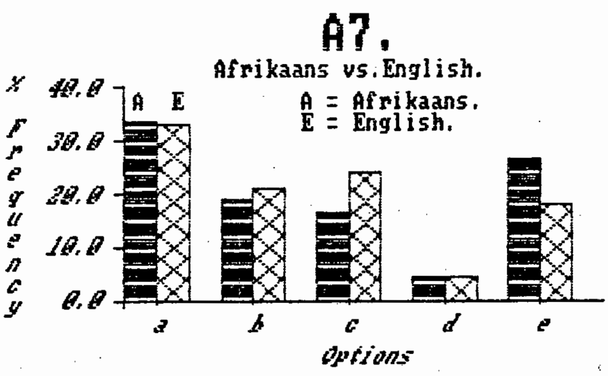
downward acting force only acting on the bucket, they also select some of the other options which suggest that two forces are acting on the bucket, with fairly high frequencies.

3. Pupils in Transkei prefer option d and c in that order. These options suggest that only one force acted on the bucket, the option which suggests an upward only force being the more popular.

4. 39% of Cape pupils and 75% of Transkei pupils select options which indicate only one force acting on the bucket.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in Cape schools select the different options.



Note:

1. The two groups differ markedly only in the frequencies with which they select options c and e.

2. Option e, which suggests that the upward force is larger than the downward force, is selected by 28% of Afrikaans-speaking

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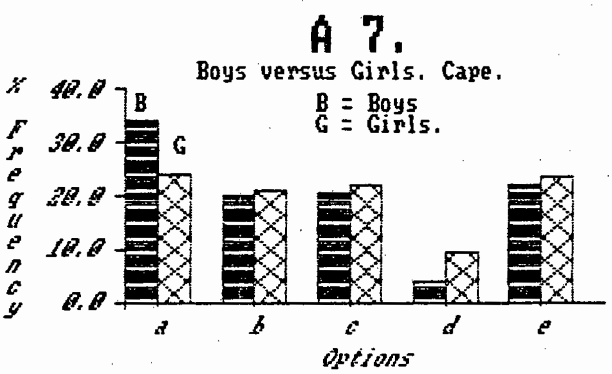
pupils and 18% of English-speaking pupils.

3. Option c, which suggests that only a downward force is acting on the bucket, is selected by 16% of Afrikaans-speaking pupils and 24% of English-speaking pupils.
4. That option d is unpopular with the pupils in the Cape is clearly illustrated.
5. 21% of Afrikaans-speaking pupils and 28% of English-speaking pupils select options which indicate that only one force is acting on the bucket.

(e) **Comparing the sexes:**

1. <u>In the Cape</u>:

The following graph compares the frequencies with which boys and girls in Cape schools select the different options.

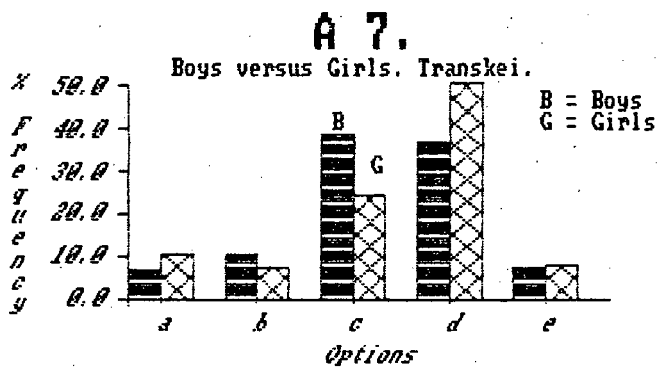


Note:

1. The two groups differ noticeably in the frequencies with which they select options a and d.
2. 34% of the boys and 24% of the girls select option a.
3. 4% of the boys and 9% of the girls select option d.
4. 26% of the boys and 33% of the girls select options which suggest a single force acting on the bucket, a downward force being the preferred choice of both groups.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in Transkei schools select the different options.

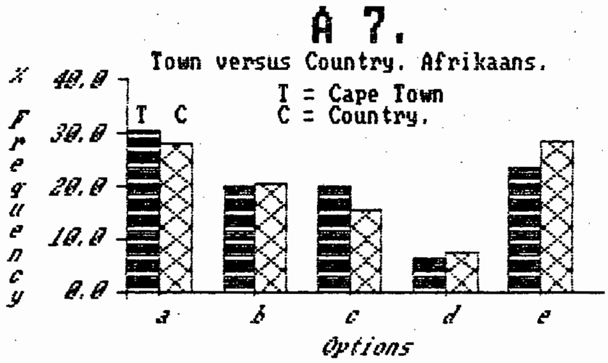


Note:

1. There is a marked preference of both the groups for options c and d. This contrasts sharply with pupils in Cape schools.
2. The boys are fairly evenly divided in their selection of options c and d.
3. The girls clearly prefer option d, the option which suggests that only an upward force is acting on the bucket. 50% of them select this option while only 37% of the boys did.
4. 75% of the boys and girls select options which indicate the presence of a single force only acting on the bucket.

(f) Comparing pupils from Cape Town and country towns:

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and country towns select the different options.



Note:

1. There are only small differences between the two groups in their selection of options c and e.
2. 29% of country pupils and 23% of city pupils select option e, the option which suggests that the upward force is larger than the downward force.
3. 20% of the city pupils and 15% of the country pupils select option c, which suggests that only a downward force acts on the bucket.

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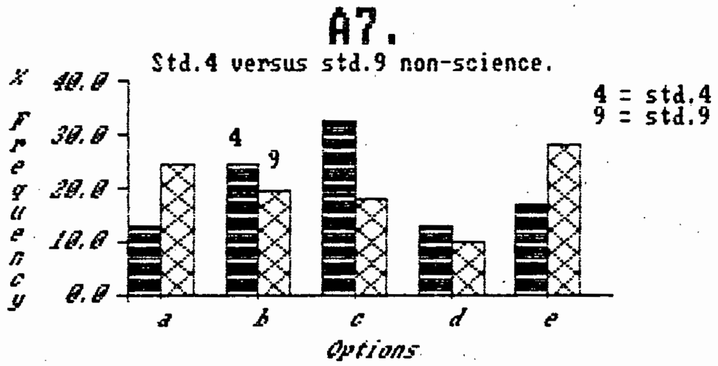
(g) **Comparing different standards:**

1. Standard 4 and standard 9 "no science" group:

The following graph compares the frequencies with which the different options are selected by Cape standard 4 pupils and standard 9 pupils who do not do science.



Note:

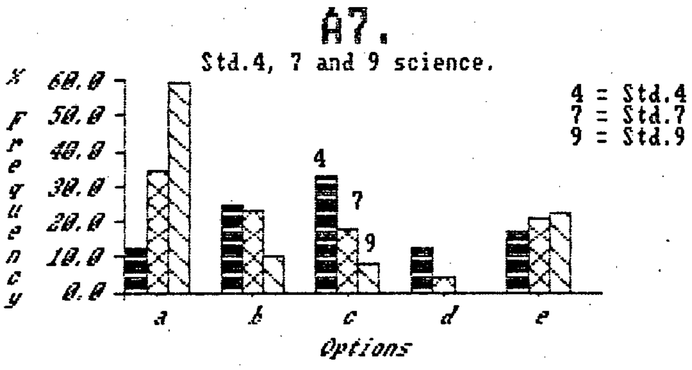
1. The two groups differ markedly in the frequencies with which they select the different options. The largest differences occur in the frequencies with which options a, c and e are selected.
2. 13% of the standard 4 group and 25% of the standard 9 group select option a, the correct option.
3. 33% of the standard 4 group and 18% of the standard 9 group select option c, which suggests that only a downward force acts on the bucket.
3. 17% of the standard 4 group and 28% of the standard 9 group select option e, which suggests that the upward force is larger than the downward force.
4. 46% of the standard 4 group and 28% of the standard 9 group

select options which indicate that only one force acts on the bucket.

5. 42% of the standard 4 group and 48% of the standard 9 group believe that two forces of unequal magnitude act on the bucket; 25% of the standard 4 group believe that a downward force is the larger while 28% of the standard 9 group believe that an upward force is the larger.

2. Standards 4,7 and 9 "science group":

The following graph compares the frequencies with which standards 4, 7 and 9 pupils who do science, select the different options.



Note:

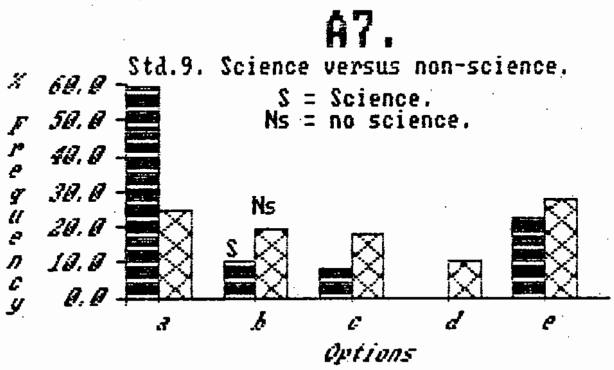
1. There is a marked increase in the frequencies with which option a, the correct option, is selected from standard 4 to standard 9.

2. Option d is the most unpopular option with all three of the groups. It is not selected at all by the standard 9 group.

3. There is a steady decrease in popularity of option c from standard 4 through to standard 9.
4. Options b and e, which suggest that two forces of unequal magnitude are acting on the bucket, are selected by a fair fraction of the groups. 22% of the standard 9 group believe that the upward force was larger than the downward force while 23% of the standard 7 group believe that the downward force was larger than the upward force.

3. <u>Standard 9 science pupils and standard 9 pupils who do not do science:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and standard 9 pupils who do not do science select the different options.



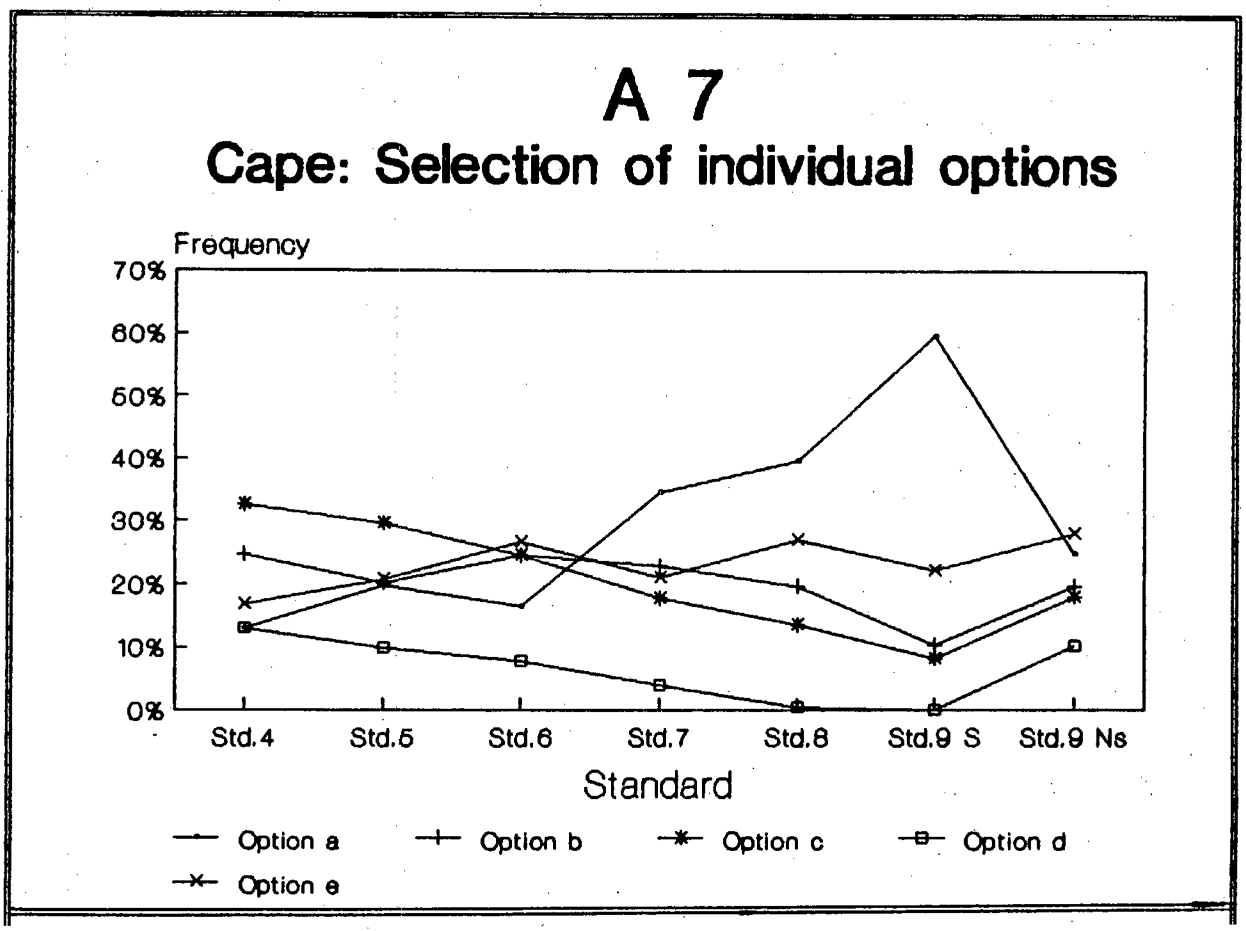
Note:

1. With the exception of option e, large differences exist in the fequencies with which the two groups select the different options.
2. 60% of the science group and 25% of the non-science group select option a, the correct option.

3. Option d is the most unpopular option with both groups - and particularly so with the science group.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by the different standards in the Cape.



Note:

1. There is an increase in popularity of option a from standard 6 through to standard 9 science pupils.
2. There is a decrease in popularity of option d.
3. The frequencies with which option c is selected fluctuates

between 20% and 30% across the different standards.

4. There is a decrease in popularity of option e from standard 4 through to standard 9 science pupils.
5. Option b receives a fair amount of support with the standards 5, 6, 7, 8 and 9 non-science pupils.

Summary:

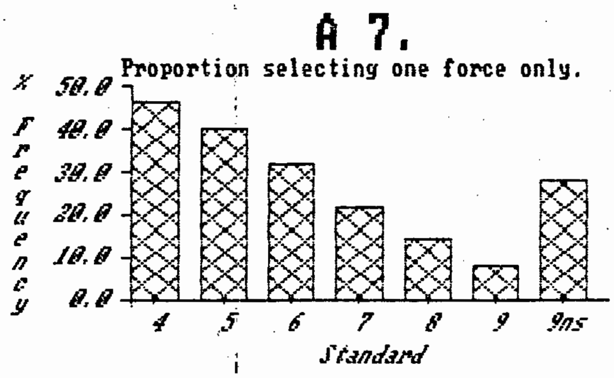
1. As far as the overall picture is concerned we find that:

   25% of the sample select option a, the correct option;
   38% of the sample select options which indicate that two forces of unequal magnitude act on the bucket;
   37% of the sample select options which indicate that only one force acts on the bucket.

2. When we compare the frequencies with which the different standards in the Cape select the different options, we find that:

   option a increases in popularity reaching a maximum with the standard 9 science pupils;
   option c, which suggests only a downward force was acting on the bucket, decreases in popularity reaching a minimum with the standard 9 science pupils;
   options which suggest two forces of unequal magnitude are acting on the bucket are fairly popular;
   option d, which suggests that only an upward force acts on the bucket, is very unpopular with all of the groups.

The following graph compares the frequencies with which the different standards select options which indicate the presence of only one force acting on the bucket.



Note:

1. There is a decrease in the frequencies with which options which indicate the presence of one force only are selected from standard 4 through to the standard 9 science pupils.

3. When we compare the frequencies with which the different standards in Transkei select the different options we find that:

options which suggest the presence of two forces acting on the bucket, are unpopular with all the standards;

option c, which suggests that only a downward force acts on the bucket, increases in popularity to reach a maximun with standard 6;

option d, which suggests only an upward force acting on the bucket, decreases in popularity to reach a minimum with standard 6, but it is the most popular choice with the other two standards.

4. When we compare the pupils in the Cape with their counterparts in Transkei we find that:

   the two groups differ in the frequencies with which they select the different options;
   Transkei pupils select the option which suggest only an upward force acting on the bucket in preference to the others while in the Cape the preferred single option is that of only a downward force acting on the bucket;
   39% of Cape pupils and 75% of Transkei pupils select options which indicate the presence of one force only acting on the bucket.

5. When we compare Afrikaans-and English-speaking pupils we find that:

   the two groups differed materially only in the frequencies with which they select options c and e;
   28% of Afrikaans-speaking pupils and 18% of English-speaking pupils believe that the upward force acting on the bucket is larger than the downward-acting force while 24% of English-speaking pupils and 16% of Afrikaans-speaking pupils believe that only a downward force acts on the bucket.

6. When we compare the frequencies with which boys and girls in the Cape select the different options we find that:

   34% of the boys and 24% of the girls select the correct option;

26% of the boys and 33% of the girls believe that only one force acts on the bucket, the downward force being the popular one.

In Transkei we find that:

boys and girls both prefer options which indicate the presence of a single force acting on the bucket, the boys being fairly evenly divided between an upward and downward force while the girls prefer an upward force. 50% of the girls and 37% of the boys believe that only an upward force acts on the bucket;
75% of boys and girls believe that a single force acts on the bucket.

7. When we compare the frequencies with which Afrikaans-speaking pupils who live in Cape Town and in country towns select the different options, we find that there are small differences in the frequencies with which the two groups select options c and e only. Slightly more country pupils thought that the upward force is larger than the downward force while slightly more Cape Town pupils thought that only a downward force acts on the bucket.

8. When we compare some of the standards we find that:

the standard 4 group and the standard 9 non-science group differed markedly in the frequencies with which they select all of the options, the most marked differences being in the selection of options a, c and e;
13% of the standard 4 group and 25% of the standard 9 group select the correct option;

33% of the standard 4 group and 18% of the standard 9 group thought that only a downward force acted on the bucket;

17% of the standard 4 group and 28% of the standard 9 group thought that the upward force acting on the bucket is larger than the downward force;

the frequencies with which the correct option are selected increases from standard 4 reaching a maximum with the standard 9 science pupils while the frequencies with which the option suggesting only a downward acting force decreases from standard 4 to standard 9;

a fair proportion of each of the groups select options which indicate a belief in two forces of unequal magnitude acting on the bucket;

the standard 9 science pupils and non-science pupils differed very markedly in the frequencies with which they select most of the options, option e being the exception.

9. When we compare the frequencies with which the individual options are selected by the different standards we find that:

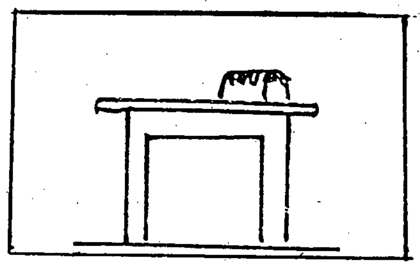
option a increases in popularity up to a maximum with the standard 9 science pupils;

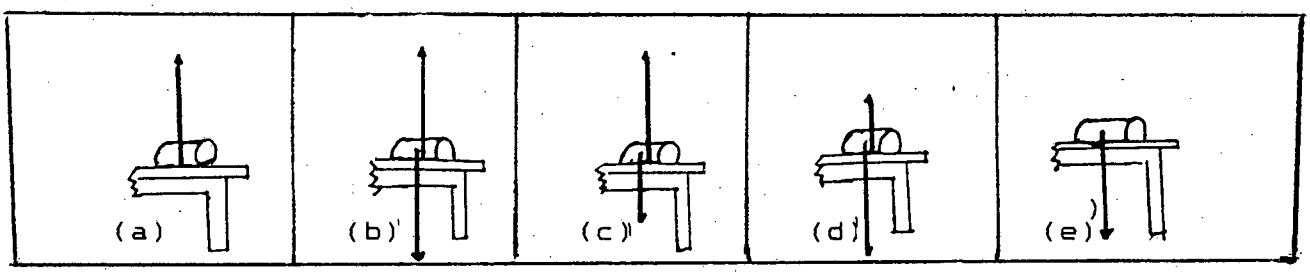
options d and e decrease in popularity with a minimum at the standard 9 science pupils;

option b, which suggests that the downward force acting on the bucket is larger than the upward force, is selected fairly consistently by all of the groups, as is option c which suggests the presence of only a downward force.

Question A 9:

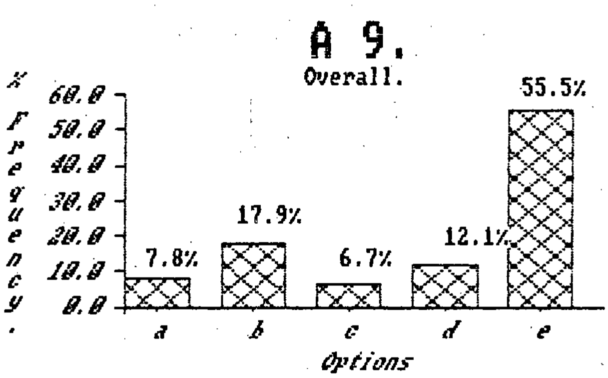
The sketch shows a loaf of bread lying on a table. The sketch which best shows and compares the forces acting on the bread, is:





(a) The overall picture:

The following graph compares the frequencies with which the different options are selected by the whole sample.



Note:

1. Option e, which suggests that the only force acting on the loaf of bread is a downward one, is overwhelmingly popular.
2. Option b, the correct option, is selected by only 18% of the sample.

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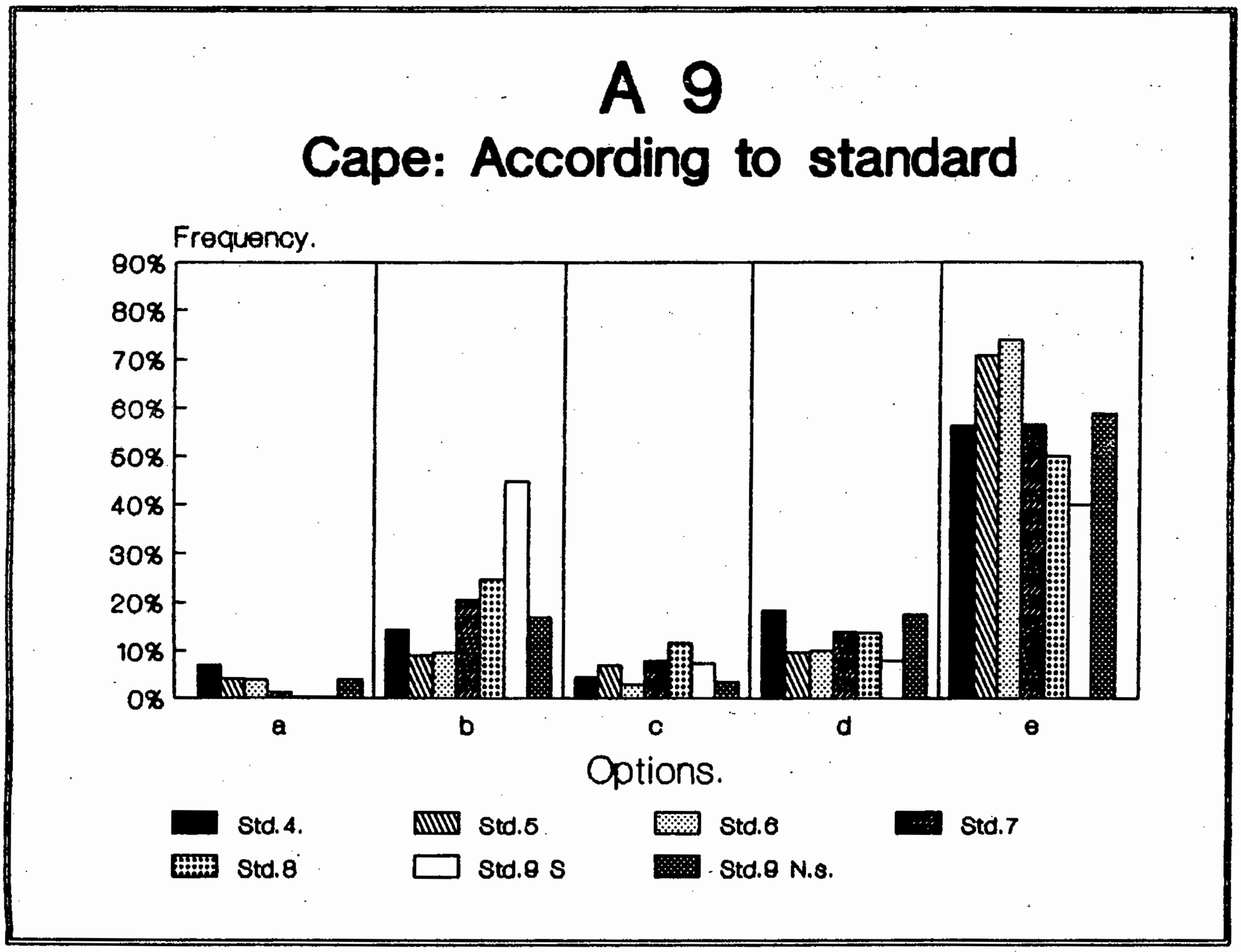
3. Options which suggest the presence of two forces acting on the loaf of bread is selected by 37% of the sample only.

(b) **According to standard:**

1. In the Cape:

The following graph compares the frequencies with which the different options are selected by the different standards in schools in the Cape.



Note:

1. Options a and c are very unpopular with all of the groups.

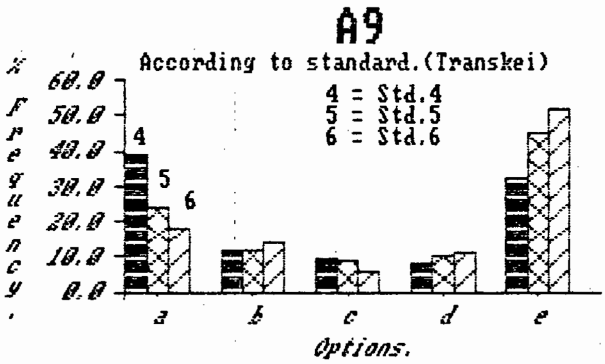
2. Option d receives fair support from most of the groups.

3. Option b, the correct option, increases in popularity to reach a maximum with the standard 9 science group.

4. There is overwhelming support for option e, the option which suggests that only a downward force acts on the loaf of bread, by all of the groups except the standard 9 science group, who nevertheless found it only slightly less attractive than option b.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which the different standards in Transkei schools select the different options:



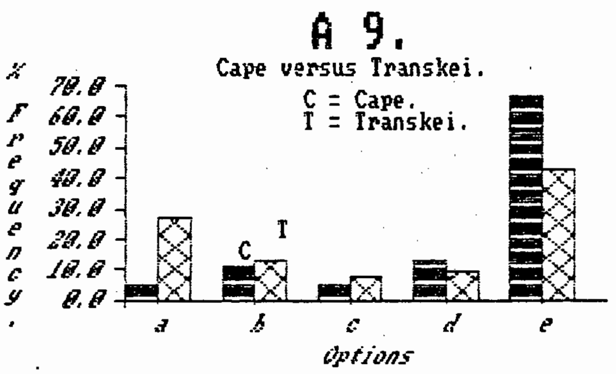
Note:

1. Options a and e, which suggest the presence of one force only acting on the loaf of bread, are the most popular although the other options receive limited support.
2. There is a decrease in the popularity of option a from standard 4 to standard 6.
3. There is an increase in popularity of option e from standard 4 to standard 6.
4. Option e is the most popular with the standard 5 and 6 groups

while option a is slightly more popular with the standard 4 group.

(c) Comparing the Cape and Transkei:

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in the Cape and Transkei select the different options.

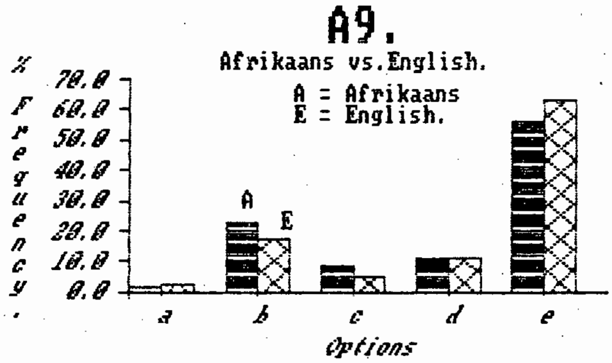


Note:

1. There are large differences in the frequencies with which the two groups select options a and e.
2. Option a, the option which suggests that an upward force only acts on the loaf of bread, is selected by 5% of Cape pupils and 27% of Transkei pupils.
3. Option e, the option which suggests that a downward force only acts on the loaf of bread, is selected by 67% of Cape pupils and 43% of Transkei pupils.
4. 72% of Cape pupils and 70% of Transkei pupils select options which indicate the presence of one force only acting on the loaf of bread.

(d) Comparing the language groups in the Cape:

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in the Cape select the different options.



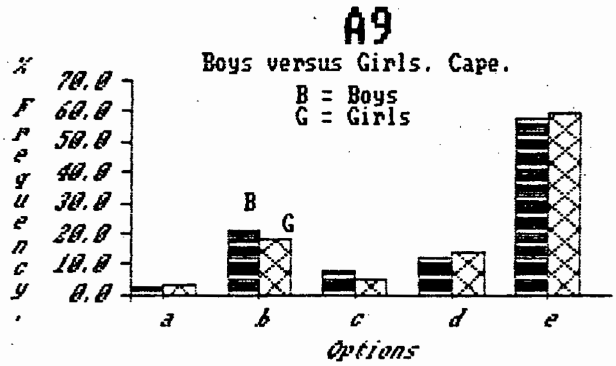
Note:

1. There is very small differences between the frequencies with which the different groups select the different options.
2. Both groups prefer option e, the option which suggests that only a downward force acts on the loaf of bread. This option is selected by 56% of the Afrikaans-speaking group and 63% of the English-speaking group.
3. Both groups found option b, the correct option, the next most popular with 23% of the Afrikaans-speaking group and 18% of the English-speaking group selecting it.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in the Cape select the different options.

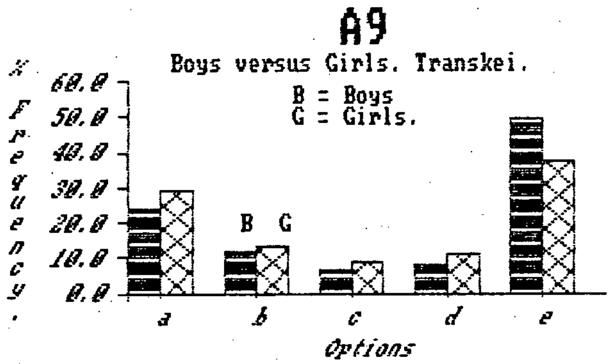


Note:

1. There are only very small differences in the frequencies with which the two groups select the different options and the overall picture for the two groups is therefore very similar.
2. 59% of the boys and 59% of the girls select option e.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in Transkei schools select the different options.

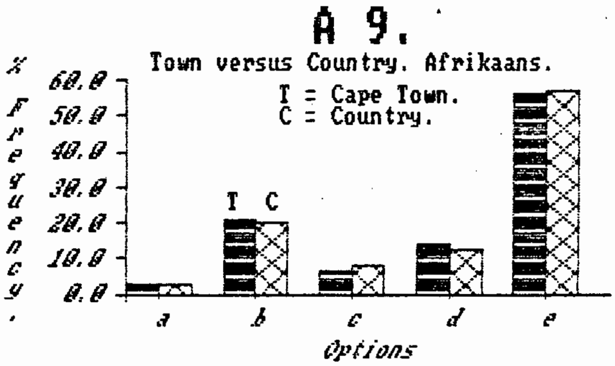


Note:

1. Although there are small differences between the frequencies with which the two groups select the different options, the general pattern is the same for both of them in that both groups prefer options a and e.
2. 24% of the boys and 29% of the girls select option a, which suggests only an upward force acting on the loaf of bread.
3. 50% of the boys and 38% of the girls select option e, which suggests that only a downward force acts on the loaf of bread.

(f) **Comparing pupils from Town and country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans- speaking pupils living in Cape Town and country towns select the different options.



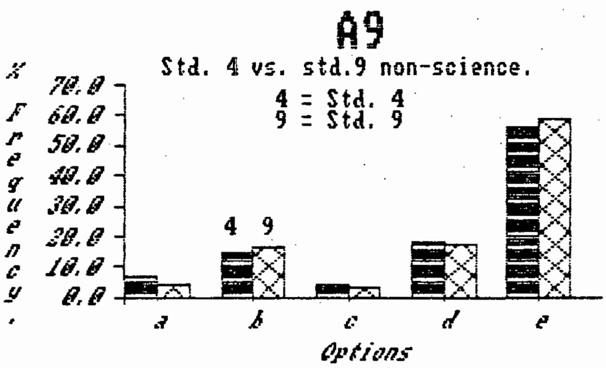
Note:

1. There is no noteworthy differences in the frequencies with which the two groups select the different options.

(g) Comparing different standards:

1. <u>Standard 4 and standard 9 non-science pupils:</u>

The following graph compares the frequencies with which standard 4 and standard 9 non-science pupils select the different options.

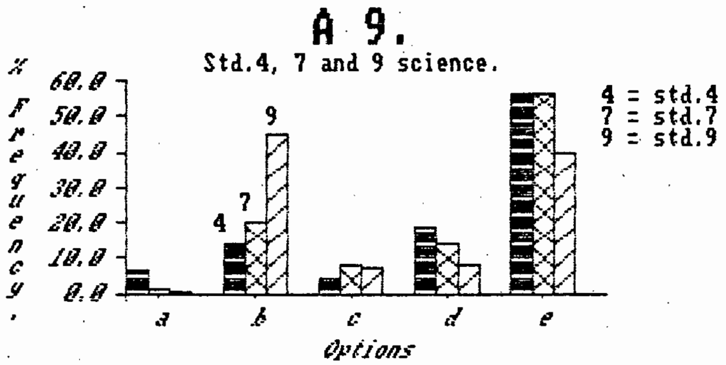


Note:

1. There is virtually no difference in the frequencies with which the two groups select the different options.

2. <u>Standards 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which pupils in standards 4, 7 and 9 science group select the different options.

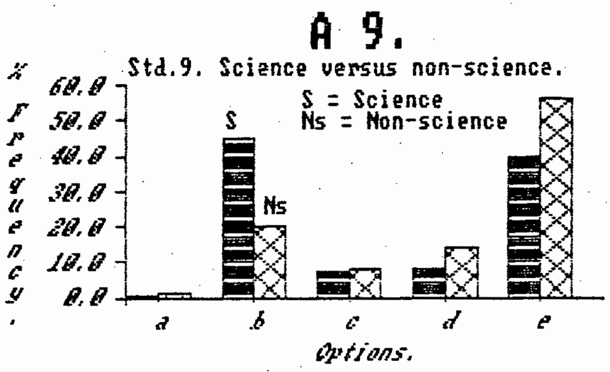


Note:

1. There is a marked increase in popularity of option b, the correct option from standard 4 to standard 9.
2. There is a decrease in popularity of option d, the option which suggests that a small upward force acts on the loaf of bread from standard 4 to standard 9.
3. Option e is very popular with the standard 4 and 7 groups and although it is not as popular as option b with the standard 9 group, it is nevertheless selected by 40% of the standard 9 group.

3. Standard 9 science and non-science groups:

The following graph compares the frequencies with which the standard 9 pupils who do science and those who do not do science select the different options.



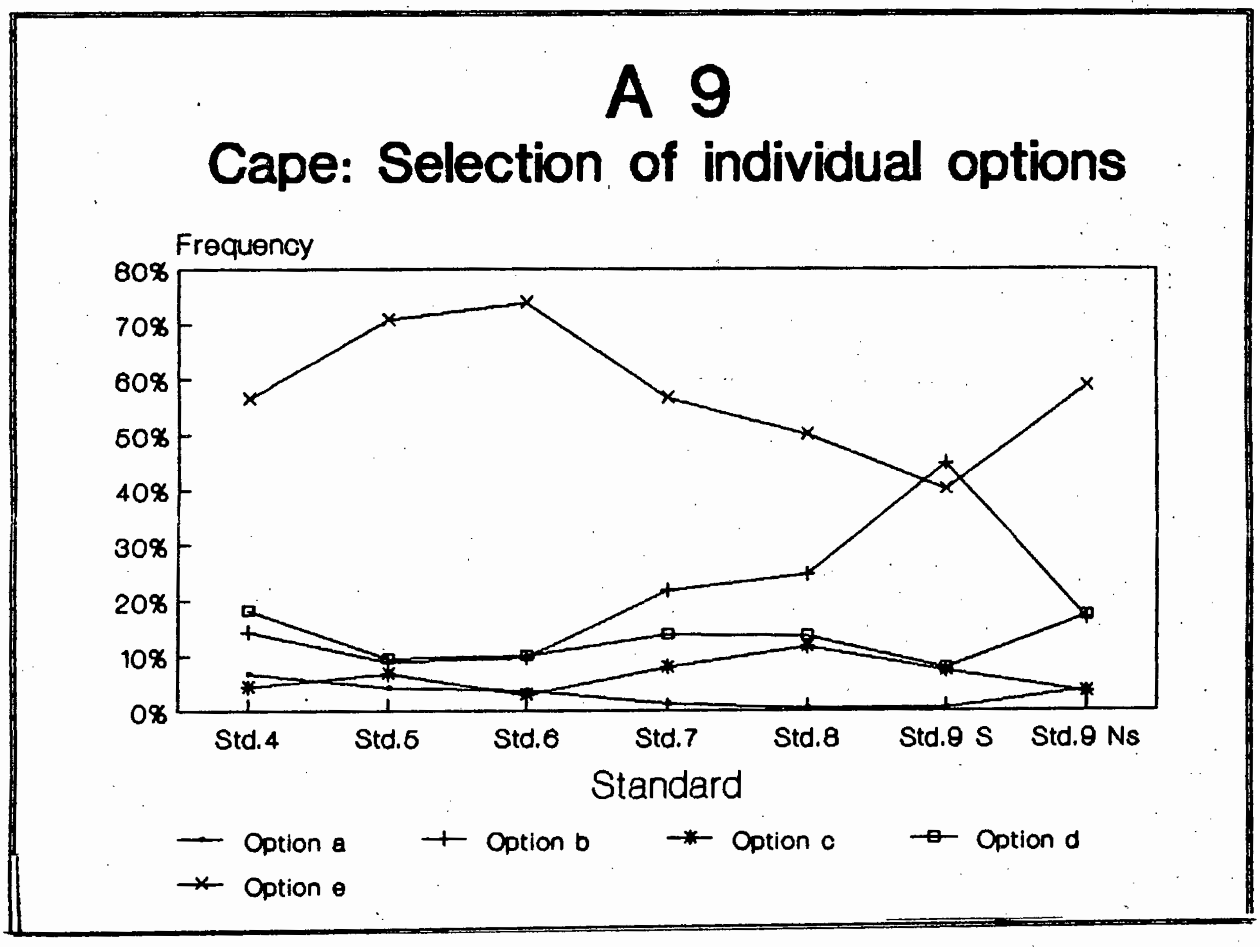
Note:

1. Option a is very unpopular with both groups.

2. The two groups differ markedly in the frequencies with which they select options b and e. Option b is selected by 45% of the science group and 17% of the non-science group. 42% of the science group and 59% of the non-science group select option e.

(h) Selection of individual options:

The following graph compares the frequencies with which the individual options are selected by the different standards.



Note:

1. There is an increase in popularity of option b, the correct option, to a maximum with the standard 9 science group.
2. Option e, the option which suggests only a single downward force acts on the loaf of bread, is very popular with all of the groups.
3. The other options which include options suggesting forces of unequal magnitude acting on the loaf, are unpopular. The option which suggests only a single upward force acting on the loaf is very unpopular with all of the groups.

Summary:

1. As far as the overall picture is concerned we find that:

   55% of the sample select the option which indicated a single downward force acting on the loaf of bread;

   37% of the sample select options which indicated two forces acting on the loaf of bread;

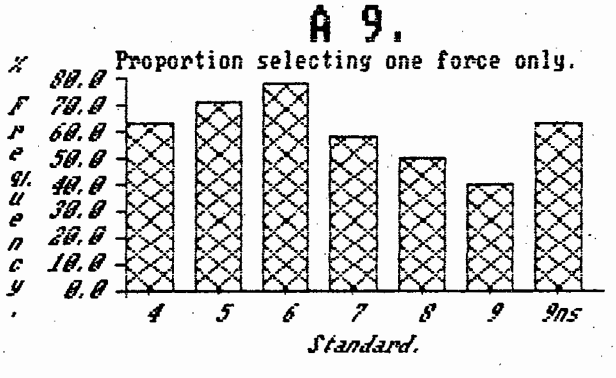
   18% of the sample select the correct option.

2. When we compare the frequencies with which the different standards in Cape schools select the different options we find that:

   option e is the favourite option of all of the classes except the standard 9 science group whose second most popular option it is;

   in Cape schools the majority of pupils in all of the different standards do not believe that the table can exert an upward force on the loaf of bread.

The following graph compares the frequencies with which options which indicate a single force only acting on the loaf, are selected by the different standards:



Note:

1. Options which indicate the presence of a single force only are selected with very high frequencies. If we take into consideration that option a is relatively unpopular, then it is clear that option e is very popular with the different groups.

3. When we compare the frequencies with which the different standards in Transkei schools select the different options we find that options a and e are selected most frequently with option e being the most popular with standard 5 and 6 pupils while option a is more popular with standard 4 pupils.

4. When we compare the pupils in standards 4, 5 and 6 in the Cape and Transkei we find that:

   the two groups differ markedly in the frequencies with which they select options a and e, with the vast majority of Cape pupils indicating a believe in only a downward force acting on the loaf of bread. A substantial proportion of Transkei pupils indicate a belief in only an upwards force acting on the loaf.
   72% of Cape pupils and 70% of Transkei pupils believe that only one force acts on the loaf of bread.

5. When we compare Afrikaans-and-English-speaking pupils we find that only very small differences exist in the frequencies with which the two groups select the different options.

6. When we compare the frequencies with which boys and girls in Cape schools select the different options we find very small differences in the frequencies with which the two groups select the different options.

   In Transkei we find that the two groups differ slightly in the frequencies with which they select the different options. Although option a receives a fair amount of support from both groups, option e, the option which indicates only a downward force acting on the loaf of bread, is the most popular among the boys and the girls.

7. When we compare the frequencies with which Afrikaans-speaking pupils who live in Cape Town and country towns select the different options, we find no real differences between the two groups.

8. When we compare some of the standards we find that:

   no appreciable difference exists between the standard 4 group and the standard 9 non-science group;

   standards 4, 7 and 9 science pupils differ in the frequencies with which they select the options and while option e is the most popular with the standard 4 and 7 groups, it is the second most popular with the standard 9 group;

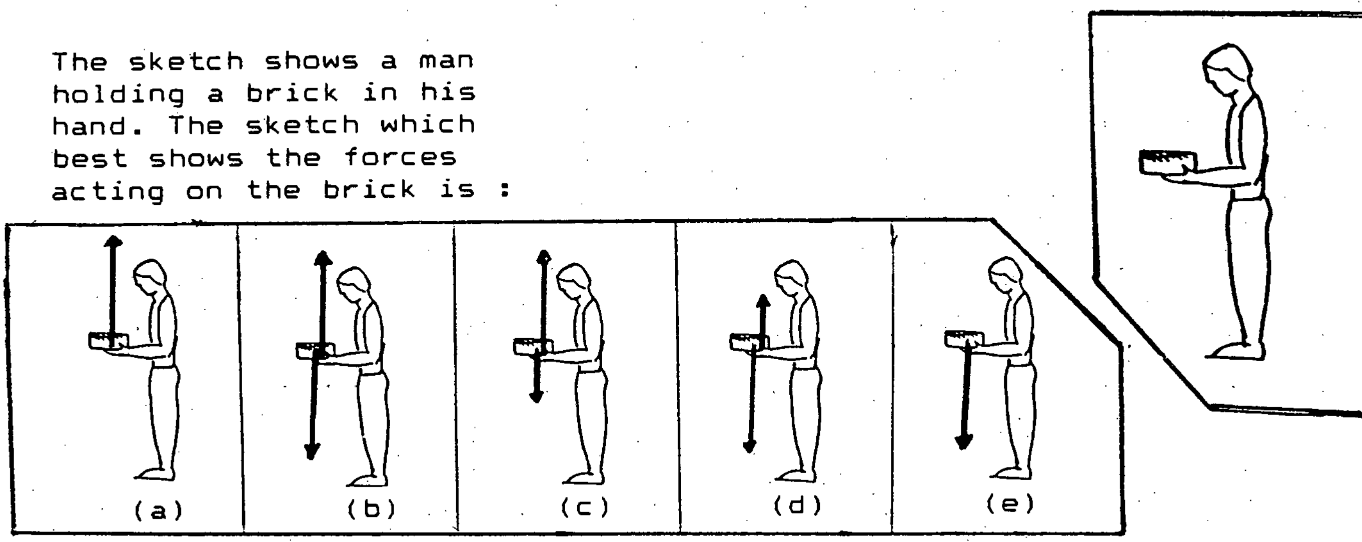
   the standard 9 science and non-science groups differed very markedly in the frequencies with which they select options b and e. The majority of the science group select the correct option while the majority of the non-science group select option e.

9. When we compare the frequencies with which the individual options are selected by the different standards in the Cape we find that:

option e is the most popular with all the groups except the standard 9 science group and that its popularity decreases to a minimum with standard 9 science pupils;
the popularity of option b increases to a maximum with the standard 9 science group;
option a is very unpopular with all of the groups.

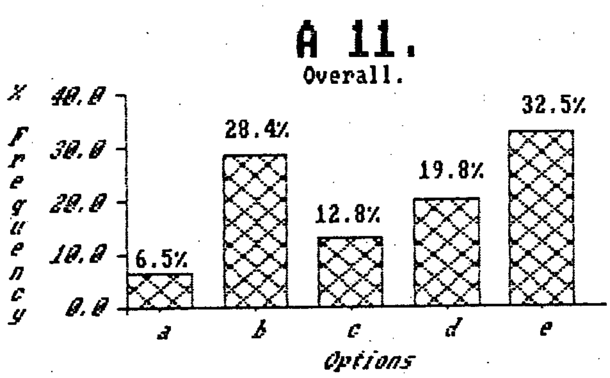
Question A 11:

The sketch shows a man holding a brick in his hand. The sketch which best shows the forces acting on the brick is :



(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



Note:

1. Option b, the correct option, is selected by 28% of the pupils.
2. 33% of the pupils select option e, the option which indicates a downward force only acting on the brick.

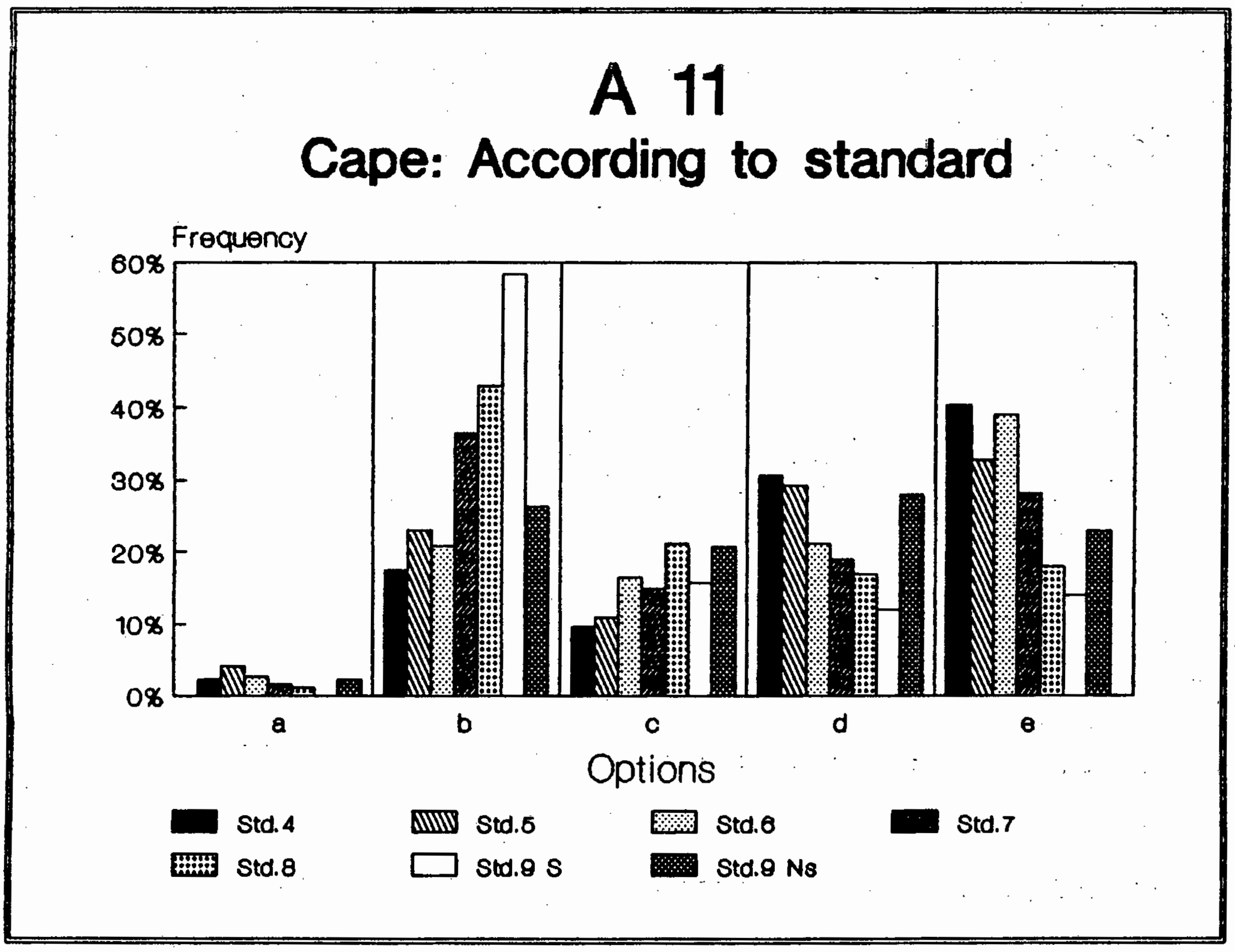
3. 20% of the pupils select option d, the option which indicates that there are two forces acting on the brick but that the downward force is larger than the upward force.

4. 39% of the pupils select options which indicate a single force only acting on the brick .

(b) According to standard:

1. In the Cape:

The following graph compares the frequencies with which Cape pupils in the different standards have select the different options.



Note:

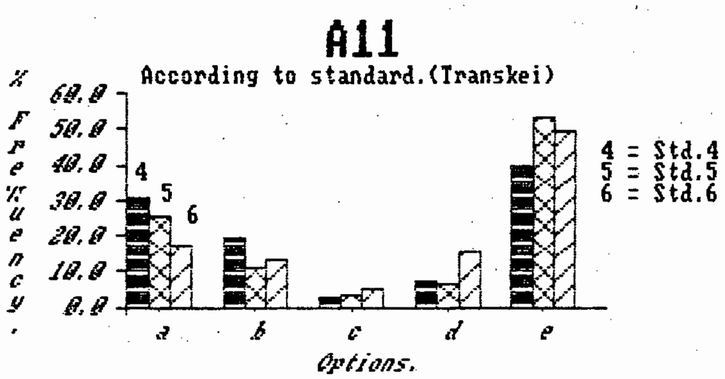
1. Option a, the option which indicates an upward force only acting on the brick, is extremely unpopular.

•

2. There is an increase in the frequencies with which the correct option, option b, is selected, reaching a maximum with the standard 9 science group. While there is very litle difference between the frequencies with which the standard 4, 5 and 6 groups select this option, there is a marked increase in the difference upon going to standard 7 group. Thereafter the difference increases steadily.
3. There is a decrease in the frequencies with which option e is selected, to a minimum with the standard 9 science group.
4. The decrease in the frequencies with which option d is selected, reaches a minimum with the standard 9 science group. This option implies that two forces are acting on the brick and that the downward force is larger than the upward force. It has reasonable support from all of the standards.
5. There is an increase in the frequencies with which option c is selected. This option implies that there are two forces acting on the brick but that the upward force is larger than the downward force.
6. the standards differ in the frequencies with which they select the different options.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which the different standards in Transkei select the different options.

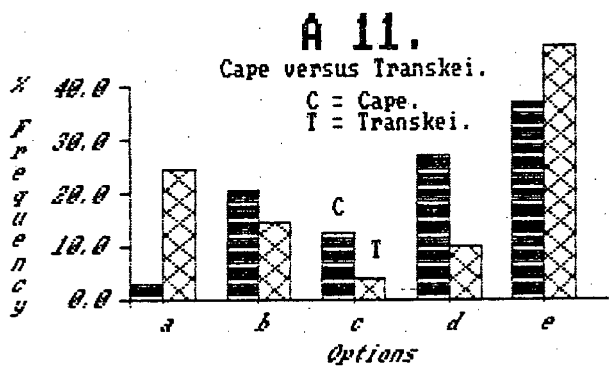


Note:

1. There is overwhelming support from all of the classes for option e, which indicates a downward force only acting on the brick.
2. There is a decrease in the frequencies with which option a is selected. This option indicates an upward force only acting on the brick.
3. Options c and d are upopular. These options indicate two forces of unequal magnitude acting on the brick.
4. The most popular choice here is for a single force acting on the brick.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in the Cape and Transkei select the different options.

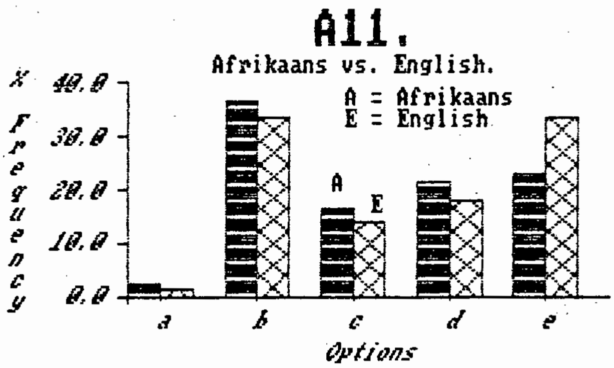


Note:

1. The groups differ markedly in the frequencies with which they select the different options.
2. Both groups find option e the most attractive. It is selected by 37% of Cape pupils and 48% Transkei pupils.
3. 24% Transkei and 3% Cape pupils select option a, the option which suggests an upward force only acting on the brick.
4. 27% of Cape and 10% of Transkei pupils select option d, the option which suggests that there are two forces acting on the brick with the upward force smaller than the downward one.
5. 20% of Cape and 14% of Transkei pupils select the correct option.
6. 12% of Cape and 4% of Transkei pupils select option c, the option which indicates two forces acting on the brick with the upward force larger than the downward one.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



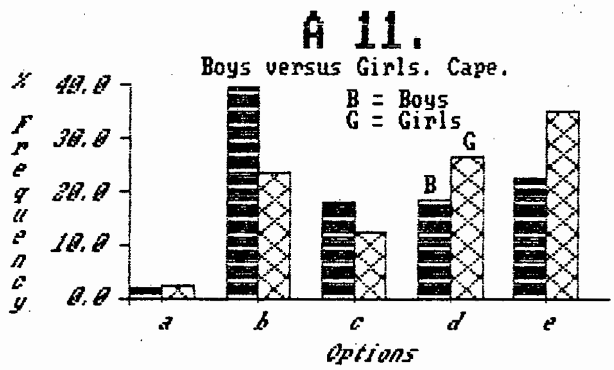
Note:

1. There are small differences in the frequencies with which the two groups select the different options but the general pattern of selection is the same.
2. It is only on option e that the two groups differ to any marked degree. This option is selected by 23% of Afrikaans- and 33% of English-speaking pupils.
3. 38% of Afrikaans-and 32% of English-speaking pupils select options which indicate two forces of unequal magnitude acting on the brick.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in school in the Cape select the different options.

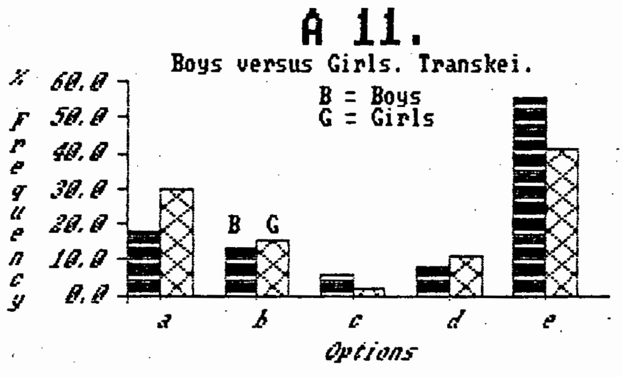


Note:

1. The two groups differ markedly in their selection of options b, c, d and e.
2. Option a is very unpopular with both groups.
3. 40% of the boys and 24% of the girls select the correct option, option b.
4. 18% of the boys and 13% of the girls select option c. This indicates a belief that two forces are acting on the brick with the upward force larger than the downward force.
5. 18% of the boys and 27% of the girls believ that the downward force is larger than the upward force acting on the brick.
6. 22% of the boys and 35% of the girls believe that only a downward force acts on the brick.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in Transkei select the different options

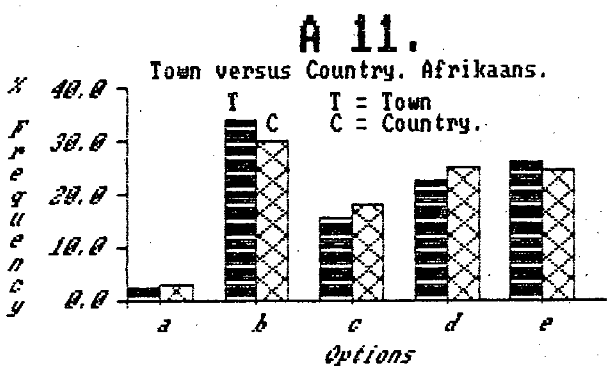


Note:

1. The two groups differ in the frequencies with which they select option a and e. These options indicate only one force acting on the brick.
2. 18% of the boys and 30% of the girls believe that an upward force only is acting on the brick.
3. 55% of the boys and 41% of the girls believe that a downward force only is acting on the brick.

(f) **Comparing pupils from Town and country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and country towns select the different options.



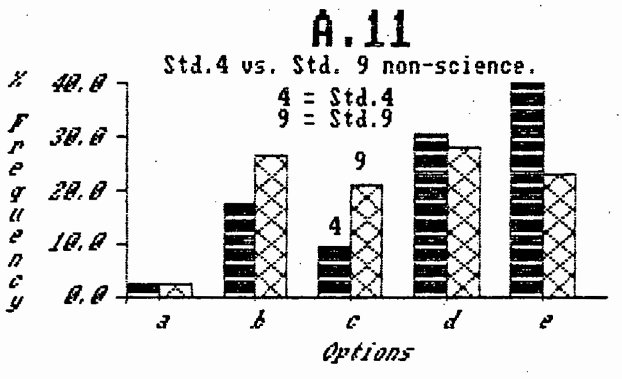
Note:

1. There is virtually no difference in the frequencies with which the two groups select the different options.
2. 34% of Cape Town and 30% of country pupils select the correct option.

(g) Comparing different standards:

1. Standard 4 and standard 9 non-science group:

The following graph compares the frequencies with which standard 4 pupils and standard 9 pupils who do not do science select the different options.

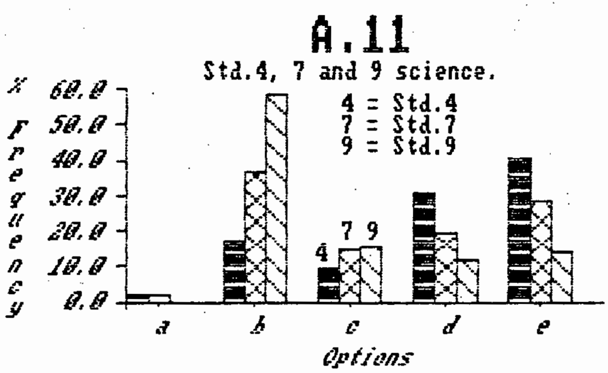


Note:

1. The two groups differ appreciably in the frequencies with which they select options b, c and e.
2. 17% of the standard 4 group and 26% of the standard 9 group select the correct option, option b.
3. 10% of the standard 4 group and 21% of the standard 9 group believe that the upward force acting on the brick is larger than the downward force.
4. 44% of the standard 4 group and 23% of the standard 9 group believe that only a downward force acted on the brick.

2. Std.4, 7 and 9 science pupils:

The following graph compares the frequencies with which standards 4, 7 and 9 pupils who do science select the different options.

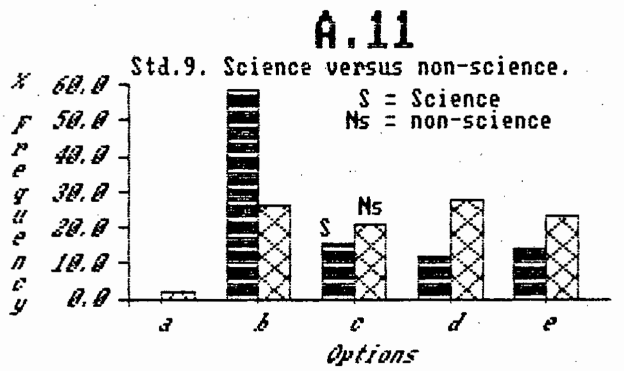


Note:

1. The increase in the frequencies with which the correct option, b, is selected from standard 4 through to standard 9. This may be the result of learning or, as the pupils who do science in standard 8 and 9 select to do so, it is also possible that they have a better grasp of science.
2. There is a decrease in the frequencies with which option e is selected.
3. While option d is fairly popular with the standard 4 group, there is a decrease in its popularity thereafter.

3. <u>Std. 9 science pupils and std. 9 non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and those who do not do science select the different options.

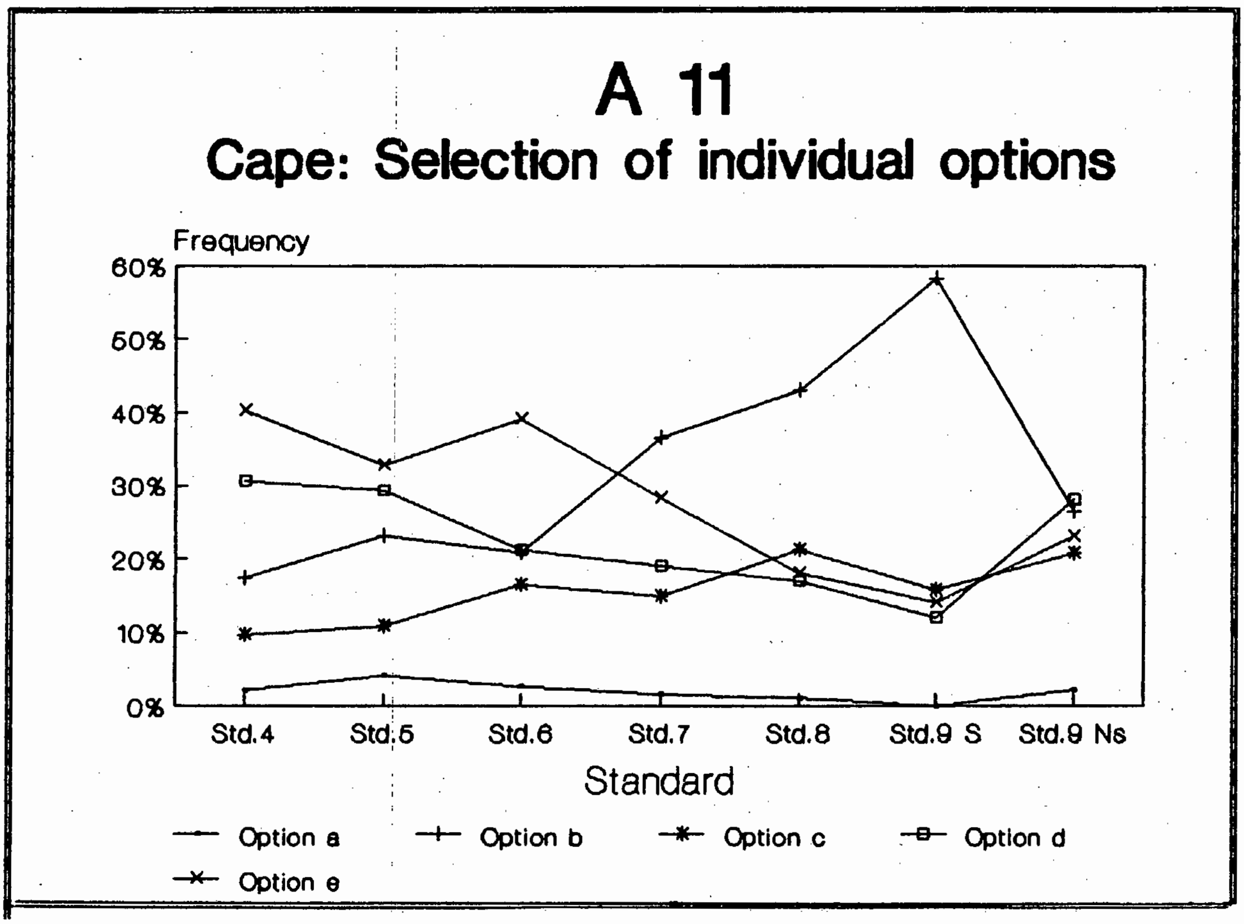


Note:

1. There is a very large difference in the frequencies with which the two groups select option b, the correct option: 58% of the science group but only 37% of the non-science group select this option.
2. 28% of the non-science group and 12% of the science group select option d, which indicates a belief in two forces acting on the brick but with the upward force smaller than the downward force.
3. The non-science group select options b, c, d and e more or less evenly while the science group showed overwhelming support for option b.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by the different standards in the Cape.



Note:

1. Option a is unpopular with all of the groups. This is the option which indicates only an upward force acting on the brick.
2. There is an increase in the popularity of option b to a maximum with the standard 9 science group.
3. There is a decrease in popularity of option e to a minimum with the standard 9 science group.

4. With the standard 4 and 5 groups option d is fairly popular. Its popularity decreases as that of option c increases. These options indicate the presence of two forces of unequal magnitude acting on the brick.

Summary:

1. As far as the overall picture is concerned we find that:

28% of the sample select the correct answer.

33% of the sample select a single downward force acting on the brick.

39% of the sample believe that a single force acts on the brick.

20% of the sample believe that two forces act on the brick with the upward force smaller than the downward force.

2. When we compare the frequencies with which the different standards in Cape schools select the different options, we find that:

the frequencies with which the different standards select the different options differ;

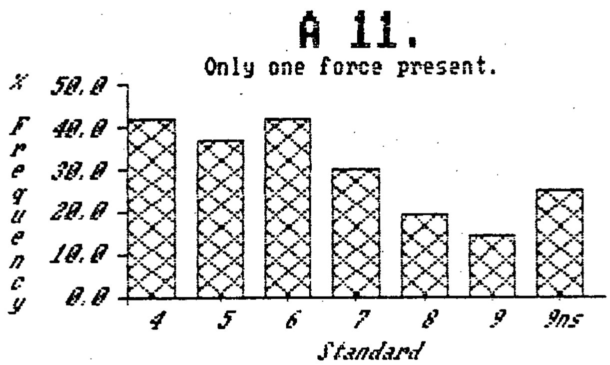
the frequencies with which option b, the correct option, is selected increases to a maximum with the standard 9 science group;

the frequencies with which option e, which suggests a single downward force acting on the brick, is selected decreases to a minimum with the standard 9 science group;

options c and d, which indicate two forces of unequal magnitude acting on the brick, has reasonable support from all of the standards;

option a, which indicates a single upward force acting on the brick, is the least popular with all of the standards.

The following graph compares the frequencies with which the different standards select options which indicate a single force only acting on the brick.



Note:

There is a decrease in the frequencies from standard 6 to the standard 9 science group. There is clearly an increases awareness of the presence of two forces acting on the brick.

3. When we compare the frequencies with which the different standards in Transkei select the different options we find that:

the standards are divided between options a and e, with option e being the more popular. This indicates that children in the Transkei have a very strong belief in a single force only

...

acting on the brick.

4. When we compare the pupils in the Cape and Transkei we find that:

   the two groups differ very markedly in the frequencies with which they select the different options but they both find option e the most attractive. This option suggests that a single downward force acts on the brick and is selected by 37% of the Cape pupils and 48% of Transkei pupils;
   3% of Cape pupils and 24% of Transkei pupils select option a which suggests a single upward force acting on the brick;
   27% of Cape pupils and 10% of Transkei pupils select option d which suggests that two forces act on the brick with the upward force being smaller than the downward force.

5. When we compare Afrikaans-and English-speaking pupils we find that the two groups differ mainly in the frequencies with which they select option e. This option is selected by 23% of Afrikaans-speaking pupils and 33% of English-speaking pupils.

6. When we compare the frequencies with which boys and girls in Cape schools select the different options, we find that:

   the two groups differ in the frequencies with which they select options b, c, d and e;
   40% of the boys and 24% of the girls select option b, the correct one;
   18% of the boys and 27% of the girls believe that the downward force acting on the brick is larger than the upward force;
   22% of the boys and 35% of the girls believe that only a

downward force acted on the brick.

In Transkei we find that:

boys and girls differ mainly in their selection of options a and e;
18% of the boys and 30% of the girls select option a, which indicates a single upwards force acting on the brick;
55% of the boys and 41% of the girls select option e, which indicates a single downward force acting on the brick;

7. When we compare Afrikaans-speaking pupils who live in Cape Town and in country towns we find that there is virtually no difference in the frequencies with which these two groups select the different options.

8. When we compare some of the standards we find that:

the standard 4 and standard 9 non-science groups differ in the frequencies with which they select options b, c, d and e. This difference is especially large in the case of option e which is selected by 40% of the standard 4 group and 23% of the standard 9 group;

there is an increase in the frequencies with which standard 4, 7 and 9 science pupils select the correct option;
there is a decrease in the frequencies with which these standards select option e which suggests a downward force only acting on the brick;

the standard 9 science and non-science groups differed very markedly in the frequencies with which they select the different options - especially in the case of option b which is selected by 58% of the science group and 37% of the non-science group.

9. When we compare the frequencies with which the individual options are selected by the different standards we find that:

option a is very unpopular with all of the groups;
option b increases in popularity reaching a maximum with the standard 9 science group;
option e decreases in popularity reaching a minimum with the standard 9 science goup.

Chapter 7

Forces involved in interaction between bodies

Introduction:

In the previous investigations involving forces acting between two bodies reviewed on p. 61 it was found that pupils or students think that :

(a) the more massive body exert the larger force. (Helm, Terry and Jones, Maloney.)

(b) when motion is involved the body causing the motion exerts the larger force.(Watts and Zylberstajn, Maloney.)

The situations which we used were rather similar to those used by Watts and Zylberstajn. In their tug-of-war with motion they found that 82% of their sample of 14 year olds believed that the person who was winning exerted the larger force. We used a similar situation to investigate the prevalence of this belief amongst our own pupils. To investigate the prevalence of the belief that the larger body exerts a larger force, we used a tug-of-war situation in which one of the competitors was obviously smaller than the other one.

Results:

1. Question A6 dealt with the tug-of-war situation between competitors of unequal size but with no motion involved. Using this situation we find that 31% of our whole sample demonstrate the belief that the more massive body exerts the larger force. However, an analysis of the frequency with

which this belief is held by pupils in the different standards clearly shows that it is by no means equally widely held by pupils in each of the different standards in schools in the Cape. The proportion of pupils who share this belief decreases dramatically across the standards from a high of 51% for standard 4 pupils to a low of 12% for standard 9 science pupils. Conversely, the proportion of pupils who believe that the forces are equally large increases steadily from a low of 33% for the standard 4 group to a high of 74% for the standard 9 science group. What is interesting is the small but consistent proportion of pupils in each of the standards who believe that the smaller competitor is exerting the larger force. This believe is shared by about 15% of the pupils in each of the standards. The reason for this belief is unclear, but it is possible that pupils believe that the smaller competitor has to try harder than the larger one if it is not to be pulled away.

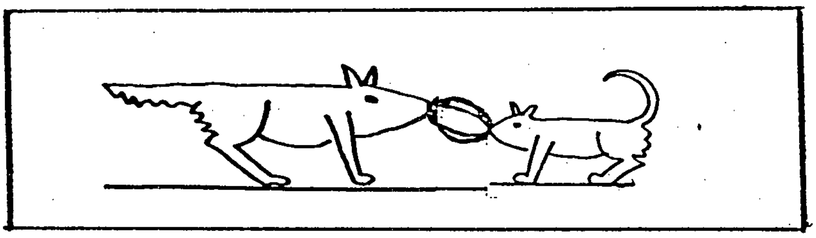
Further analysis of the data indicates that on our sample 40% of the girls and 25% of the boys in Cape schools believe that the larger competitor pulls the harder of the two. This belief seems to be much more widely held by girls. Although interpretation of the data from Transkei on this question is problematical as the pupils may have been guessing, there is some evidence that here too this belief is held more widely by girls than by boys

2. Question A 12 dealt with a tug-of-war situation in which motion is involved. Using this situation we found that 77% of our total sample believe that the force exerted by the

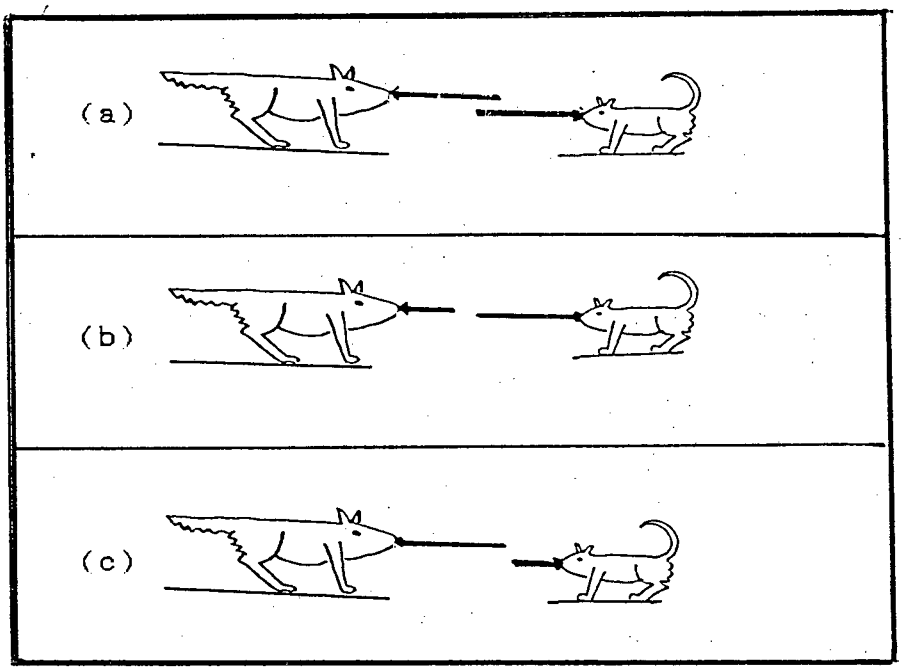
competitor in whose direction the system is moving, is the larger force. This belief is widely held by pupils in all of the standards in schools in the Cape. As a matter of fact, the proportion of pupils who hold this belief actually increases from a low of 83% for standard 4 pupils to a high of 98% for standard 9 science pupils. This belief is so prevalent that further analysis of the data reveals no appreciable differences between any of the groups. On this question as well it is difficult to interpret the data from the Transkei as the pupils appear to be guessing. That this should be so on these two questions is in itself very interesting.

Our finding that about 86% of the standard 6 pupils in schools in the Cape select the option which indicate this belief is in excellent agreement with the findings of Watts and Zylberstajn who found that 82% of their sample of 14 year olds also share this belief.

Question A 6

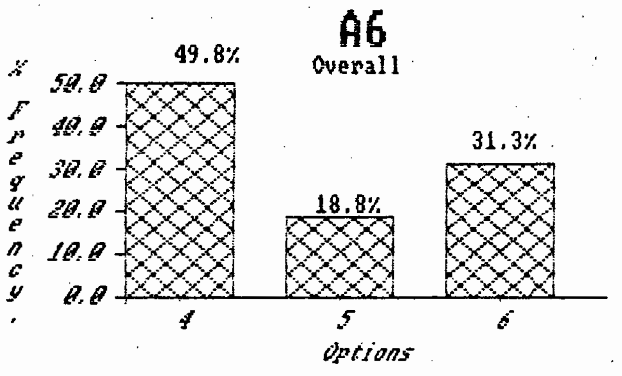


The sketch shows two dogs pulling against each other at opposite ends of a sack. They are not moving. The sketch which best shows how hard each dog is pulling, is:



(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



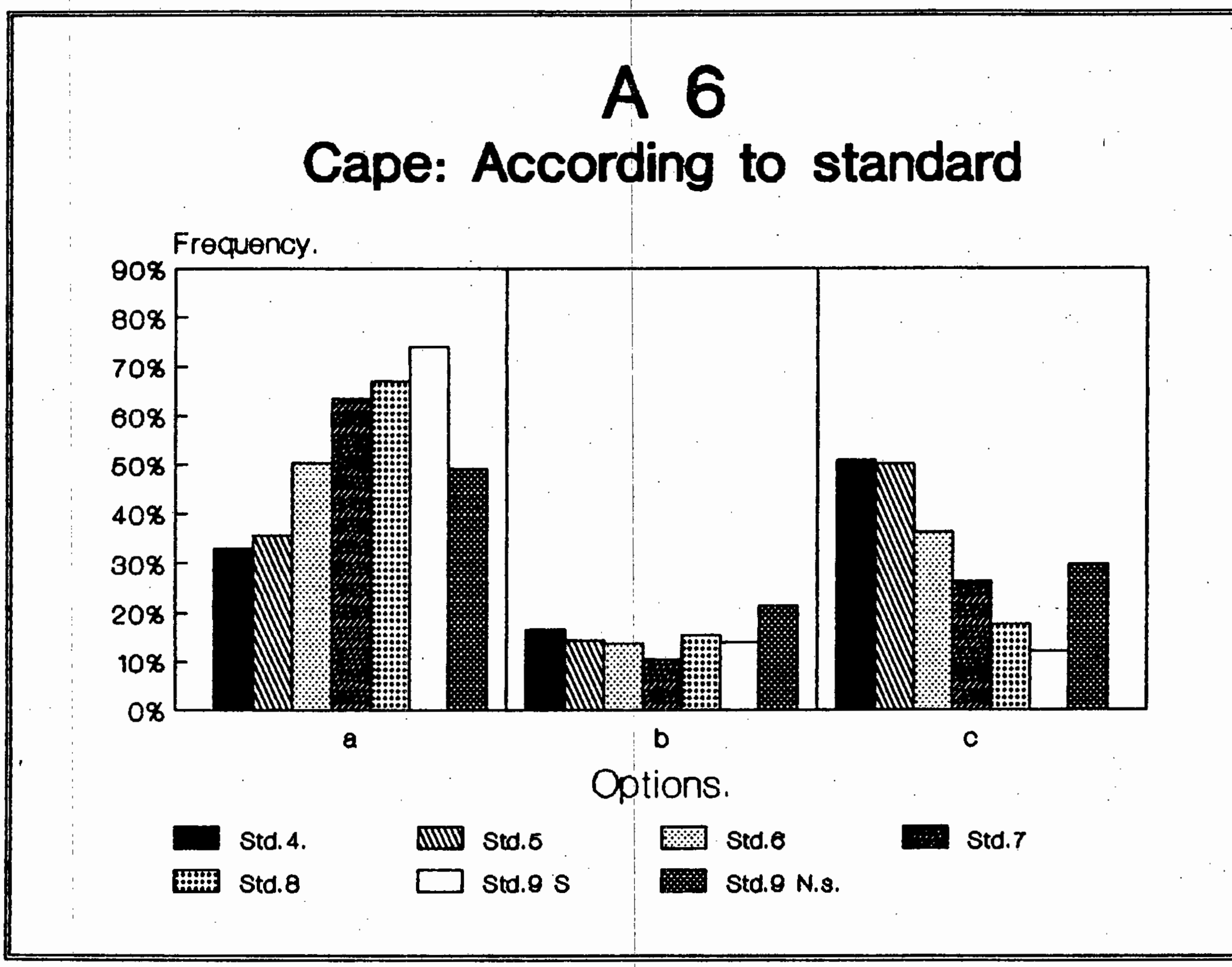
Note:

1. 50% of the sample select option a, the option which suggests that the dogs are pulling equally hard.
2. 19% of the pupils select option b, the option which suggests that the small dog is pulling harder than the large dog.
3. 31% of the pupils select option c, the option which suggests that the large dog is pulling harder than the small dog.

(b) **According to standard:**

1. <u>In the Cape</u>:

The following graph compares the frequencies with which pupils in the different standards in schools in the Cape select the different options.



Note:

1. The increase in the frequencies with which option a, the option which suggests that the dogs are pulling equally hard, is selected from standard 4 through to the standard 9 science pupils. This suggests an increased awareness of the magnitude of the forces involved in the interaction as the pupils progress through school. This may be due to learning or to

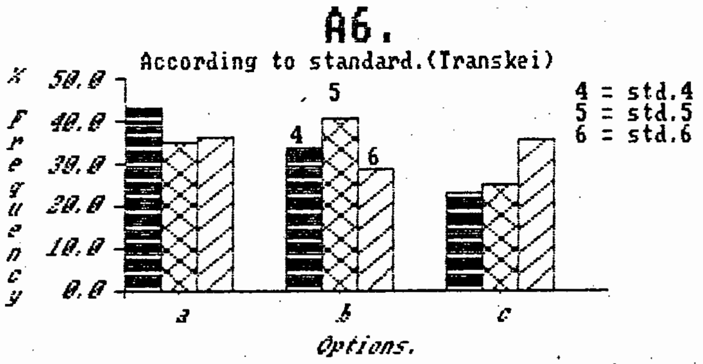
maturation. It is also possible that because there is no motion present that the pupils do not see the necessity for an unbalanced force.

2. The decrease in the frequencies with which option c, the option which suggests that the large dog is pulling harder than the small dog, is selected from standard 4 through to the standard 9 science pupils. The younger pupils appear to be influenced by the relative sizes of the dogs more so than by a belief that motion requires an unbalanced force in the direction of motion.

3. The small variation in the frequencies with which option b, the option which suggests that the small dog is pulling harder than the large one, is selected by pupils in all standards.

2. <u>In Transkei</u> :

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.

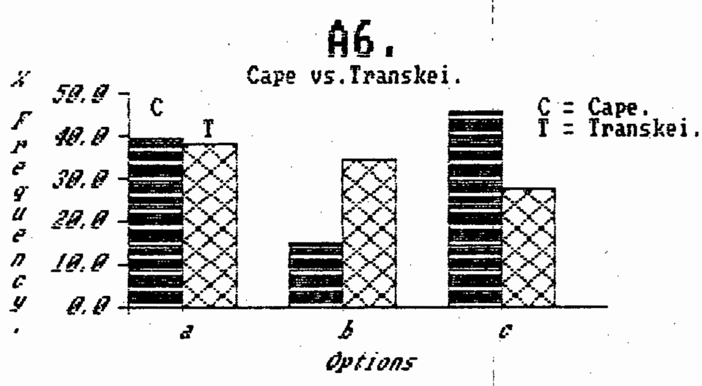


Note:

1. There was comparatively little variation in the frequencies with which the different standards select the different options.
2. Pupils in each of the different standards select a different option as the most popular with them. Thus the standard 4 pupils find option a the most popular, the standard 5 pupils find option b the most popular while the standard 6 pupils find options a and c about equally attractive.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.



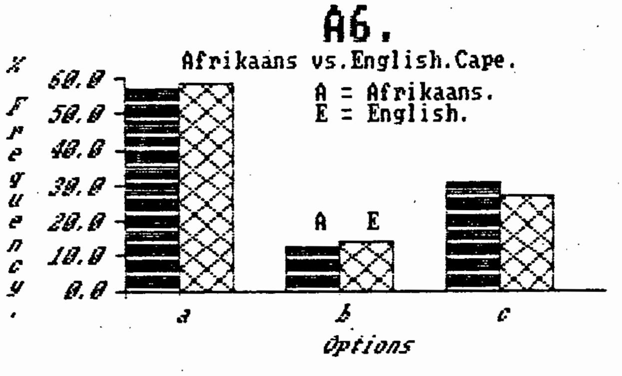
Note :

1. There is virtually no difference in the frequencies with which the two groups select option a, the option which suggests that the two dogs are pulling equally hard. It is selected by about 39% of both groups.

2. There is a substantial difference in the frequencies with which the two groups select option b, the option which suggests that the small dog is pulling harder than the large dog. 15% of pupils in Cape and 34% of pupils in Transkei schools select this option.
3. There is also a substantial difference in the frequencies with which pupils in the two groups select option c, the option which suggests that the large dog pulls harder than the small one. It is selected by 46% of pupils in Cape and 28% of pupils in Transkei schools.

(d) **Comparing Afrikaans-and English-speaking pupils:**

The following graph compares the frequencies with which Afrikaans-and English-speaking pupils in Cape schools select the different options.



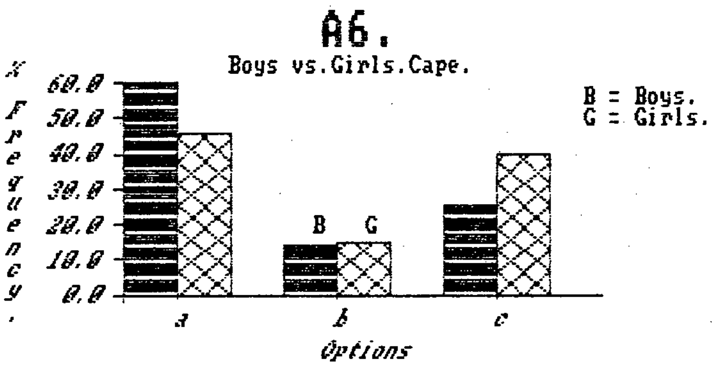
Note :

1. There is no noteworthy differences in the frequencies with which the pupils in the two groups select the different options.
2. Option a is selected by about 58% of both sets of pupils.
3. Option b is selected by about 13% of both sets of pupils.
4. Option c is selected by about 29% of both sets of pupils.

(e) **Comparing the sexes:**

1. <u>In the Cape</u>:

The following graph compares the frequencies with which boys and girls in Cape schools select the different options.

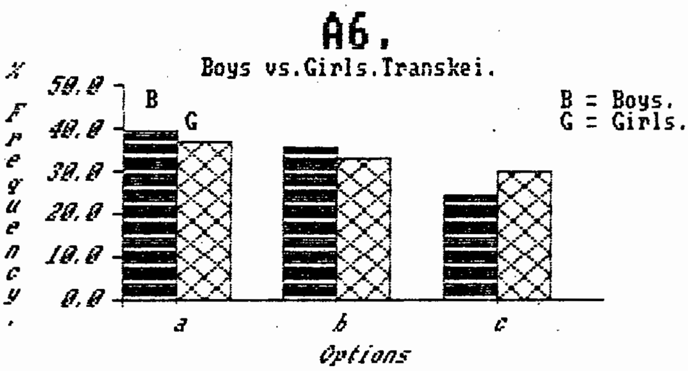


Note :

1. The two groups differ in the frequencies with which they select options a and c.
2. 60% of the boys and 45% of the girls select option a.
3. 25% of the boys and 40% of the girls select option c.
4. Option b is selected by about 15% of both boys and girls.

2. <u>In Transkei</u>:

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

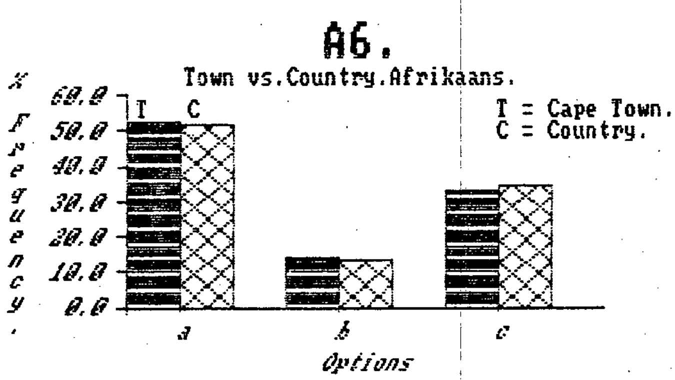


Note:

1. There are only small differences in the frequencies with which the two groups select options a and b.
2. 25% of the boys and 30% of the girls select option c.

(f) Comparing pupils from Town and Country areas:

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and country towns select the different options.



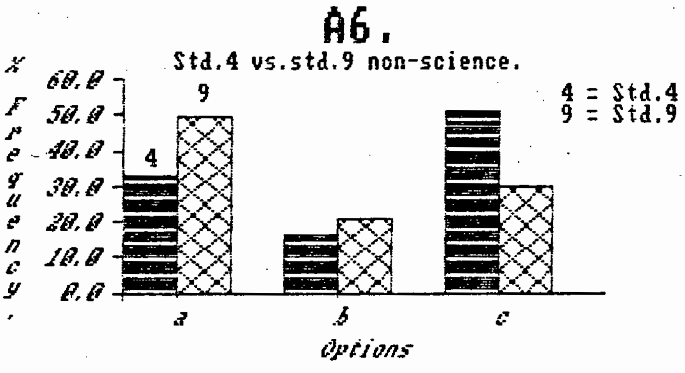
Note:

1. There is very little difference in the frequencies with which the two groups select the different options.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which pupils in standard 4 and pupils in standard 9 who do not do science select the different options.

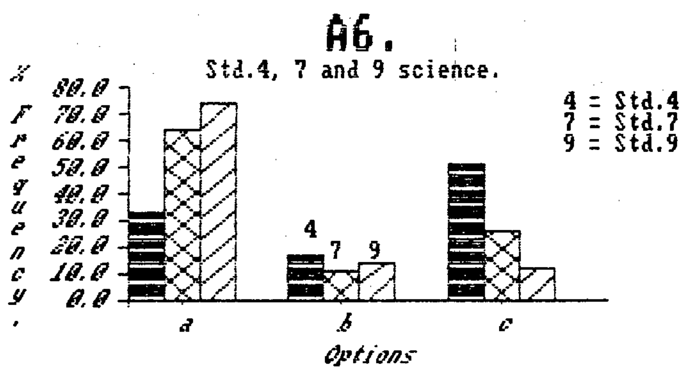


Note:

1. The two groups differ markedly in the frequencies with which they select options a and c.
2. 33% of the standard 4 and 49% of the standard 9 pupils select option a.
3. 51% of the standard 4 and 30% of the standard 9 pupils select option c.
4. 16% of the standard 4 and 21% of the standard 9 pupils select option b.

2. Standards 4, 7 and 9 science group:

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.

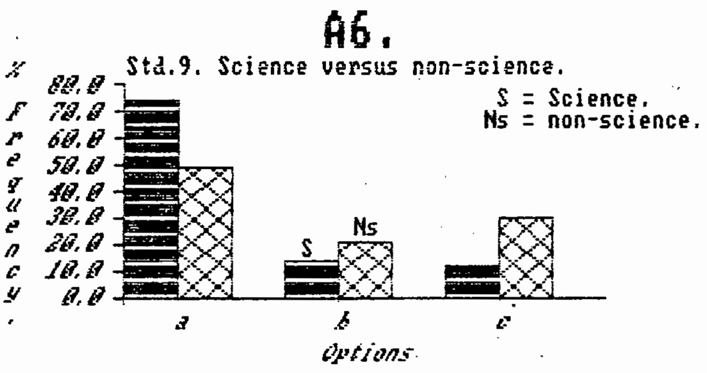


Note:

1. There, is an increase in the frequencies with which the groups select option a.
2. There is a rather small difference in the frequencies with which the groups select option b.
3. There is a decrease in the frequencies with which the groups select option c. This option is selected by 51% of the standard 4, 26% of the standard 7 and 12% of the standard 9 pupils.

3. <u>Standard 9 science and non-science pupils</u>:

The following graph compares the frequencies with which standard 9 pupils who do science and who do not do science at school select the different options.

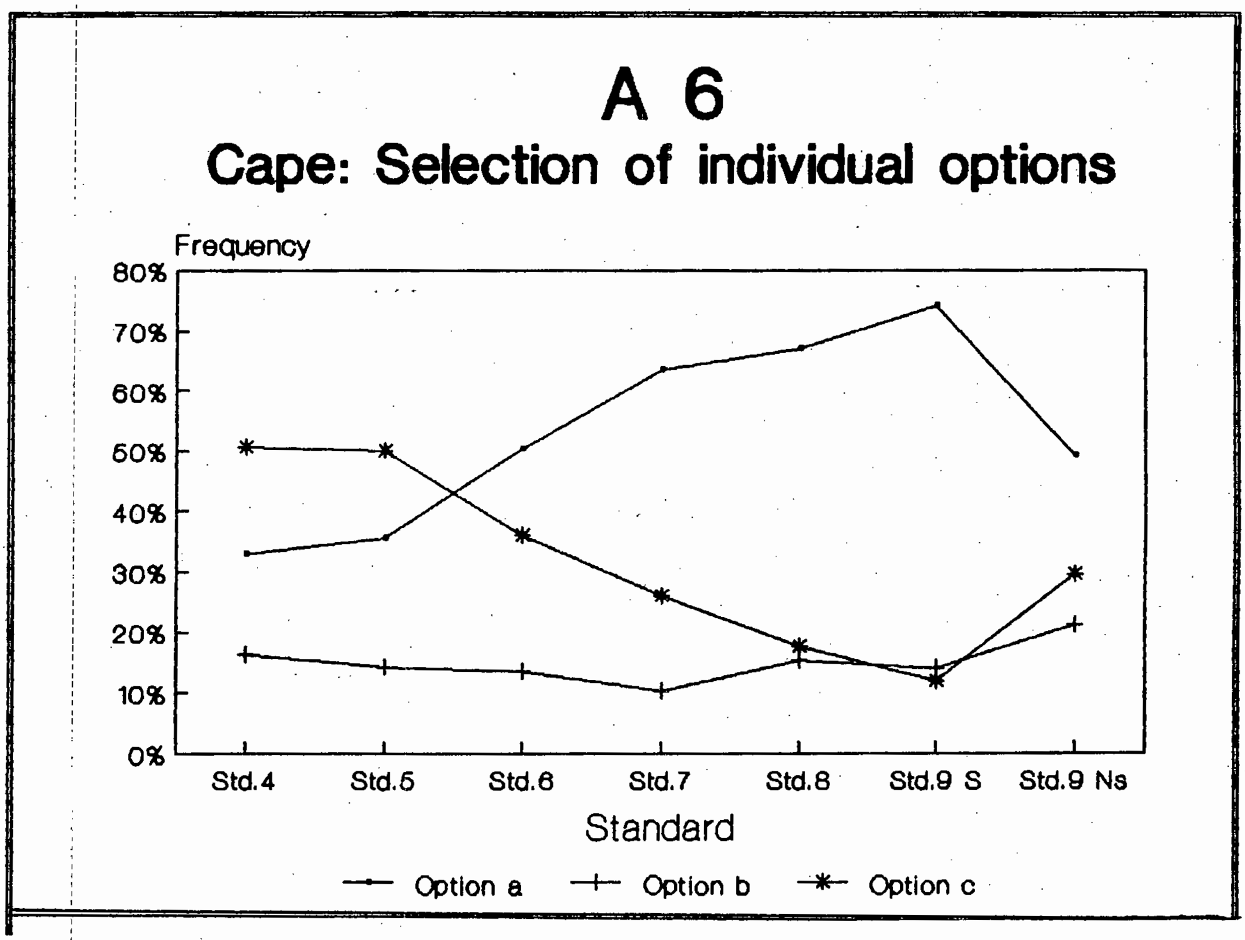


Note:

1. There are marked differences in the frequencies with which the two groups select the different options.
2. 74% of the science and 49% of the non-science pupils select option a.
3. 14% of the science and 21% of the non-science pupils select option b.
4. 12% of the science and 30% of the non-science pupils select option c.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by the different standards in schools in the Cape.



Note:

1. There is an increase in popularity of option a to a maximum with the standard 9 science pupils.
2. There is a decrease in the popularity of option c to a minimum with the standard 9 science pupils.
3. Option b is selected with fairly consistent frequencies by all of the standards.

Summary:

1. When we examine the overall picture we find that:

   50% of the sample select option a, indicating a belief that the two dogs pull equally hard.
   19% of the sample select option b, indicating a belief that the small dog is pulling harder than the large one.
   31% of the sample select option c, indicating a belief that the large dog is pulling harder than the small one.

2. When we compare the frequencies with which pupils in the different standards in schools in the Cape select the different options we find that:

   There is an increase in the frequencies with which option a is selected, reaching a maximum with the standard 9 science pupils. This indicates that the belief that the dogs have to pull equally hard becomes more common as the pupils grow older.
   Option b, the option which suggests that the small dog has to pull harder, is selected with more or less the same frequency by all of the classes, the frequency being about 15%.
   The frequencies with which option c is selected decreases from standard 4 to a minimum with the standard 9 science group. This indicates that the belief that the large dog pulls harder is much more popular with younger pupils.

   In the Transkei we find that there is small variation in the frequencies with which the different classes select the different options.

3. When we compare the frequencies with which standards 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options we find that:

39% of the pupils of both groups believe that the dogs are pulling equally hard;
15% of the pupils from the Cape and 34% of the pupils from Transkei believe that the small dog is pulling harder than the large one;
46% of the pupils from the Cape and 28% of the pupils from Transkei believe that the large dog is pulling harder than the small dog.

4. When we compare Afrikaans-and English-speaking pupils in Cape schools we find that there is no noteworthy difference in the frequencies with which the two groups select the different options, option a being selected by 58% of the pupils, option b by 13% and option c by 29% of the pupils.

5. When we compare boys and girls in the Cape we find that:

60% of the boys and 45% of the girls believe that the dogs are pulling equally hard;
25% of the boys and 40% of the girls believe that the large dog is pulling harder than the small one.

In Transkei we find that boys and girls do not differ greatly in the frequencies with which they select the different options, although there is some evidence that the girls find option c more attractive than the boys. This means that, as in the Cape, more girls than boys believe that the larger dog is pulling harder than the small one.

6. When we compare Afrikaans-speaking pupils who attend schools in Cape Town and country towns we find that there is no difference in the frequencies with which the two groups select the different options.

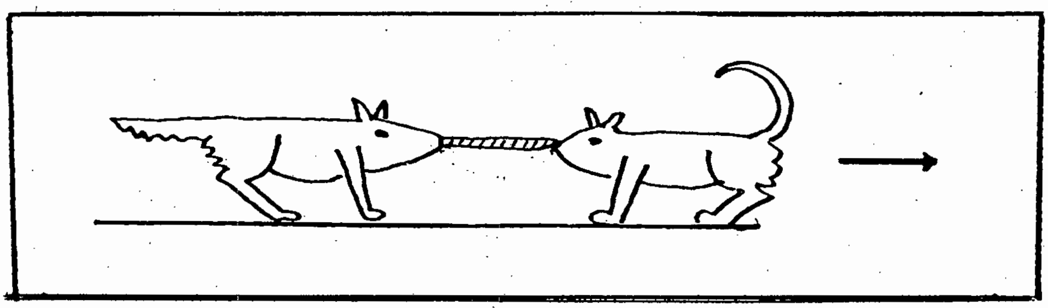
7. When we compare the frequencies with which pupils in some of the standards select the different options, we find that:

   the standard 4 pupils prefer option c which indicate a belief that the larger dog pulls harder than the small one;
   this belief becomes less popular with pupils in higher classes, with pupils in higher classes preferring option a which indicates a belief that the dogs are pulling equally hard. This belief is most popular with the standard 9 science pupils.
   If we consider the standard 9 non-science group to be reasonably representative of the "man in the street" then it means that the belief that the large dog pulls harder is held by about 30% of them.

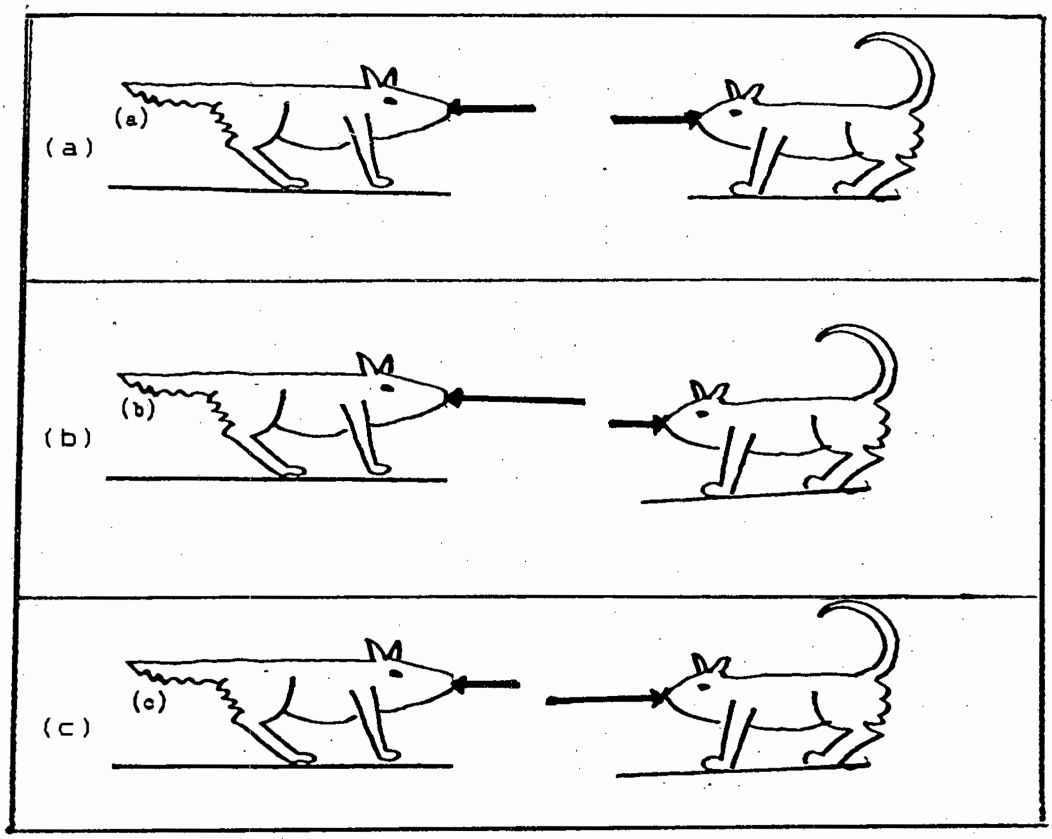
8. A comparison of the frequencies with which the individual options are selected by the different standards in Cape schools clearly reflects the increased popularity of option a and the decrease in popularity of option c with the higher standards.

   What is of interest is the small but consistent frequencies with which all of the groups select option b, the option which suggests that the small dog is pulling harder than the large one.

Question A 12

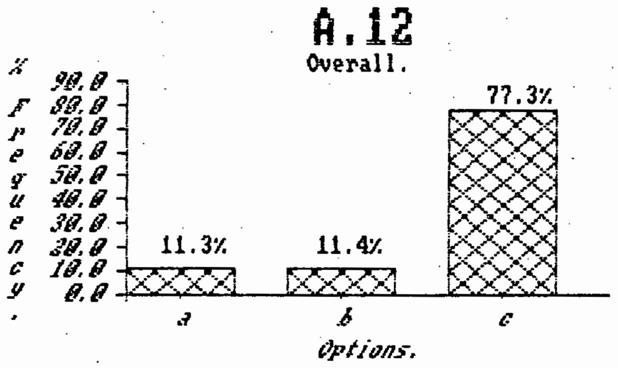


The sketch shows two dogs pulling against each other at opposite ends of a rope. They are moving slowly towards the right. The sketch which best shows how hard each dog is pulling, is:



(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



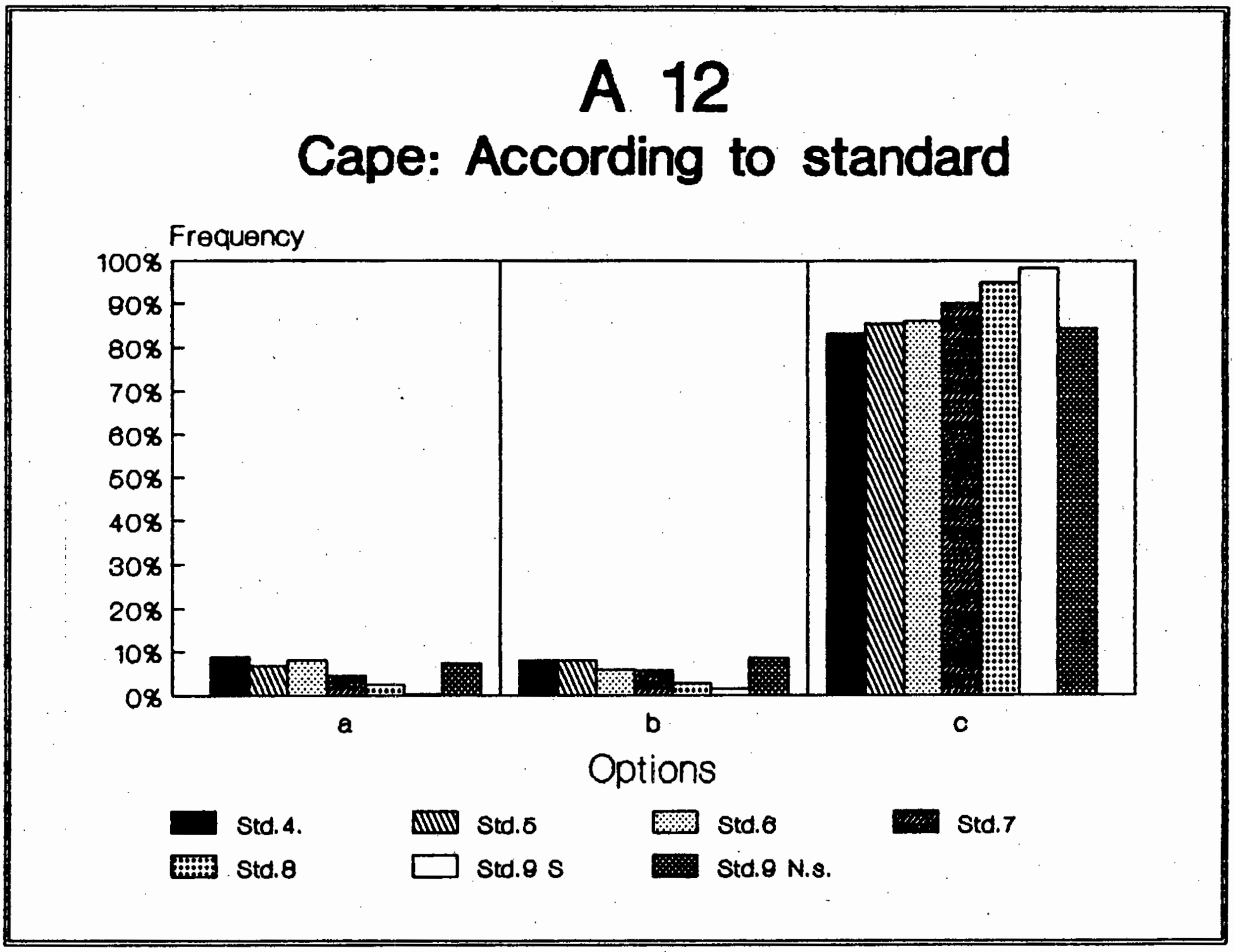
Note :

1. Option a, the option which suggests the the dogs are pulling equally hard, is selected by 11% of the sample.
2. Option b, the option which suggests that the dog who is being pulled along, is pulling the harder of the two, is selected by 11% of the sample.
3. Option c, the option which suggests that the dog who is pulling the other one away is pulling the harder of the two, is selected by 77% of the sample.

(b) **According to standard:**

1. <u>In the Cape.</u> :

The following graph compares the frequencies with which Cape pupils in the different standards selected the different options.



Note:

1. There is overwhelming support for option c, the option which suggests that the dog who is winning the tug-of-war is the one who is pulling the harder of the two, by pupils in all of the classes

2. The support for option c increases steadily to a maximum with the standard 9 science pupils. This may be as a result of a

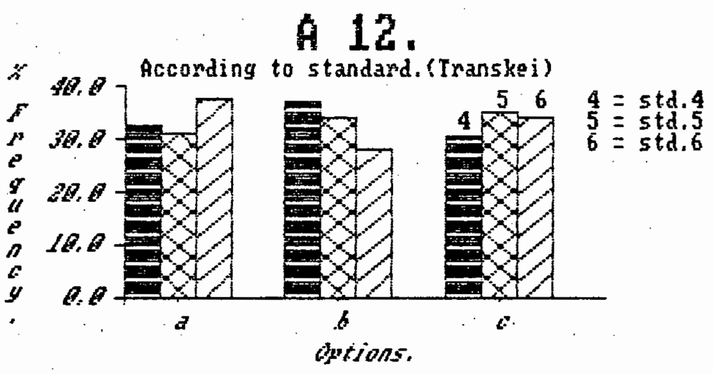
firmer commitment to the belief that movement implies a force in the direction of motion with increasing age, or as a result of a firmer belief in folk-wisdom which asserts that the dog which is winning, must be pulling the harder of the two, with increasing age.

3. Options a and b receive little support from all of the classes, with the support for option a decreasing to a minimum with the standard 9 science pupils. This option suggests that the dogs are pulling equally hard.

4. The already small frequencies with which pupils select option b, the option which suggests that the dog who is being pulled along has to pull the harder of the two, decreases to reach a minimum with the standard 9 science pupils.

2. In Transkei:

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in Transkei select the different options.

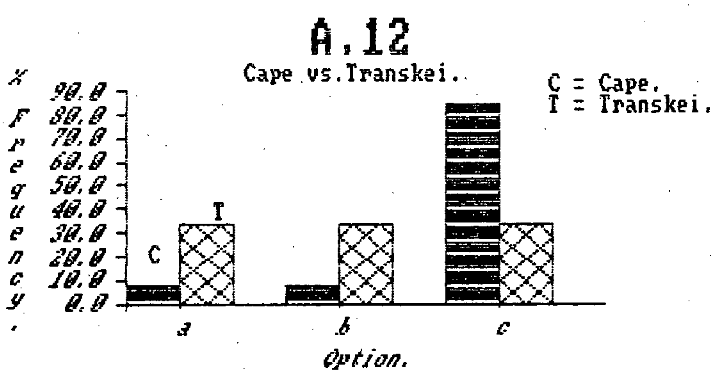


Note:

1. The frequencies with which pupils in the different standards select the different options show remarkably little variation. One has to consider that guessing played an important part here. There is a possibility that the language of the question was misunderstood.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.

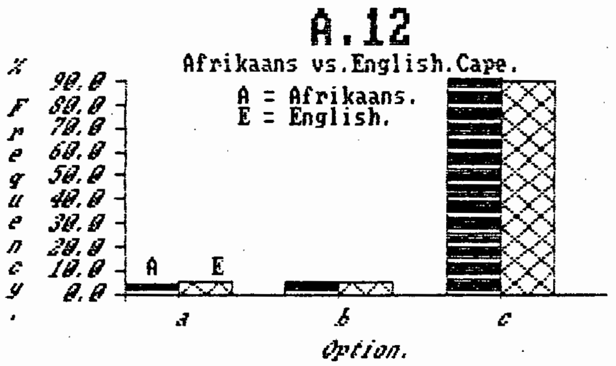


Note:

1. The two groups differ from each other in the frequencies with which all three of the options are selected.
2. Pupils from Cape schools overwhelmingly select option c. This option is selected by 85% of pupils in Cape schools but only by 33% of pupils in Transkei schools.
3. 8% of Cape pupils select option a.
4. 7% of Cape pupils select option b.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and English-speaking pupils in schools in the Cape select the different options.



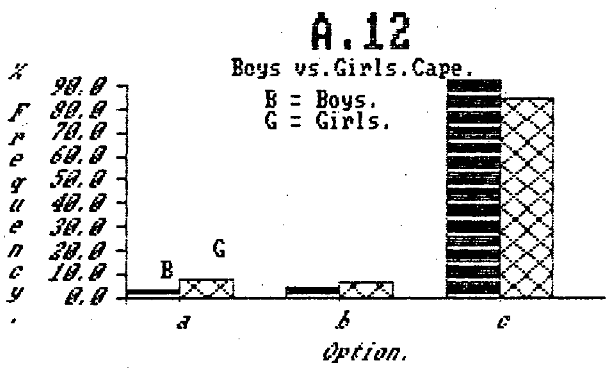
Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.
2. Option b is selected by about 90% of each of the groups.

(e) **Comparing the sexes:**

1. In the Cape:

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.



Note:

1. There are only small differences in the frequencies with which boys and girls select the different options.
2. 93% of the boys and 85% of the girls select option c.
3. 3% of the boys and 8% of the girls select option a.
4. 4% of the boys and 7% of the girls select option b.

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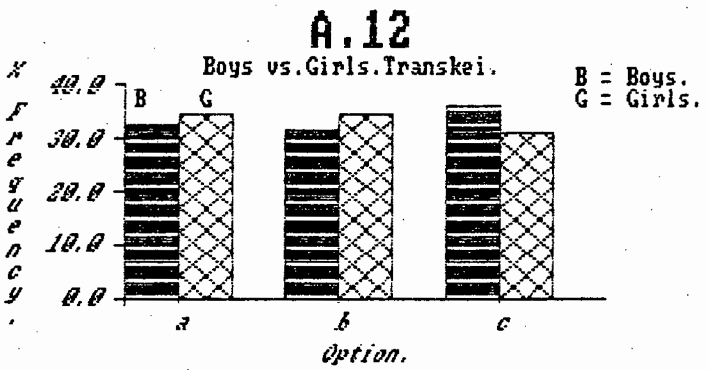
2. <u>In Transkei</u>:

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

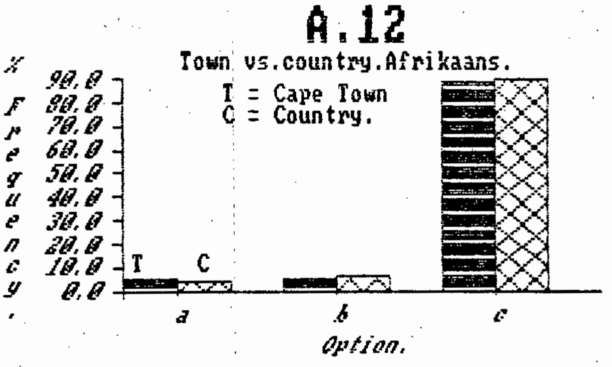


Note:

1. The two groups respond very similarly to the different options.

(f) **Comparing pupils from Town and Country areas**:

The following graph compares the frequencies with which Afrikaans-speaking pupils who attend school in Cape Town and in country towns select the different options.



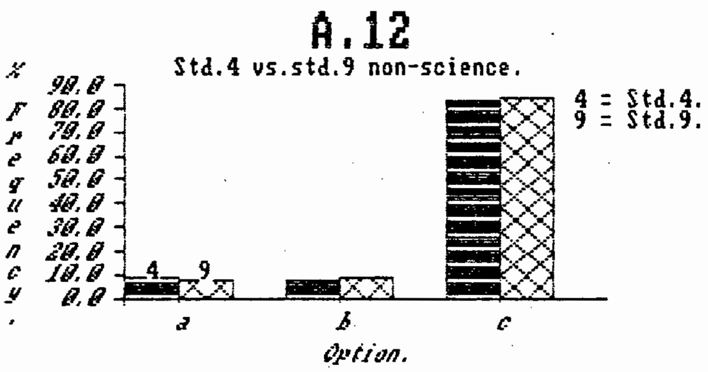
Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.

(g) Comparing some standards:

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 3 and standard 9 pupils who do not do science in school select the different options.

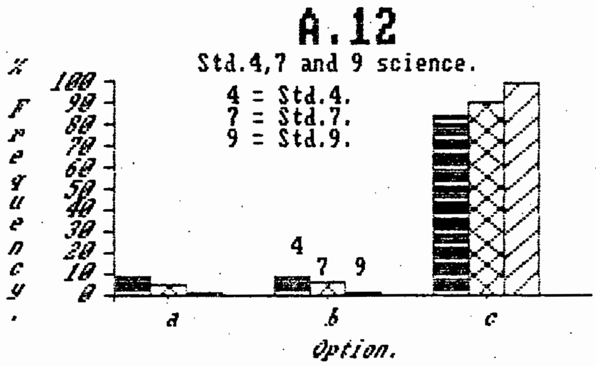


Note :

1. There is no appreciable difference in the way that these two groups respond to the different options.

2. <u>Standards 4, 7 and 9 science pupils</u>:

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.

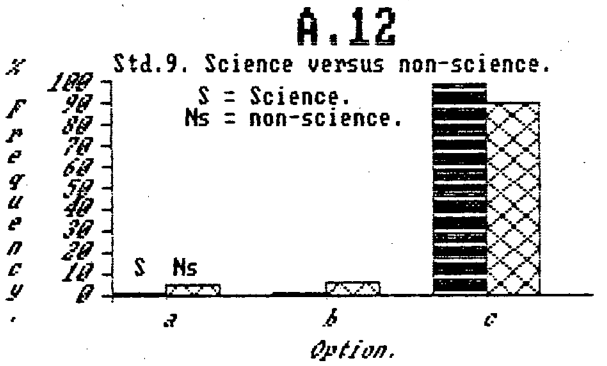


Note:

1. There is overwhelming support for option c by all three the groups.
2. There is a gradual increase in this support to a maximum with the standard 9 science pupils who select it 98% of the time.
3. There is minimal support for options a and b by all three of the groups and especially the standard 9 science group.

3. <u>Standard 9 science and non-science pupils</u>:

The following graph compares the frequencies with which standard 9 pupils who do science and who do not do science select the different options.

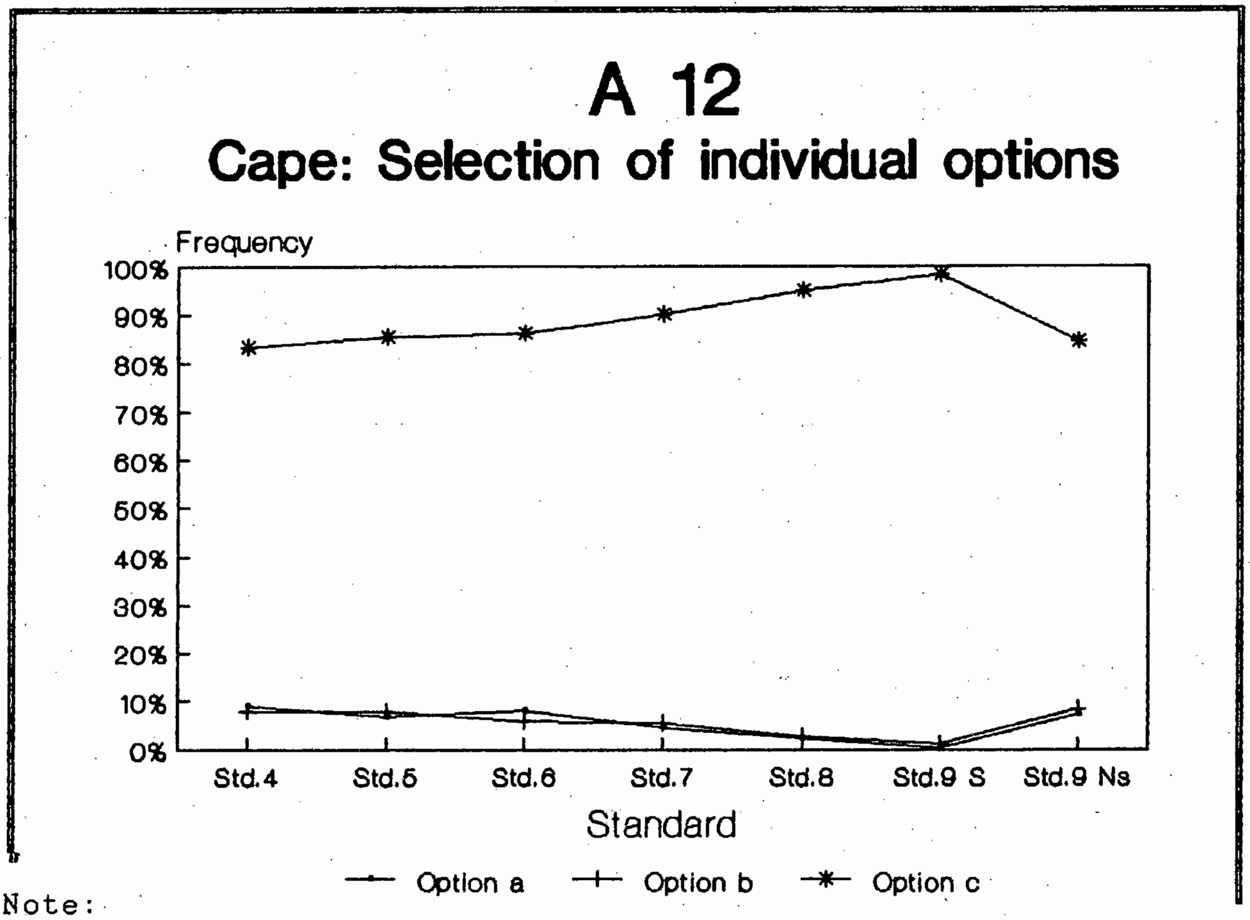


Note:

1. There is overwhelming support by both groups for option c. Quite clearly the belief that the dog who is winning the tug-of-war is pulling the harder of the two, is very firmly entrenched amongst pupils in all of the standards.

(h) Selection of individual options:

The following graph compares the frequencies with which the individual options are selected by the pupils in the different standards.



Note:

1. The graph clearly shows the overwhelming popularity of option c, as well as the fact that the frequencies with which it is selected increases steadily up to a maximum with the standard 9 science pupils.

Summary:

The important findings arising from this question are that:

option c, the option which suggests that the dog which is pulling the other one away, is pulling the harder of the two, is overwhelmingly selected by pupils in schools in the Cape. The frequencies with which it is selected increases up to maximum with the standard 9 science pupils, who select it with a frequency of 98%. This one option so overwhelms the others that no other comparisons show any appreciable differences in the frequencies of selection other than that of the Cape and Transkei. However, it is very possible that on this question pupils from Transkei may have been guessing.

Chapter 8

Gravity

Overview

1. *Gravity and height:*

Introduction:

In a review of investigations into ideas about the relationship between the force of gravity and height above the ground, (see p. 82) we find that:

* children think that gravity increases with height. (Watts and Zylberstajn ,1981.)
* students at university think that gravity decreases with height.(Gunstone and White, 1981, McDermott, 1984, Champagne and Klopfer, 1980)

It appears that both the type of question used and the age of the sample influences the response obtained. Watts and Zylberstajn asked children which one of two cars held at different heights on a hill will be attracted more strongly by the earth - a question similar to our own. Gunstone and White asked university students to predict what would happen to a system consisting of two objects of equal mass suspended by a string over a pulley and initially held at different heights if the system is released and free to move. Watts and Zylberstajn did the same but they used children who were about 14 years old. While Gunstone and White report that over 30%, of their sample of students could not correctly predict what would happen because many of them thought that the block nearer the ground would be heavier, in the case of

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Watts and Zylberstajn 78% of their sample thought that the system would move until the blocks were level with each other because the force on the block in mid-air is stronger than the force on the one on the ground. However, only 48% of the same children thought that the car higher up the hill is attracted by a stronger force than the one lower down.

Results:

Two questions, A5 and B5, in the questionnaire deals with the beliefs which pupils have about gravity and in particular the belief that the force of gravity increases with height.

The results of our own work indicate that the idea that gravity increases with height is firmly held by the pupils in our schools. On question A5 40% of the pupils think that the bird will be attracted by a larger force while it is gliding than when it is on the ground while on question B5 47% of the pupils think that the man at the top of the hill has to push harder than the man at the bottom. This is in excellent agreement with the findings of Watts and Zylberstajn who report that 48% of their sample also think in this way. Furthermore, the results on question A5 indicate that the idea that the force acting on the bird decreases with height becomes more popular with the standard 8 and 9 science pupils. That this should happen is also implied by the work of Gunstone and White and other researchers who have worked with older students.

What was of particular interest in question A5 is that about 15% of the sample actually think that no force acts on the bird while it is gliding. This idea decreases in popularity with pupils in the higher standards.

We find that pupils in standards 4, 5 and 6 in schools in the Cape and Transkei share the belief that the force of gravity increases with height. On A5 this belief is more widely held by pupils in Transkei schools while on B5 the option which indicates this belief is selected with much the same frequency by the two groups.

We find that Afrikaans-and English-speaking pupils do not really differ to any appreciable extent in the frequencies with which they select the different options presented to them.

We find on both questions that the frequency with which girls in Cape schools select the option which suggests that the force of gravity is greater at a greater height, to be consistently higher than that with which boys select the same option. It is also clear from the results that more boys are of the opinion that gravity does not change with an increase in height. In Transkei schools we find no appreciable difference in the frequencies of responses of girls and boys to the different options.

We find no noteworthy differences in the frequencies with which Afrikaans-speaking pupils who live in Cape Town and in country towns select the different options on these two questions.

We find that the frequency with which the standard 9 non-science group select the options which indicate that the force of gravity increases with height to be consistently larger than that of the standard 4 pupils.

•

We find that the frequency with which the standard 9 science group select the option which indicates that the force of gravity does not change with increase in height to be consistently larger than that of the non-science group. The non-science group consistently select the options which indicate a belief in gravity increasing with height with a frequency higher than the science group. However, the difference depends on the situation presented.

2. *Rising and falling objects:*

Introduction:

In a review of the investigations into beliefs about falling objects, (see p.88) we find that pupils at schools and students at universities believe that:

* heavier objects fall faster than lighter ones. (Za'Rour,1975, Whitaker,1982, Maloney,1985, Champagne and Klopfer,1984) The proportion of the sample holding this belief differs from 10% (Whitaker) to 80% (Champagne and Klopfer, Maloney).

Questions B1 and B3 present situations in which objects of unequal weight are allowed to fall. More particularly, the one object is twice as heavy as the other. Pupils are required to compare the speeds with which the objects reach the bottom of their fall. We assumed that a fair proportion of the pupils will have been told that all objects fall with equally fast and expect to find that a substantial proportion of the pupils will indicate that the two objects have the same speed at the end of their fall. We decided to change the situation slightly in B2 by having objects rising, as this is a more unusual situation as far as discussion in school is concerned. We therefore asked pupils to indicate the heights reached by objects of different mass. To see whether the responses are context-dependent we included B3 in which pupils had to decide on the speeds of two toy cars of unequal mass running down an incline. We believe that all of the situations depicted are quite common to the experience of most children.

Question B2 requires them to compare the heights reached by two objects, the one being twice as heavy as the other. We believe that a belief that "heavier falls faster" strongly implies that "heavier is attracted more strongly" and this in turn implies that "lighter should go higher".

Results:

We find that on questions B1 and B2 which both involve free fall situations, 63% of the sample believe that the heavier ball has the greater speed of the two, while 68% of the sample believe that the lighter ball reaches the greater height. Furthermore, 51% of the sample believe that the heavier ball travells twice as fast as the lighter ball and 47% of the sample believe that the lighter ball reaches twice as high as the heavier one.

Question B3 involves cars racing down an incline and here we find that 55% of the sample believe that the heavier car has the greater speed, with 39% believing that it actually travells twice as fast as the lighter one. It is clear that the belief that "heavier means faster" is very widely held but, it is also clear from our work that the belief is context-dependent. That the context determines the response selected is further supported by the fact that while on B1 5% of the pupils believe that the lighter ball is the faster of the two, 20% of the pupils on B2 believe that the heavier ball reaches the greater height and 31% on B3 believe that the lighter car moves the faster of the two. It is also interesting to note that while 29% of the sample believe that the two balls in B1 reach the ground with the same speed, 14% believe this about the cars on B3, and 13% believe that the balls in B2 will reach the same height. One can only speculate about the reasons for this, but in terms of Claxton's views different mini-theories are being used. At an in-service training course for teachers in physical science teachers were asked to indicate the position of a free-falling ball which is twice as massive as another one and whose position is indicated at two positions along its path. Only one person did not indicate the positions correctly. In another question the teachers were asked to indicate the position of a ball which is twice as massive as another one and whose position is indicated at two positions along its path when the balls are thrown upwards. Only one person now indicated the position correctly. When one of the teachers, who is a first class cricketer, was asked to explain his selection, he said "everyone knows that you can throw a cricket ball higher than a tennis ball ". It will seem to us that this kind of "life knowledge" is being used here, especially in the "cars down the incline" problem and to a lesser extent in the "rising balls" problem.

The following graphs clearly indicate the context-dependency of the responses to the questions involving falling objects. We compare the frequency with which similar options are selected by pupils and groups of pupils in schools in the Cape. The options are indicated as follows:

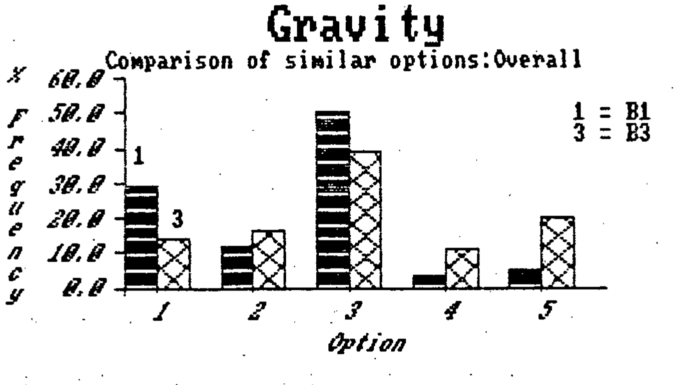
Option 1: The objects have the same speed

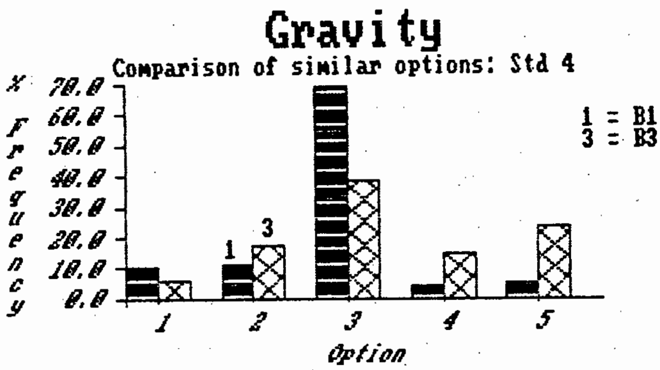
Option 2: The heavier object has the greater speed

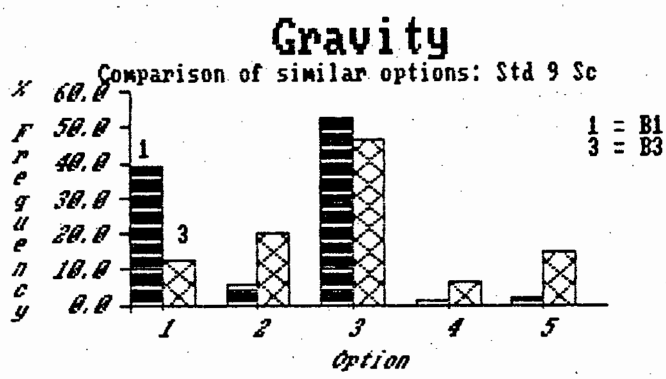
Option 3: The heavier object's speed is double that of the lighter one

Option 4: The lighter object has the greater speed

Option 5: The lighter object's speed is double that of the heavier one.







The overall result reported above include pupils from Transkei. As we report below, these pupils do not share the belief that heavier means faster or lower, to quite the same extent as pupils in the Cape, so that for the Cape the proportion of pupils sharing this belief is actually higher than that reported overall. The graphs on pp.401 and 420 show the situation in schools in the Cape. It is clear from these that the beliefs illustrated are widely held and with frequencies which are in good agreement with those reported by Maloney and Champagne and Klopfer.

We find that on all three of the questions the majority of pupils in most of the classes in the Cape select the option which suggest a belief that the heavier object will fall twice as fast as the lighter one, or reach half the height of the lighter one when thrown upwards. The standard 6 pupils do not share this belief quite as widely as pupils in the other standards do. We can think of no reason why this is so but on all three of the questions this is quite clear.

We find that in Transkei the responses of the pupils to the different questions to be very context dependent. While the majority of pupils show a belief that the heavier ball will fall faster than the lighter one on B1, the majority of them believe that the lighter car will be moving the faster of the two in B3.

We find that standard 4, 5 and 6 pupils in the Cape and Transkei differ quite widely from each other in the belief that heavier objects fall faster. On B1 and B2 66% and 72% respectively of the pupils in the Cape select options which indicate a belief that heavier objects fall faster and lighter objects reach a greater height while only 54% and 51% of the pupils in Transkei select similar options. On B3 this changes to 57% for pupils in the Cape and 39% of pupils in Transkei. The majority of pupils in Transkei believe that the lighter car has the greater speed at the foot of the incline.

We find that a slightly higher proportion of Afrikaans-speaking than English-speaking pupils consistently select options which indicate a belief that heavier means faster or that lighter means higher.

We find on B1 and B2, that a substantially larger proportion of girls than boys in schools in the Cape believe that the heavier object falls faster and the lighter one reaches a greater height. The majority of the girls in both cases actually believe that the heavier ball falls twice as fast as the lighter one and that the lighter ball reaches twice the height of the heavier one. However, on B3 the reverse is true. A greater proportion of the boys than girls believe that the heavier car has the greater speed. A substantial proportion of the girls now believe that the lighter car will be moving the faster than the heavier.

In Transkei we find that it is only on B1 that the proportion of boys and girls who believe that the heavier ball falls faster, is different. On both the other questions there is really no appreciable difference between these two groups.

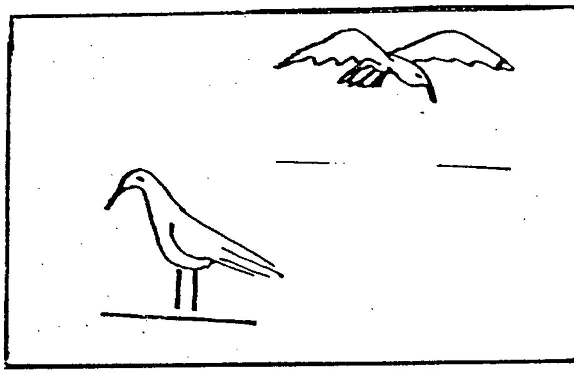
We find that a small, but consistently larger proportion of Afrikaans-speaking pupils in schools in country towns believe that the heavier object will fall faster or that the lighter object will reach higher, than their counterparts in schools in Cape Town. That this belief is held more strongly by pupils in country schools is further supported by the fact that a larger proportion of these pupils believe that the heavier object moves twice as fast as the lighter one and that the lighter one will reach twice the height of the heavier one.

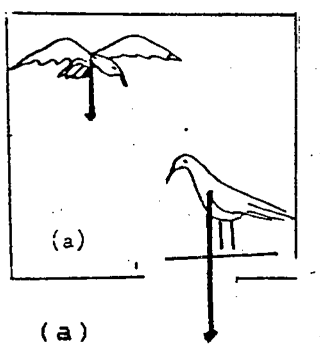
We find that the belief that the heavier ball will fall faster and that the lighter ball will reach a greater height, to be more widely held by standard 4 pupils than by standard 9 non-science pupils. When dealing with the cars down the incline these two groups do not appreciably differ from each other.

Finally, we find that the fact that pupils have been exposed to more science teaching in school does not greatly influence their beliefs about rising and falling objects.

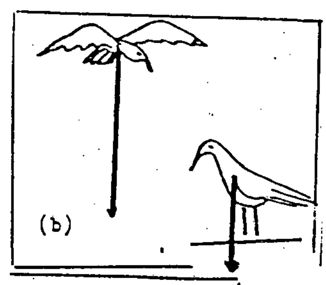
Question A 5

The sketches show the same bird sitting on the ground and gliding along 100 metres high in the air. The pair of sketches which best compares the sizes of the force with which the earth attracts the bird when it is sitting on the ground and again while it is gliding, is:

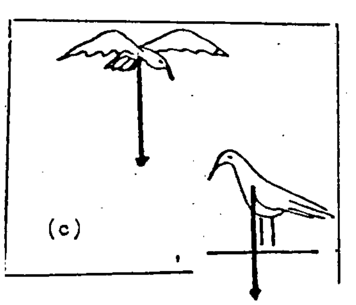




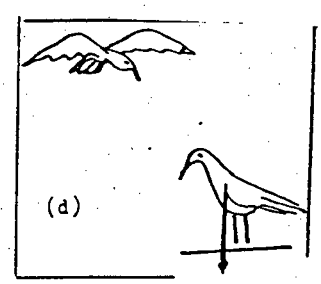
(a)



(b)



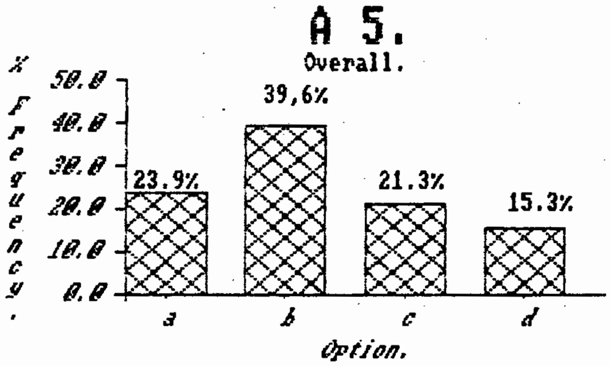
(c)



(d)

(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



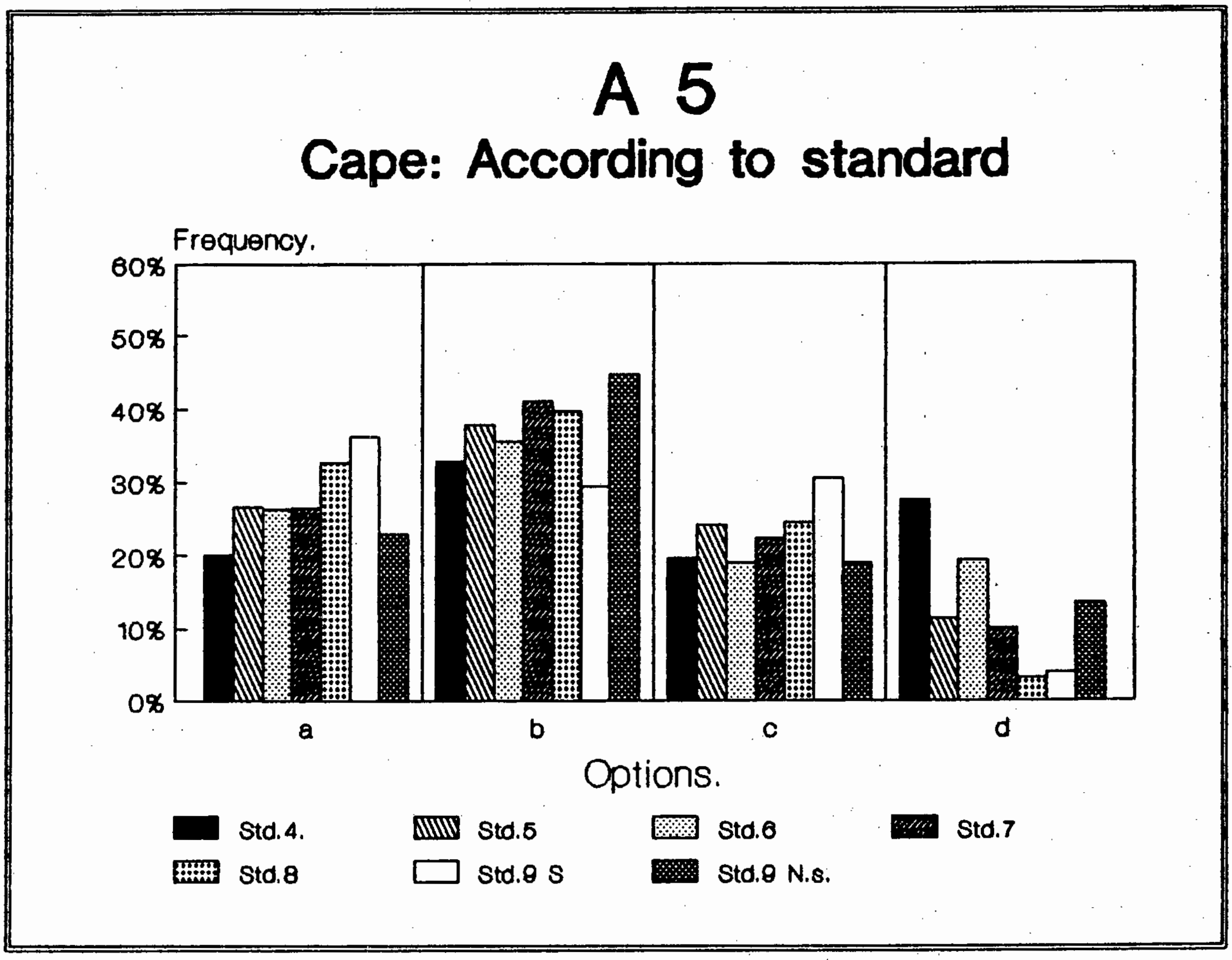
Note:

1. 24% of the sample think that the force of attraction on the bird decreases with height while a further 15% think that no force acts on the bird while it is gliding. This means that 39% of the sample think that the force with which the earth attracts the bird decreases with height.
2. 40% of the sample think that the force of attraction on the bird increases with height.
3. 21% of the sample think that height has no effect on the force of attraction.

(b) **According to standard:**

1. In the Cape:

The following graph compares the frequencies with which Cape pupils in the different standards selected the different options.



Note:

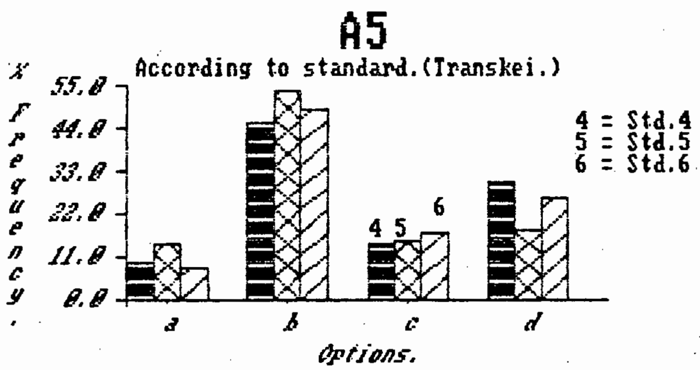
1. There are no dramatic differences in the frequencies with which the different standards select the different options.
2. The belief that the force of attraction on the bird will be less above the ground is the most strongly held by standards 8 and 9 science pupils.
3. With the exception of the standard 9 science pupils, the most popular option with all of the other standards is option b,

the option which suggests that the force of attraction on the bird increases with height.

4. The standard 4 group find option d, the option which suggests that no force acts on the bird while it is gliding, the second most attractive.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which Transkei pupils selected the different options.

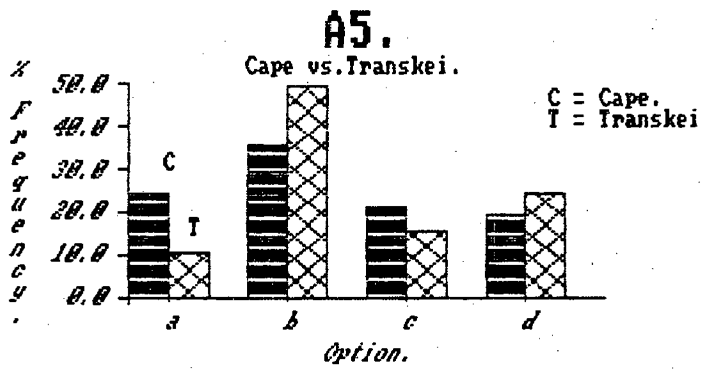


Note:

1. There is overwhelming support by all of the classes for option b, the option which suggests that the force of attraction on the bird increases with height.
2. The next most popular option with all the different standards is option d, the option which suggests that no force of attraction acts on the bird while it is gliding.
3. Option a, the option which suggests that the force of attraction on the bird is less the higher up it is, is the least popular with all the different standards.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.



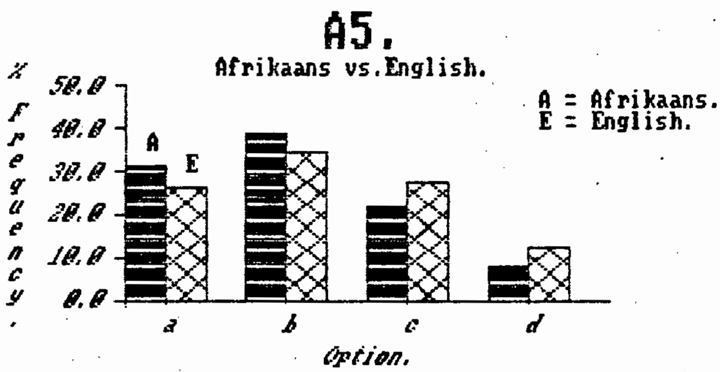
Note:

1. Pupils in both the Cape and Transkei find option b, the option which suggests that the force of attraction on the bird increases with height, the most popular, but there is a large difference in the frequencies with which the two groups select the option. It is selected by 50% of the pupils from Transkei and 36% of pupils from the Cape.
2. Option a, which suggests that the force of attraction acting on the bird decreases with height, is selected by 24% of pupils from the Cape and only 11% of pupils from Transkei.
4. 19% of the pupils from the Cape and 25% of the pupils from Transkei select option d, the option which suggests that no force of attraction acts on the bird while it is gliding. This means that 43% of the pupils from the Cape and 36% of the pupils from Transkei select options which suggests that

the force of attraction acting on the bird decreases with height.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape selected the different options.



Note:

1. There are small differences in the frequencies with which the two groups select the different options. Option a, which suggests that the force of attraction is less above the ground, is selected by 31% of the Afrikaans-speaking pupils and 26% of the English-speaking pupils. However, if we include with this option the frequencies with which option d, the option which suggests that no force of attraction acts on the bird while it is gliding, then 39% of Afrikaans-speaking pupils and 39% of English-speaking pupils select options which indicate a belief in the fact that the force of attraction decreases with increase in height.

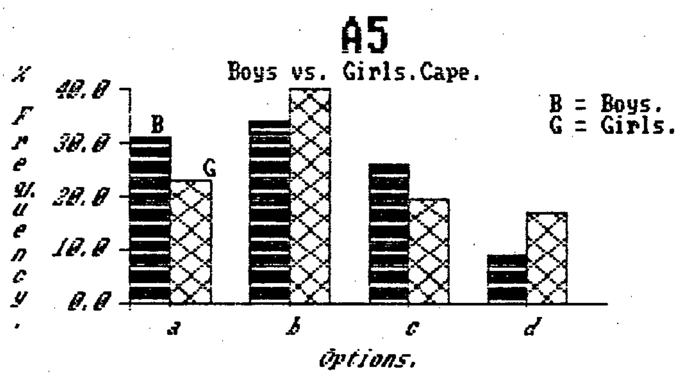
2. 39% of the Afrikaans-and 34% of the English-speaking pupils select option b, the option which suggests that the force of attraction acting on the bird increases with height.

3. The correct option, option c, is selected by 22% of Afrikaans-and 27% of English-speaking pupils.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.



Note:

1. There are small differences in the frequencies with which the two groups select the different options.

2. 31% of the boys and 23% of the girls select option a, the option which suggests that the force of attraction on the bird is less above the ground.

3. 9% of the boys and 17% of the girls select option d, the option which suggests that no force acts on the bird while it

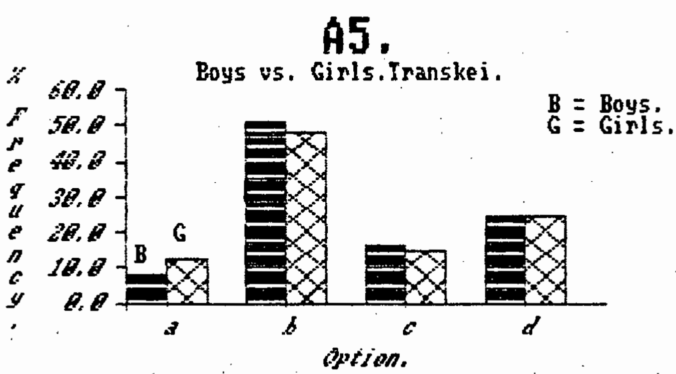
is gliding. This means that 40% of both boys and girls select options which suggest that the force acting on the bird decreases with increase in height.

4. 34% of the boys and 40% of the girls select option b, the option which suggests that the force acting on the bird increases with height.

5. 26% of the boys and 20% of the girls select option c, the option which suggests that the force acting on the bird does not change with an increase in height.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

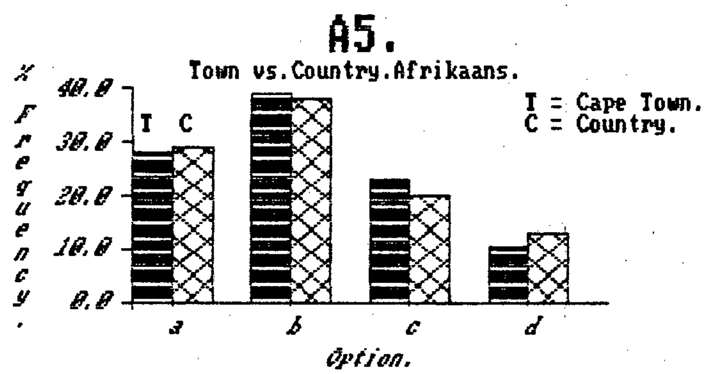


Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.

(f) **Comparing pupils from Town and Country areas:**

The following graph compares the frequencies with which Afrikaans-speaking pupils living in Cape Town and country towns select the different options.



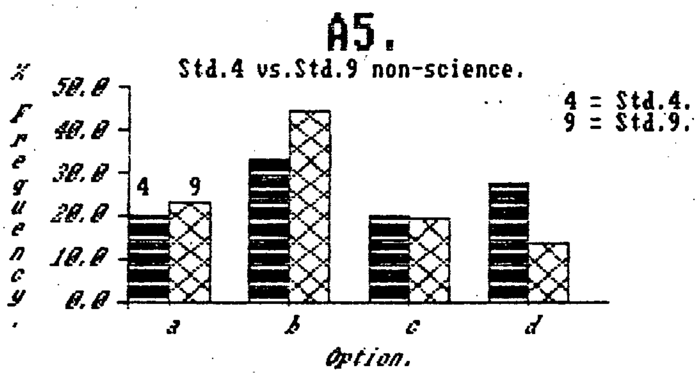
Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.

(g) **Comparing different standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 non-science pupils in Cape schools select the different options.

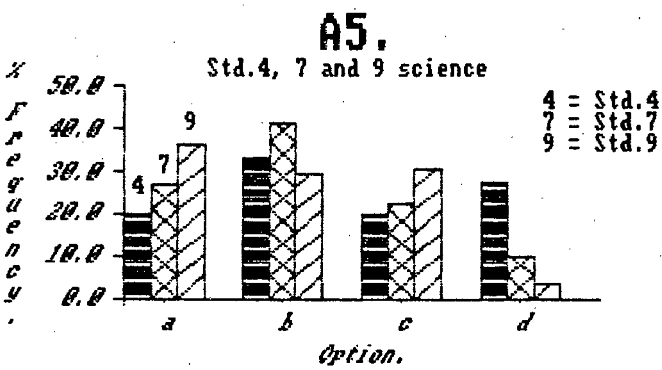


Note:

1. There are appreciable differences in the frequencies with which the two groups select options b and d.
2. 33% of standard 4 and 45% of the standard 9 non-science group select option b, the option which suggests that the force acting on the bird increases with height.
3. 28% of standard 4 and 13% of the standard 9 group select option d, the option which suggests that there is no force acting on the bird while it is gliding. This means that 48% of the standard 4 group and 36% of the standard 9 group select options which suggest that the force acting on the bird decreases while it is gliding.

2. <u>Standards 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils in Cape schools select the different options.

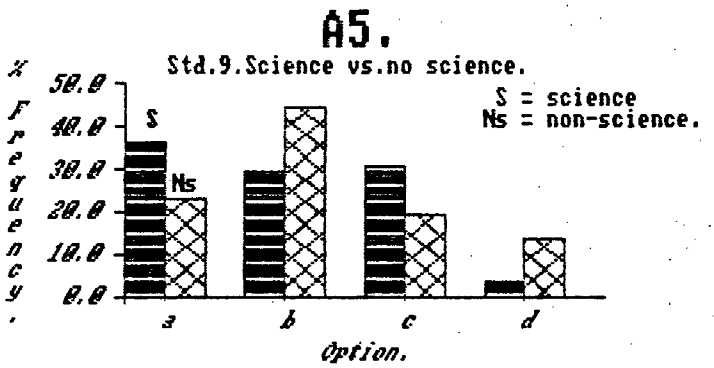


Note:

1. There is an increase in the frequencies with which option a, the option which suggests that the force of attraction on the bird decreases with height, is selected from standard 4 through to the standard 9 science pupils.
2. There is an increase in the frequencies with which option c, the correct option, is selected.
3. There is a sharp decrease in the frequencies with which option d, the option which suggests that the no force is acting on the bird while it is gliding, is selected.
4. 48% of standard 4, 37% of standard 7 and 41% of standard 9 science pupils select options which indicate that the force of attraction acting on the bird decreases while it is gliding.

3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and who do not do science in Cape schools select the different options.



Note:

1. There are fairly large differences in the frequencies with which the different options are selected by the two groups.
2. 35% of the science and 23% of the non-science pupils select option a, the option which suggests that the force of attraction acting on the bird decreases with increase in height.
3. 30% of the science and 45% of the non-science pupils selected option b, the option which suggests that the force of attraction on the bird increases with height.
4. 30% of the science and 19% of the non-science group select option c, the option which suggests that the force does not change with height above the ground.
5. 6% of the science and 13% of the non-science group select

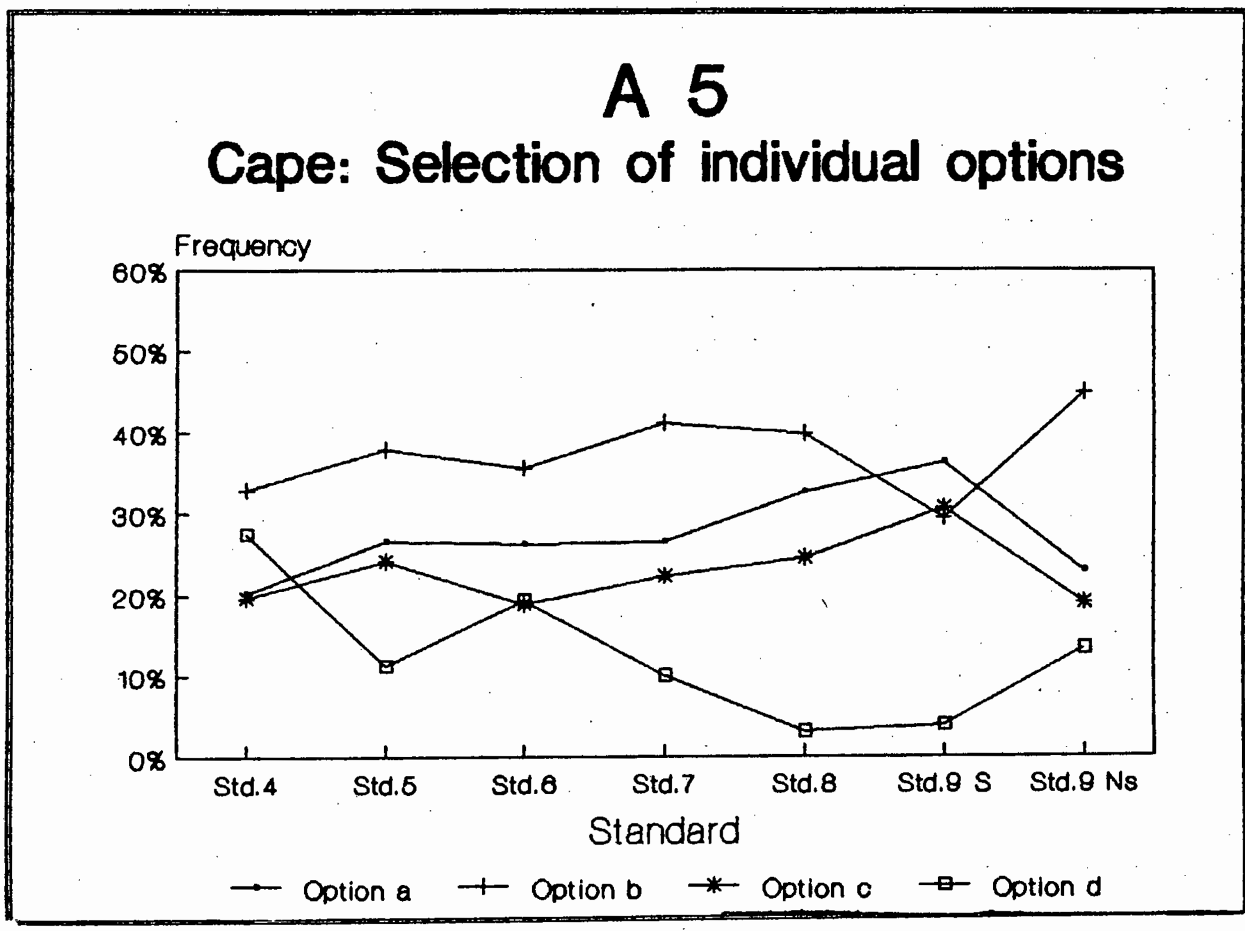
option d, the option which suggests that the bird has no force acting on it while it is gliding.

6. 41% of the science group and 36% of the non-science group select options which indicate that the force of attraction acting on the bird decreases while it is gliding.

7. With the science pupils the belief that the force acting on the bird decreases with height is the most popular one while with the non-science group the belief that the force actually increases with height is the most popular one.

(h) Comparing individual options:

The following graph compares the frequencies with which individual options are selected by the different standards in Cape schools.



Note:

1. Option b, the option which suggests that the force acting on the bird increases while it is gliding, is relatively popular with all of the groups except the standard 9 science group.
2. There is an increase in popularity of option a, the option which suggests that the force acting on the bird is less while it is gliding, to a maximum with the standard 9 science pupils.

3. There is an increase in popularity of option c, the option which suggests that there is no difference in the force acting on the bird while it is gliding, to a maximum with the standard 9 science pupils.
4. There is a decrease in popularity of option d, the option which suggests that there is no force acting on the bird while it is gliding, to a minimum with the standard 9 science group.

Summary:

1. When we examine the overall picture we find that:

   40% of the sample select the option which indicates a belief that the force acting on the bird increases with height;
   39% of the sample select options which indicate a belief that the force acting on the bird is either reduced while it is gliding or that no force acts on it while it is gliding.

2. When we compare the frequencies with which the pupils in the different standards in the Cape select the different options, we find that:

   there are no dramatic differences in the frequencies with which the different standards select the different options;
   with the exception of the standard 9 science group, the other standards all find option b the most popular, indicating a belief that the force acting on the bird increases with height;
   the popularity of option a increases across the standards indicating an increase in the belief that the force acting on

the bird decreases with height above the ground.

In Transkei we find that the pupils in all the standards overwhelmingly favour option b, indicating a belief that the force acting on the bird increases with height above the ground.

3. When we compare the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options we find that:

   both groups favour option b, but while this option is selected by 50% of the pupils in Transkei it is only selected by 36% of the pupils in the Cape;

   24% of the pupils in the Cape and 11% of the pupils in Transkei select option a, indicating a belief that the force acting on the bird decreases with height, while a further 25% of pupils in Transkei and 19% of pupils in the Cape select option d, thereby indicating a belief that no force acts on the bird while it is gliding.

4. When we compare the frequencies with which Afrikaans-and English-speaking pupils in schools in the Cape select the different options, we find that very small differences exist in the frequencies with which the different options are selected.

5. When we compare the frequencies with which boys and girls in Cape schools select the different options we find that:

   small differences exist in the frequencies with which the two groups select the different options;

31% of the boys and 23% of the girls select option a, indicating a belief that the force acting on the bird is less while it is gliding;

9% of the boys and 17% of the girls select option d, indicating a belief that no force acts on the bird while it is gliding.

In Transkei we find no noteworthy difference between boys and girls when we compare the frequencies with which the two groups select the different options.

6. When we compare the frequencies with which Afrikaans-speaking pupils in schools in Cape Town and country towns select the different options, we find no noteworthy differences.

7. When we compare the frequencies with which pupils in some of the standards select the different options we find that:

both standards 4 and 9 non-science pupils find option b the most popular but that while this option is selected by 33% of the standard 4 group, it is selected by 45% of the standard 9 group;

25% of the standard 4 group and 13% of the standard 9 group select option d, indicating a belief that no force acts on the bird while it is gliding;

there is an increase in the frequencies with which option a is selected as we go from standard 4 to standard 9 science pupils, indicating an increase in the belief that the force acting on the bird decreases with height;

there is an increase in the frequencies with which the option which suggests that there is no difference in the force, is selected as we go from standard 4 to standard 9 science pupils;

there is a decrease in the frequencies with which option d is selected indicating a decrease in the belief that there is no force acting on the bird while it is gliding, as we go from standard 4 to standard 9 science pupils;

the standard 9 science and non-science pupils differ quite markedly in the frequencies with which they select the different options. 30% of the science and 45% of the non-science groups select option b. 35% of science and 25% of the non-science groups select option a. This means that the science group favoured the belief that the force of attraction on the bird decreases with height while the non-science group favoured a belief that the force acting on the bird actually increases with height.

8. When we compare the frequencies with which the individual options are selected by the different standards we find that:

option b is the preferred option of all the groups except the standard 9 science group. This indicates a widely held belief that the force acting on the bird increases with height.

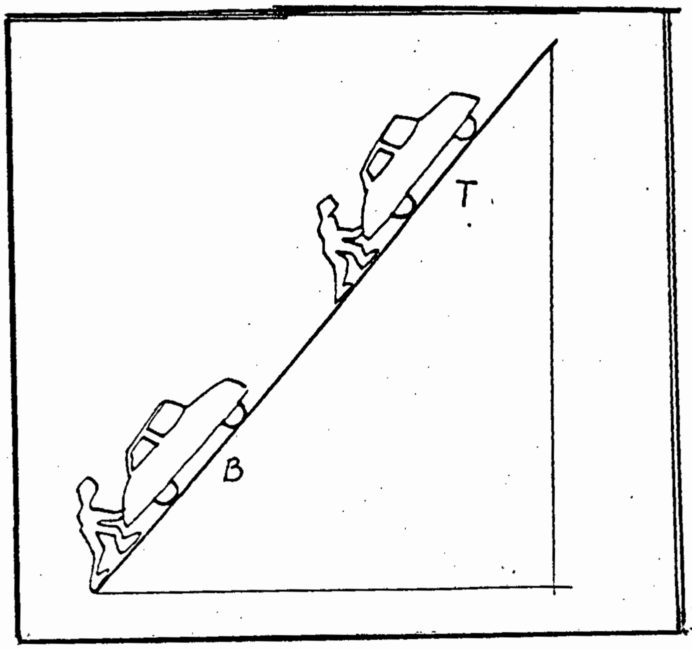
There is an increase in the popularity of option a across the standards, indicating an increase in the belief that the force acting on the bird is actually less while it is gliding.

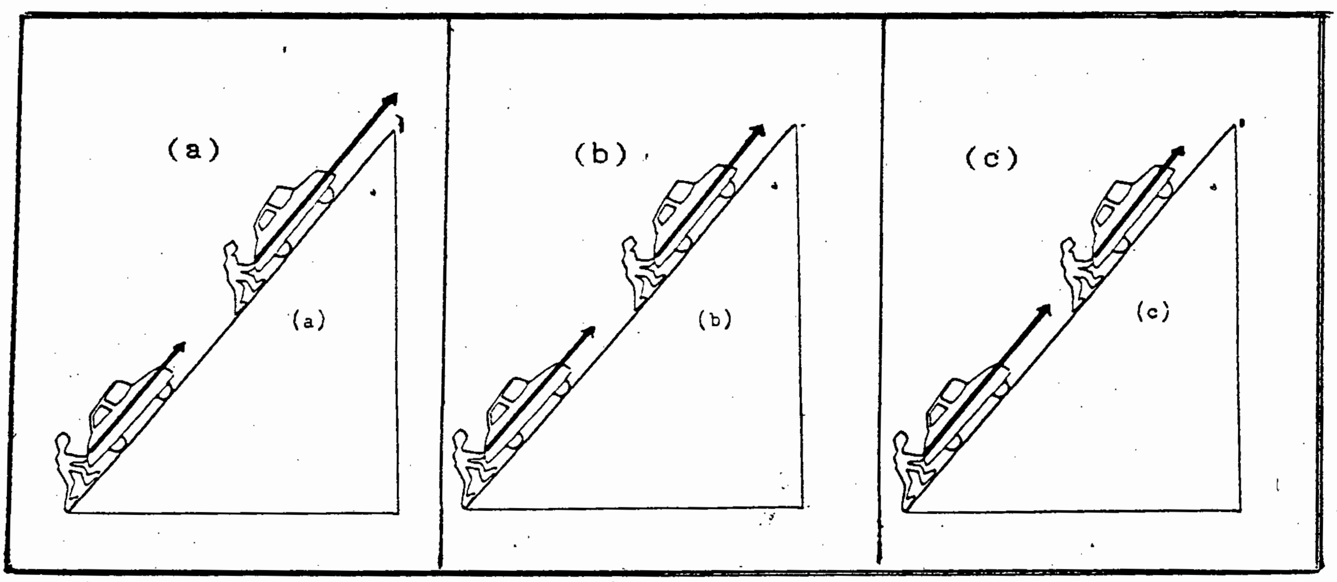
There is an increase in the popularity of option c, indicating an increase in the belief that the force of gravity does not change.

There is a decrease in the popularity of option d, indicating a decrease in the belief that no force acts on the bird while it is gliding.

Question B 5

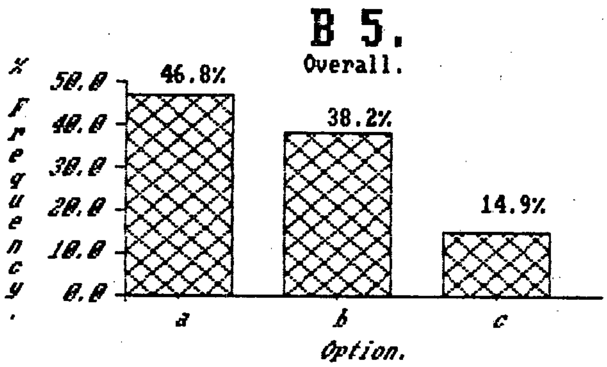
The sketch shows two identical cars being held on a hill by two men. The cars are not moving. The car at T is higher up the hill than the car at B. The sketch which best compares the sizes of the forces which each of the men has to produce to hold his car, is:





(a) **The overall picture:**

The following graph compares the frequencies with which the different options are selected by the whole sample.



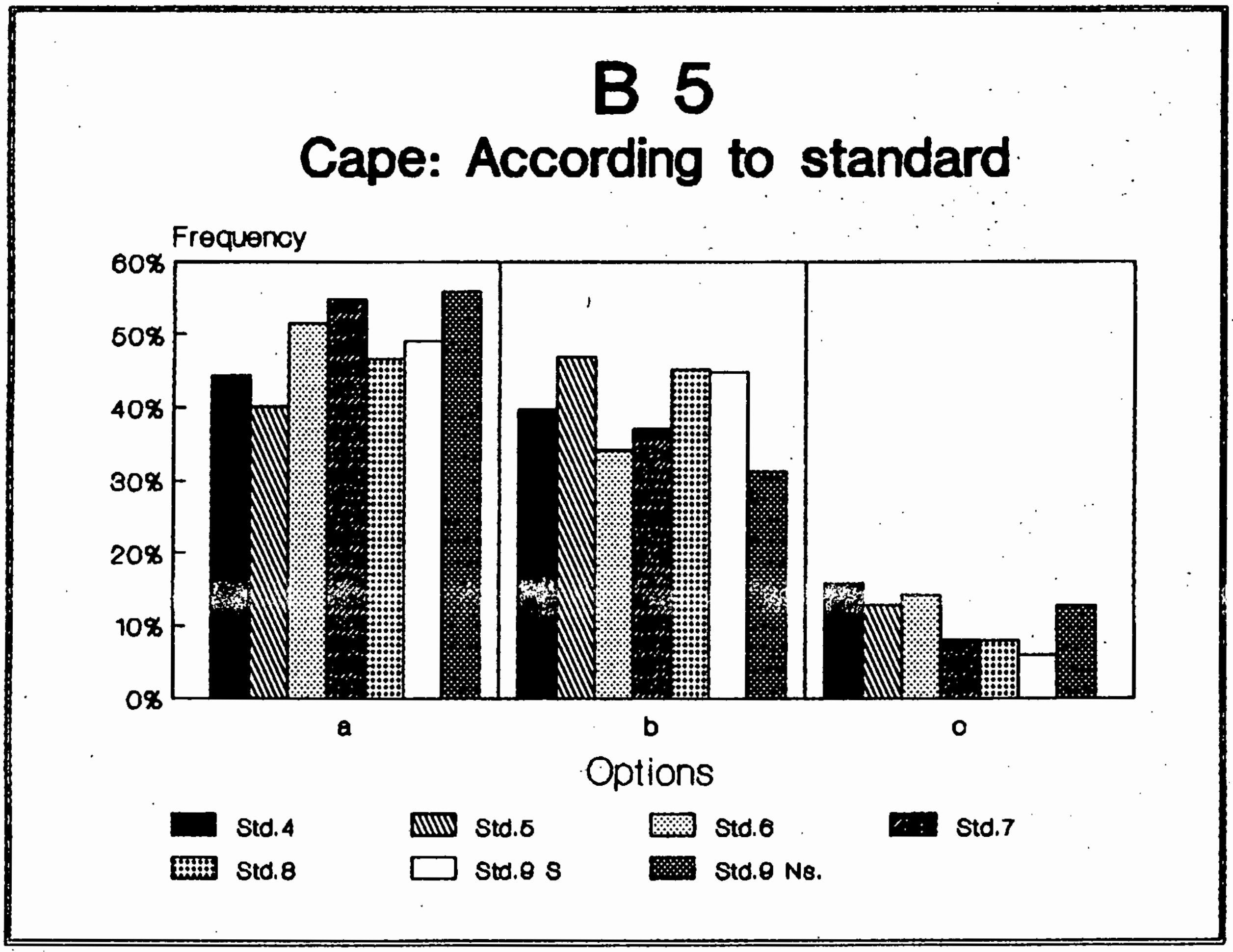
Note:

1. 47% of the sample select option a, the option which suggests that the man at the top has to push harder to hold his car.
2. 15% of the sample select option c, the option which suggests that the man at the bottom has to push harder to hold his car.
3. 38% of the sample select option b, the correct option.

(b) **According to standard:**

1. In the Cape:

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



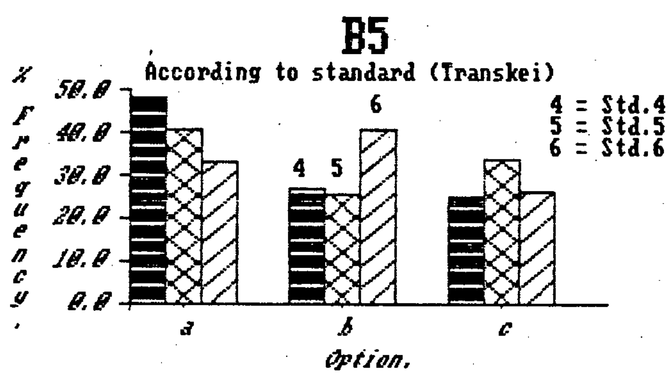
Note:

1. With the exception of the standard 5 group, all of the other standards find option a the most attractive.
2. Option c, the option which suggests that the person at the bottom of the hill has to push harder to hold his car, is the least popular with all of the standards.
3. The standard 5 group select the correct option, option b, with a higher frequency than the standard 4 and 7 groups.

4. The standards 8 and 9 science pupils select the correct option with a notably higher frequency than standards 6 and 7 and the standard 9 non-science group.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in schools in Transkei select the different options.

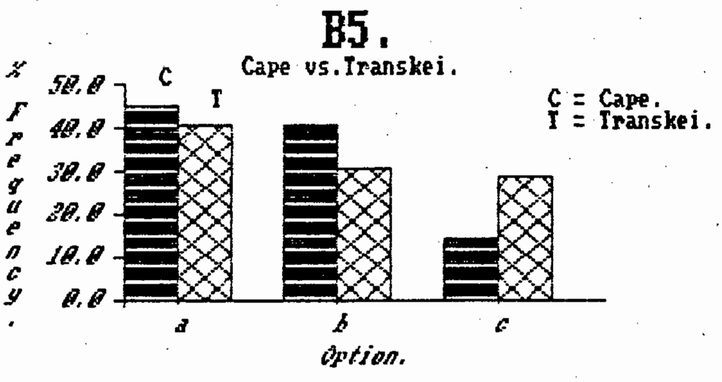


Note:

1. Option a, the option which suggests that the man at the top of the hill has to push harder to keep his car there, is the favourite option of the standard 4 and 5 groups.
2. The standard 6 group select option b, the correct option, more frequently than the other two options.
3. Option c is selected with a fairly high frequencies by all of the classes.

(c) Comparing the Cape and Transkei:

The following graph compares the frequencies with which standard 4, 5 and 6 pupils in the Cape and Transkei schools select the different options.

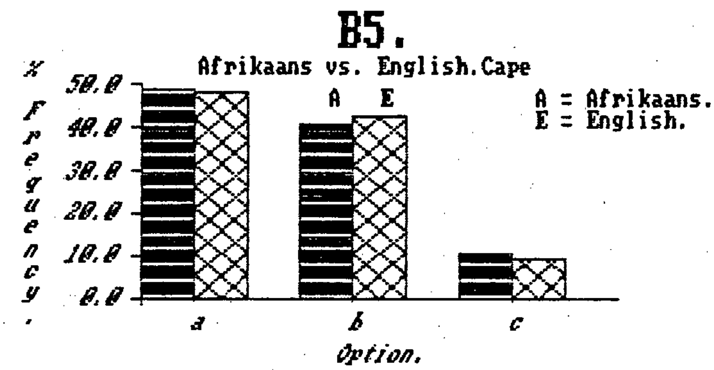


Note:

1. There is a small difference in the frequencies with which the two groups select option a, the option which suggests that the man at the top of the hill has to push harder to keep his car there. It is selected by 45% of the pupils in the Cape and 41% of the pupils in Transkei.
2. 41% of the pupils in the Cape and 31% of the pupils in Transkei select option b, the correct option.
3. 14% of the pupils in the Cape and 29% of the pupils in Transkei select option c, the option which suggests that the man at the bottom has to push harder to keep his car there.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



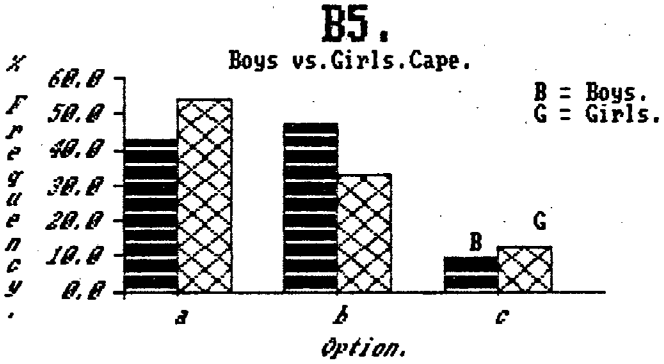
Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.
2. 48% of both of the groups select option a. This suggests that they believe that the man higher up the hill has to push harder to keep his car there.
3. About 9% of both groups select option c. This suggests that they believe that the person at the bottom of the hill has to push harder to hold his car there.
4. About 41% of both groups select option b, the correct option.

(e) Comparing the sexes:

1. In the Cape:

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

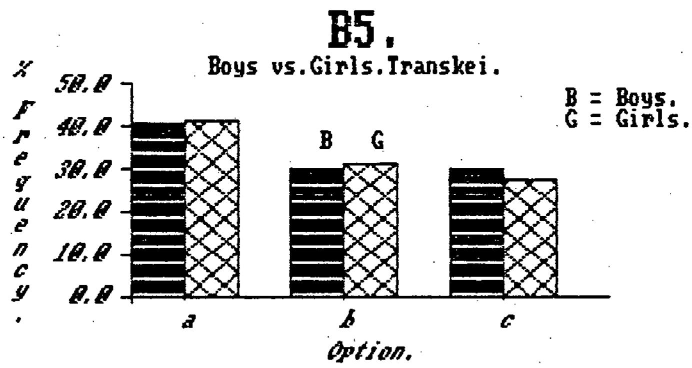


Note:

1. There are notable differences in the frequencies with which the two groups select options a and b.
2. 43% of the boys and 54% of the girls select option a, the option which suggests that the man at the top of the hill has to exert a larger force on the car to keep it there.
3. 48% of the boys and 33% of the girls select the correct option, option b.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

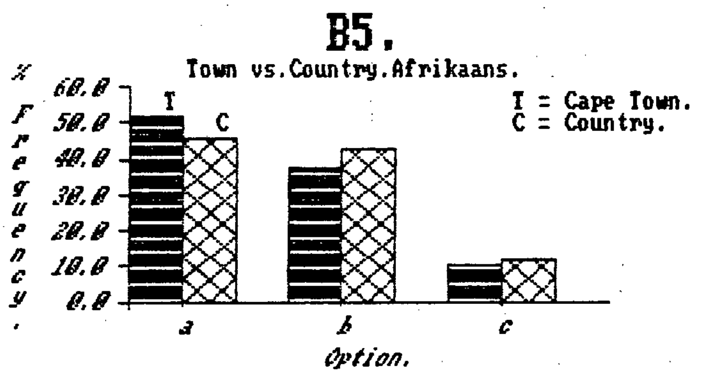


Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.

(f) Comparing pupils from Town and country areas:

The following graph compares the frequencies with which Afrikaans-speaking pupils in schools in Cape Town and country towns select the different options.



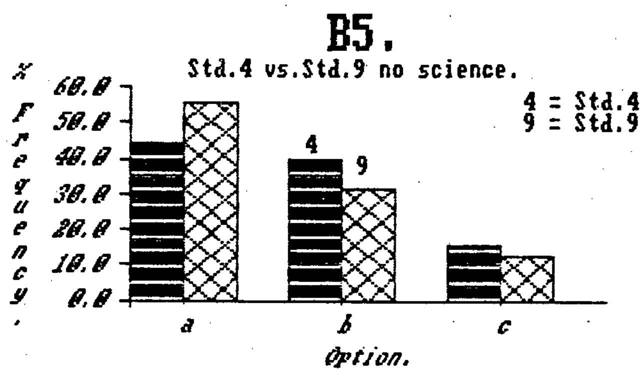
Note:

1. There are small differences in the frequencies with which the two groups select options a and b.
2. 52% of the pupils living in Cape Town and 46% of the pupils living in country towns select option a.
3. 38% of the pupils living in Cape Town and 43% of the pupils living in country towns select option b.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science select the different options.

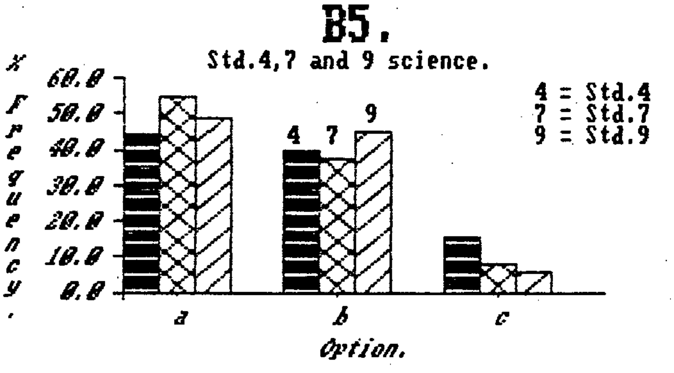


Note:

1. There are differences in the frequencies with which the two groups select all three of the options.
2. 44% of the standard 4 and 56% of the standard 9 group select option a.
3. 40% of the standard 4 and 31% of the standard 9 group select option b.
4. 16% of the standard 4 and 13% of the standard 9 group select option c.

2. <u>Standard 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which standard 4, 7 and 9 pupils who do science select the different options.



Note:

1. There are small differences in the frequencies with which the groups select the different options.
2. Option a is very popular with all three the groups but is most popular with the standard 7 group.
3. There are very small differences in the frequencies with which the groups select option b.
4. There is an interesting decrease in the frequencies with which option c is selected but it is noteworthy that it is still selected by 8% of the standard 9 science group.

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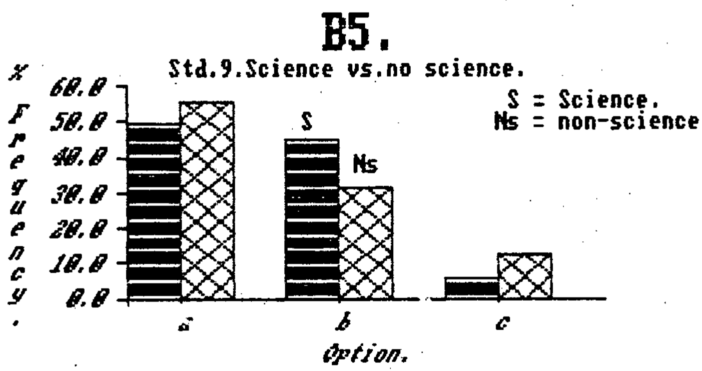
3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do science and who do not do science select the different options.



Note:

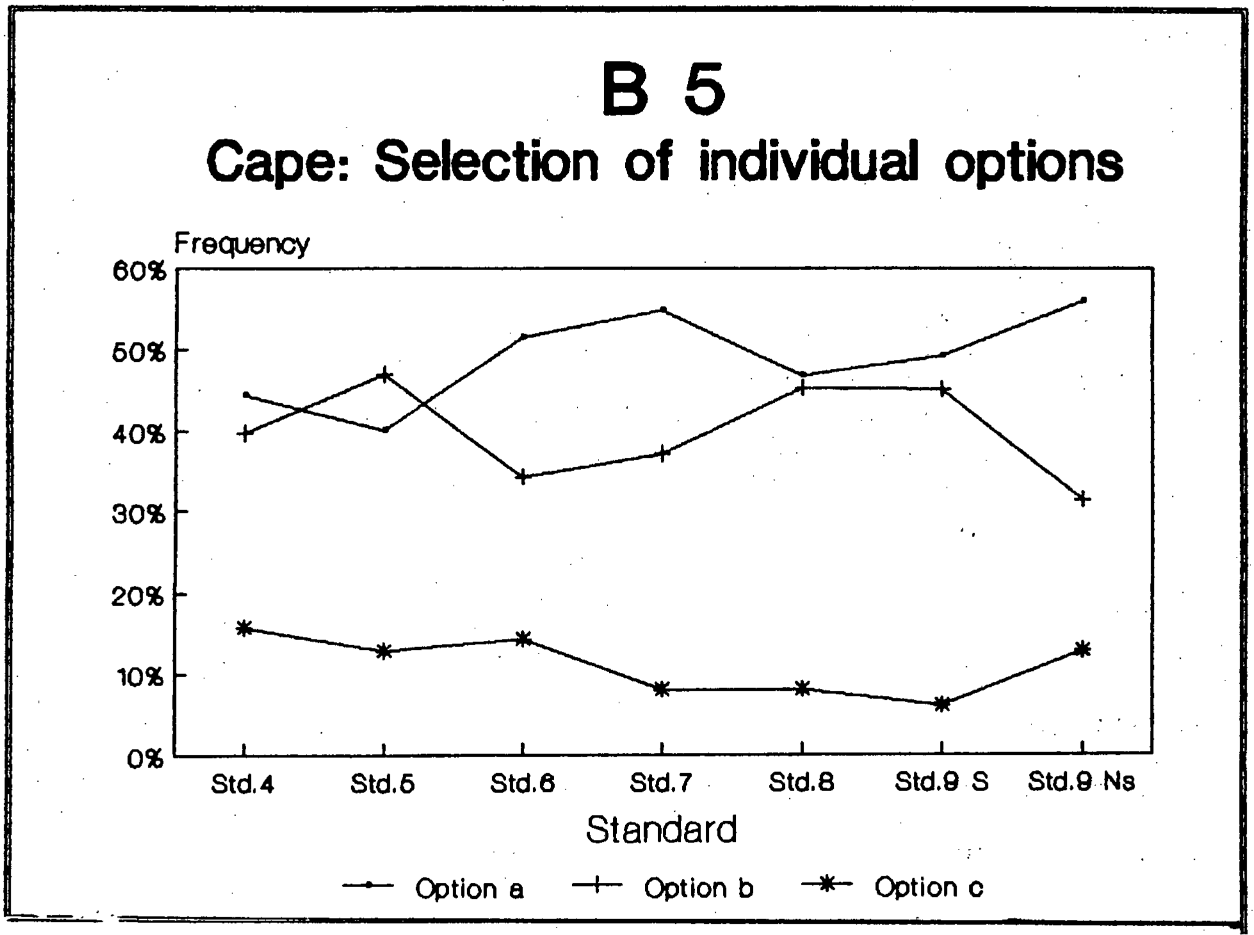
1. 49% of the science pupils and 56% of the non-science pupils select option a.

2. 45% of the science pupils and 31% of the non-science pupils select option b.

3. 8% of the science pupils and 13% of the non-science pupils select option c.

(h) Selection of individual options:

The following graph shows the selection of individual options by the different standards.



Note:

1. With the exception of the standard 5 group, option a is the most popular option with all of the groups.
2. There is a gradual increase in the frequencies with which the correct option, b, is selected from standard 6 to the standard 9 science group.
3. Option c is the most unpopular option with all of the groups and its popularity decreases to a minimum with the standard 9 science group.

Summary:

1. When we examine the overall picture we find that 47% of the pupils select option a. This implies that the belief that the force of gravity increases with height is very widely held. However, we also find that about 15% of the sample believe that the force required to hold the car low down is greater than it is higher up. This implies a belief that the force of gravity decreases with height.

2. When we compare the frequencies with which pupils in the different standards in Cape schools select the different options, we find that:

   there are no dramatic differences in the frequencies with which the different groups select the different options;
   with the exception of the standard 5 group, all of the other standards select option a with the highest frequencies. The standard 5 group select option b the most frequently.

   In Transkei schools we find that:

   standards 4 and 5 pupils select option a most frequently while the standard 6 pupils select option b most frequently;
   option c is fairly popular with all of the classes.

3. When we compare the frequencies with which standards 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options, we find that:

   both groups select option a as the most popular option. This option is selected by 45% of the pupils in the Cape and 41% of the pupils in Transkei.

41% of the pupils in the Cape and 31% of the pupils in Transkei select option b;

option c is selected by 14% of the pupils in the Cape and 29% of the pupils in Transkei. This is an appreciable difference.

4. When we compare the frequencies with which Afrikaans-and English-speaking pupils in schools in the Cape select the different options, we find that:

there is no noteworthy differences between the frequencies with which the two groups select the different options;

option a is selected by 48% of the pupils in both of the groups;

option c is selected by about 9% of the pupils in both of the groups.

5. When we compare the frequencies with which boys and girls in Cape schools select the different options, we find that:

43% of the boys and 54% of the girls select option a;

48% of the boys and 33% of the girls select option b;

In Transkei schools we find no difference between the frequencies with which boys and girls select the different options.

6. When we compare the frequencies with which Afrikaans-speaking pupils living in Cape Town and in country towns select the different options, we find that:

52% of the pupils from Cape Town and 46% of the pupils from country towns select option a;

38% of the pupils from Cape Town and 43% of the pupils from country towns select option b.

7. When we compare the frequencies with which pupils in some of the standards select the different options, we find that:

56% of the non-science standard 9 group and 44% of the standard 4 group select option a;

40% of the standard 4 group and 31% of the standard 9 non-science group select option b;

the standard 9 science pupils select option b more frequently but the difference between this group and the other groups on this item is not a large one;

the frequencies with which option c is selected decreases across the standards to a minimum with the standard 9 science group;

49% of the standard 9 science group select option a.

8. When we compare the frequencies with which the individual options are selected by the different classes, we find that

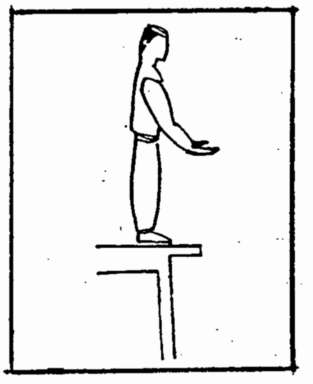
option a is the most popular with all the groups except the standard 5 group;

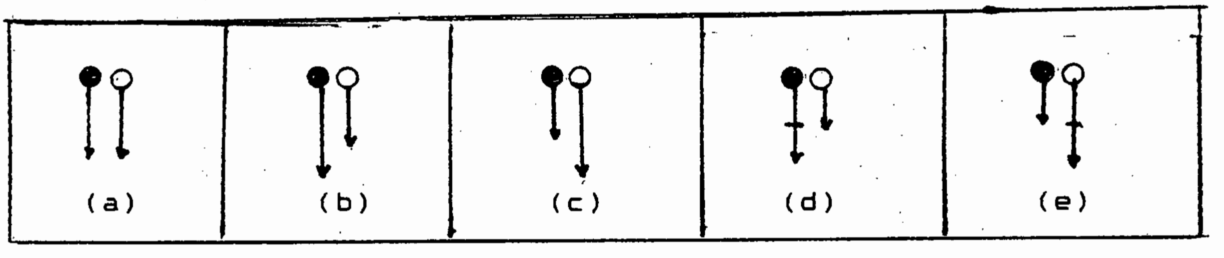
option b increases in popularity to a maximum with the standard 9 science group;

option c is the most unpopular and decreases in popularity to a minimum with the standard 9 science group.

Question B 1

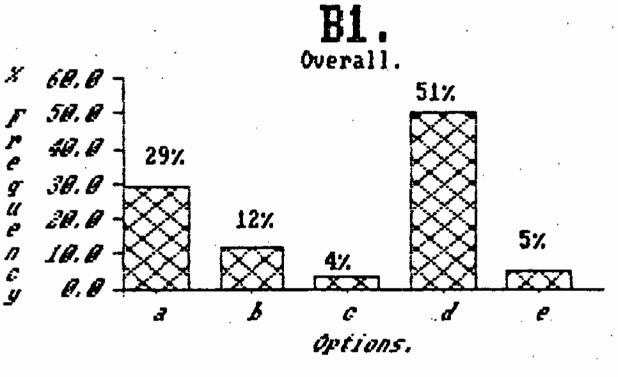
The sketch shows a boy who is standing on a table. He has two marbles in his hand. The black one is twice as heavy as the white one. He drops them at the same time and they fall towards the ground. The sketch which best shows the relative speeds with which the marbles hit the ground, is :





The overall picture:

The following graph shows the frequencies with which the whole sample selects the different options.



Note:

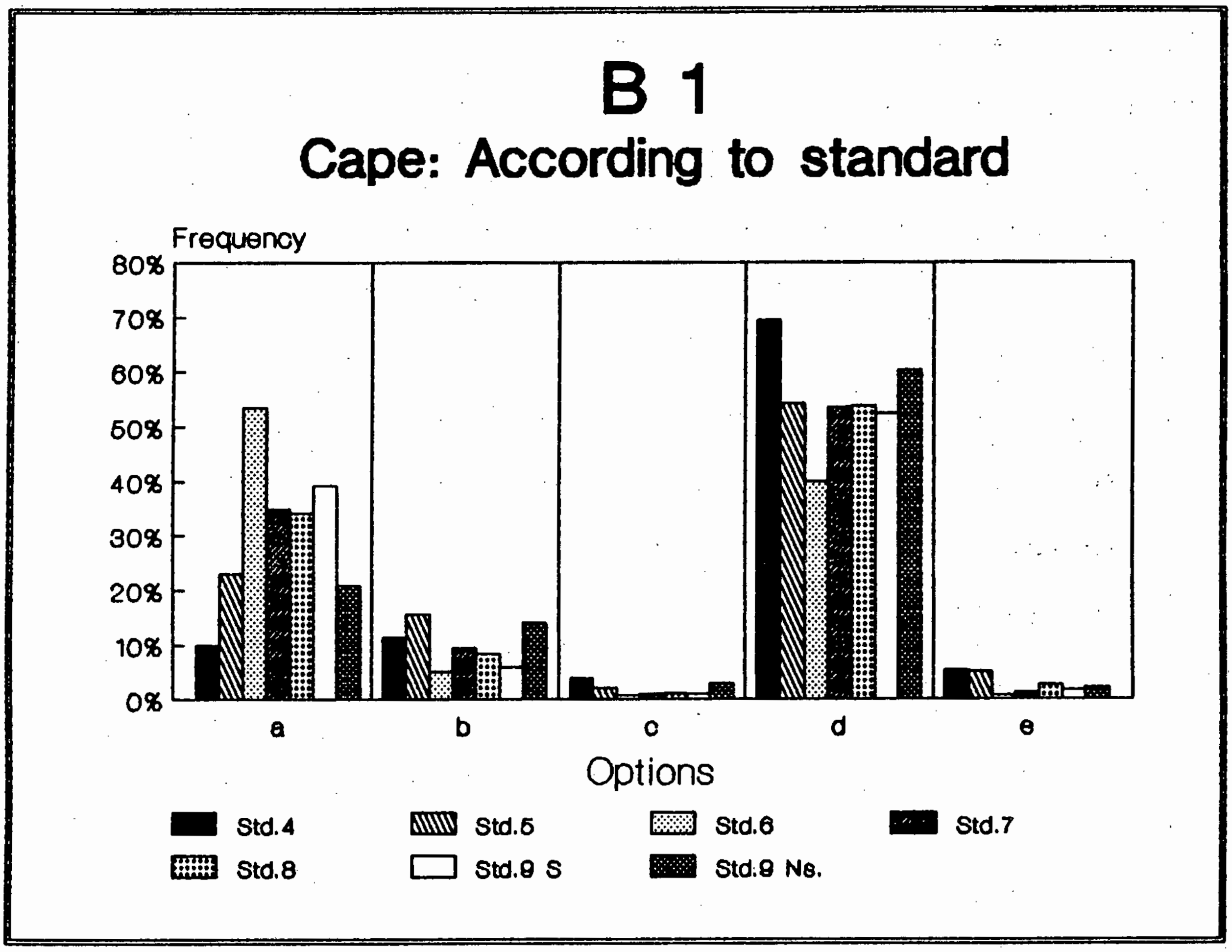
1. 29% of the sample select option a, the option which suggests that the two balls will strike the ground with the same speed.

2. 12% of the sample select option b, the option which suggests that the heavy ball will be the faster of the two.
3. 4% of the sample select option c, the option which suggests that the lighter ball will be the faster of the two.
4. 51% of the sample select option d, the option which suggests that the heavier ball will be moving twice as fast as the lighter one when they strike the ground.
5. 5% of the sample select option e, the option which suggests that the lighter ball will be moving twice as fast as the heavier one when they strike the ground.
6. 63% of the sample select options which suggest that the heavier ball will be the faster of the two while 9% of the sample select options which suggest that the lighter ball will be the faster one.

(b) According to standard:

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

1. Option a receives what is almost exceptionally heavy support from standard 6 pupils.

2. Option a was not very popular with the standards 4, 5 and 9 pupils who do not do science.

3. With the exception of the standard 6 pupils, pupils in the other standards overwhelmingly select option d, the option

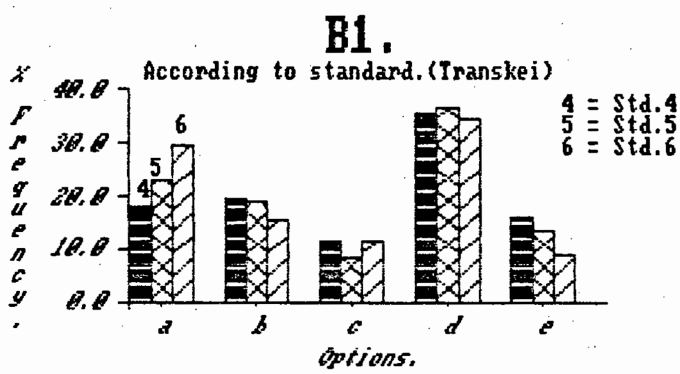
which suggests that the heavier ball will be moving twice as fast as the lighter one when it strikes the ground. This option is particularly popular with the standard 4 pupils.

4. The standard 6 group also select option b, the option which suggests that the heavier ball will move the faster of the two, with a very low frequencies.

5. Options c and d, the options which suggests that the lighter ball will move the faster of the two, is very unpopular with the pupils in all of the standards.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

1. Although option a is not the most popular option, there is an increase across the standards in the proportion of pupils who select it.

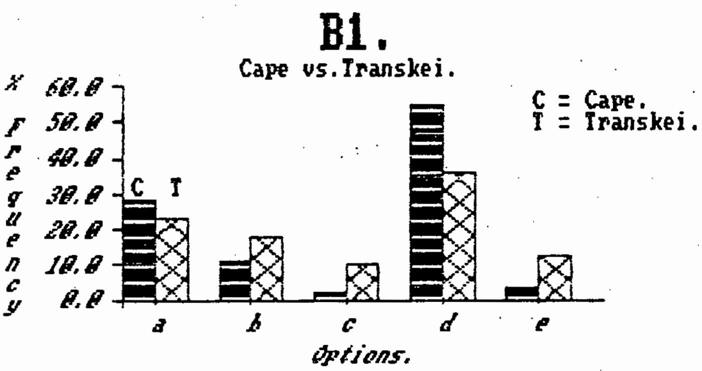
2. Option d, the option which suggests that the heavier ball will

be moving twice as fast as the lighter one, is the most popular with pupils in all of the standards.

3. The next most popular option with the pupils in the different standards is option b, the option which suggests that the heavier ball will be moving the faster of the two.
4. Options c and d, the options which suggest that the lighter ball will be moving the faster of the two, is selected by a small proportion of pupils in all of the standards.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.



Note:

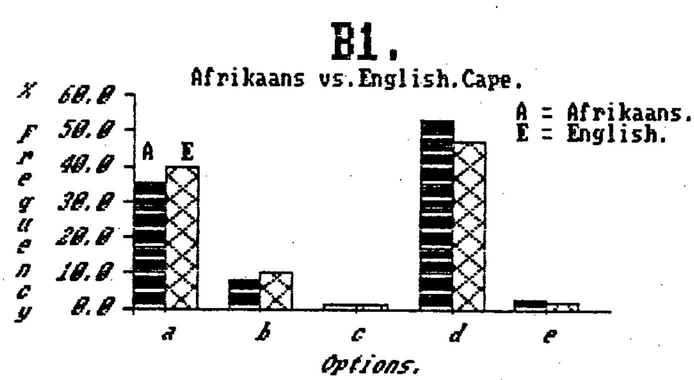
1. Although there are differences in the frequencies with which the two groups select the various options, both groups find option d the most popular option with option a the next most popular.
2. 29% of pupils in the Cape and 23% of pupils in Transkei select

option a.

3. 11% of pupils in the Cape and 18% of pupils in Transkei select option b.
4. 55% of pupils in the Cape and 36% of pupils in Transkei select option d. This means that 66% of the pupils in the Cape and 54% of the pupils in Transkei select options which suggest that the heavier ball will be moving the faster of the two.
5. 6% of the pupils in the Cape and 23% of the pupils in Transkei select options which suggest that the lighter ball will be moving the faster of the two.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



Note:

1. There are only small differences in the frequencies with which the two groups select options a and d.
2. 35% of Afrikaans-and 40% of English-speaking pupils select

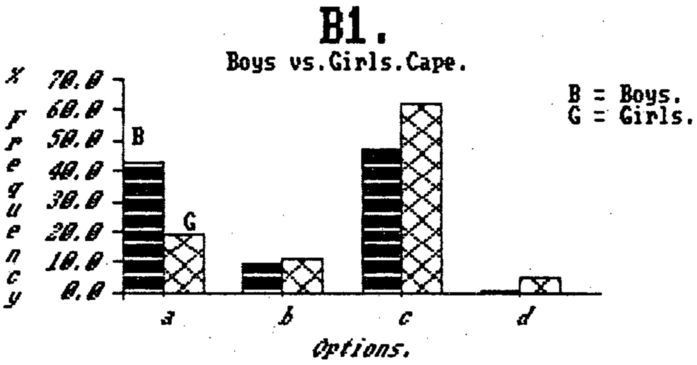
option a.

3. 53% of Afrikaans-and 47% of English-speaking pupils select option d.
4. 61% of Afrikaans-and 57% of English-speaking pupils select options which suggest that the heavier ball will be moving the faster of the two.
5. 4% of Afrikaans-and 3% of English-speaking pupils select options which suggest that the lighter ball will be moving the faster of the two.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

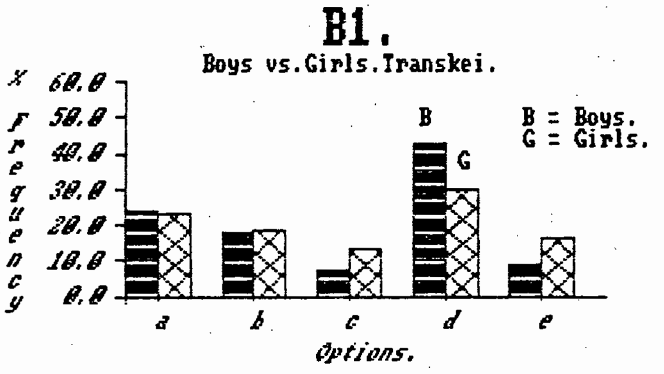


Note:

1. There are substantial differences in the frequencies with which the two groups select options a and d.
2. 43% of the boys and 19% of the girls select option a.
3. 47% of the boys and 62% of the girls select option d.
4. 56% of the boys and 73% of the girls select options which suggest that the heavier ball will be moving the faster of the two.
5. 1% of the boys and 8% of the girls select options which suggest that the lighter ball will be moving the faster of the two.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.



Note:

1. There is a fairly large difference in the frequencies with which the two groups select option d.
2. 43% of the boys and 30% of the girls select option d.
3. 60% of the boys and 48% of the girls select options which suggest that the heavier ball will be moving the faster of the two.
4. Option a is selected by about 23% of the pupils in both groups.
5. 16% of the boys and 29% of the girls select options which suggest that the lighter ball will be moving the faster of the two.

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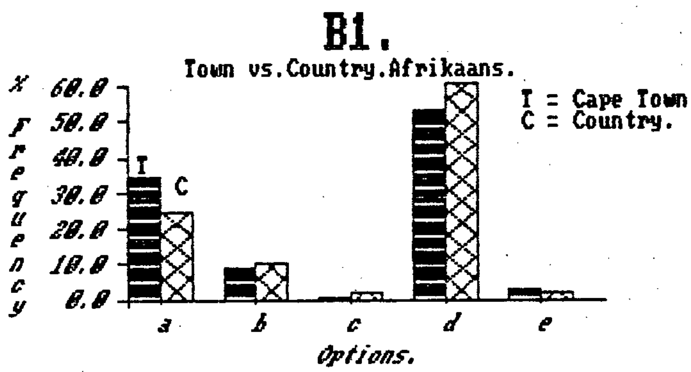
(f) **Comparing Town and Country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans-speaking pupils who attend schools in Cape Town and in country towns select the different options.



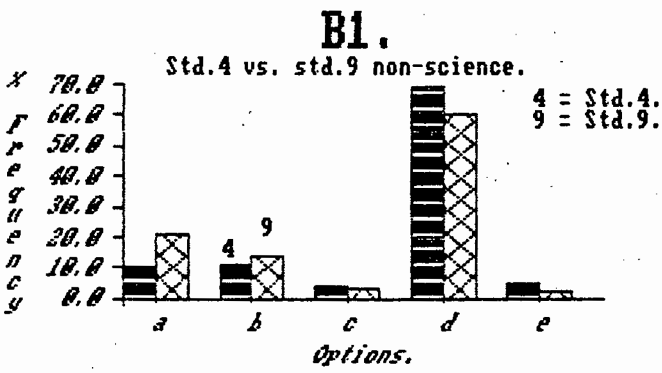
Note:

1. There are only relatively small differences in the frequencies with which the two groups select options a and d.
2. 34% of pupils in schools in Cape Town and 25% of pupils in schools in country towns select option a.
3. 53% of pupils in schools in Cape Town and 61% of pupils in schools in country towns select option d.
4. 62% of pupils in schools in Cape Town and 71% of pupils in schools in country towns select options which suggest that the heavier ball will be moving the faster of the two.
5. 4% of the pupils in both groups select options which suggest that the lighter ball will be moving the faster of the two.

(g) **Comparing some of the standards:**

1. <u>Standard 4 and standard 9 non-science pupils:</u>

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science at school select the different options.

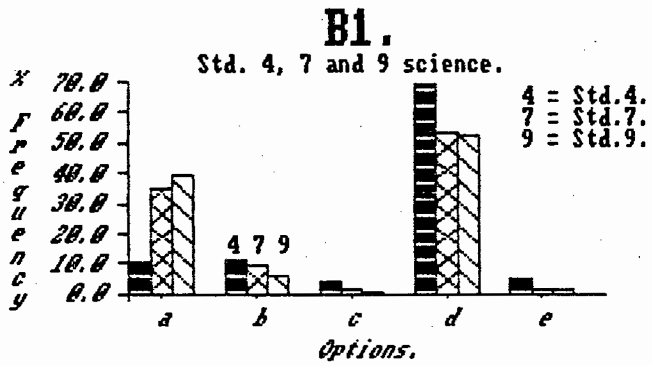


Note:

1. There are only relatively small differences in the frequencies with which the two groups select options a and d.
2. 10% of standard 4 and 21% of standard 9 pupils select option a.
3. 69% of standard 4 and 60% of standard 9 pupils select option d.
4. 80% of standard 4 and 74% of standard 9 pupils select options which suggest that the heavier ball will be moving the faster of the two.
5. 9% of the standard 4 and 5% of the standard 9 pupils select options which suggest that the lighter ball will be moving the faster of the two.

2. Standard 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standards 4, 7 and 9 pupils who do science select the different options.

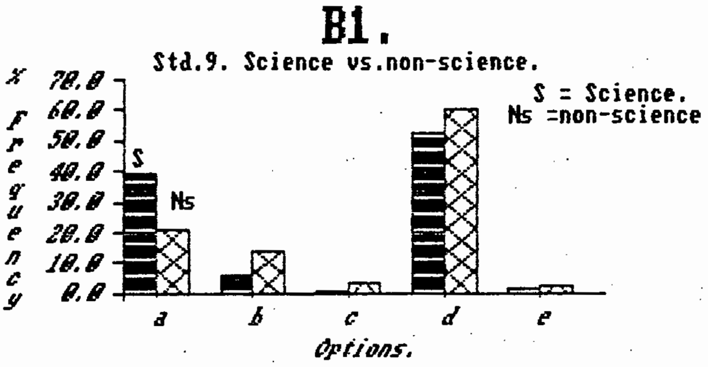


Note:

1. Option a becomes steadily more popular with the pupils in the higher standards.
2. Option d is the favourite choice of the pupils in all three the standards, particularly the standard 4 pupils.
3. It is clear that in each standard the proportion of the pupils who select options which suggest that the heavier ball will move the faster of the two, far outweighs any other options.

3. Standard 9 science and non-science pupils:

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.

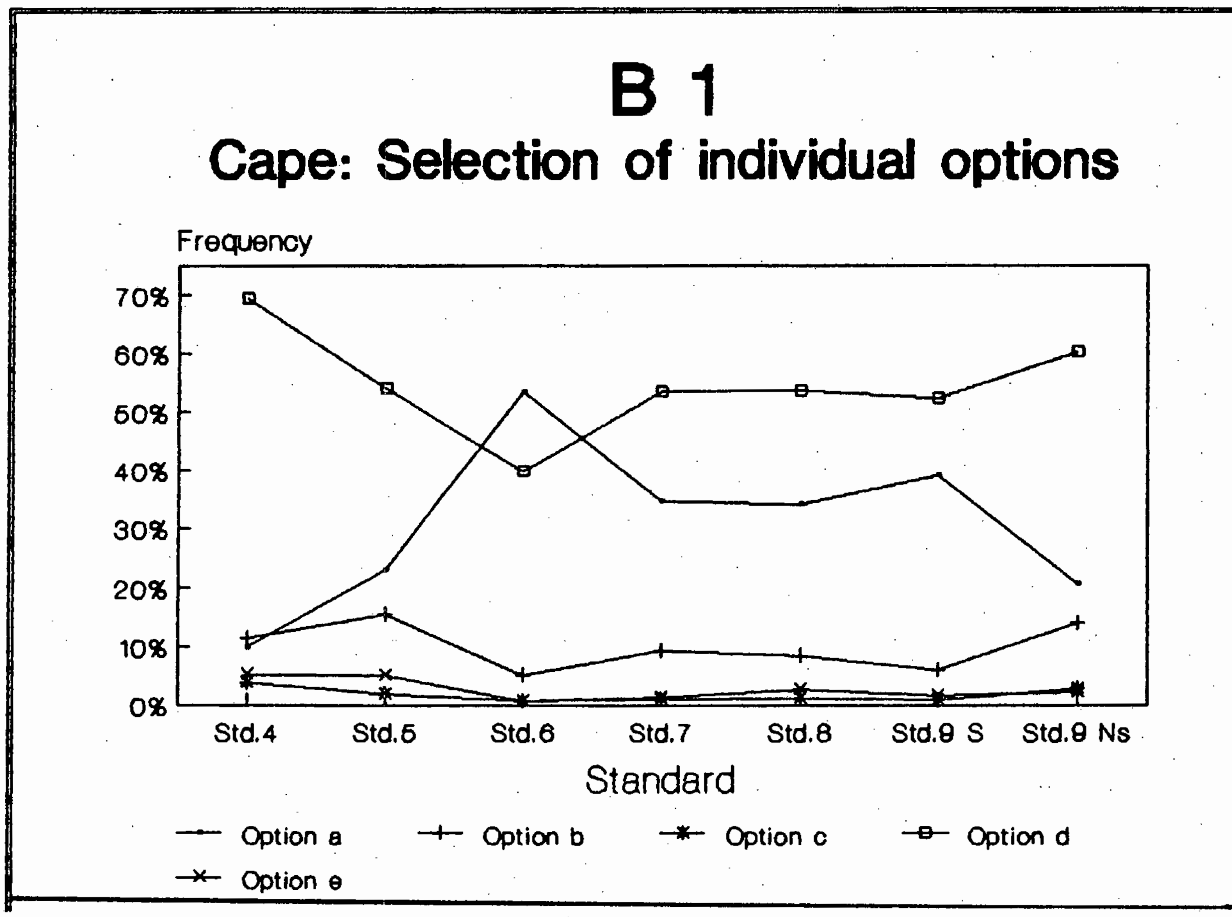


Note:

1. There are notable differences in the frequencies with which the two groups select options a, b and d.
2. 39% of the science and 21% of the non-science pupils select option a.
3. 52% of the science and 60% of the non-science pupils select option d.
4. 58% of the science and 74% of the non-science pupils select options which suggest that the heavier ball will be moving the faster of the two.
5. 3% of the science and 5% of the non-science pupils select options which suggest that the lighter ball will be moving the faster of the two.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by the different standards.



Note:

1. The frequencies with which the pupils in the different standards select option d shows a clear minimum with the standard 6 pupils.

2. The frequencies with which option a are selected show a clear maximum with the standard 6 pupils.

Summary:

1. When we examine the overall picture we find that:

   29% of the pupils select option a. This indicates a belief that the two balls will reach the ground with the same speed.
   62% of the pupils select options which indicate a belief that the heavier ball will be moving the faster of the two. 51% actually believe that the heavier ball will be moving twice as fast as the lighter one.
   8% of the sample believe that the lighter ball will be moving the faster of the two.

2. When we compare the frequencies with which pupils in the different standards in schools in the Cape select the different options we find that:

   with the exception of pupils in standard 6, pupils in all of the other standards overwhelmingly select option d, the option which suggests that the heavier ball will be moving twice as fast as the lighter one.
   Standard 6 pupils overwhelmingly select option a, the option which suggests that the two balls will be moving equally fast. That this belief is a firm one with standard 6 pupils is further confirmed if we look at the following graph, which compares the frequencies with which pupils in the different standards select options which suggest a belief that the heavier ball will be moving faster than the lighter one.

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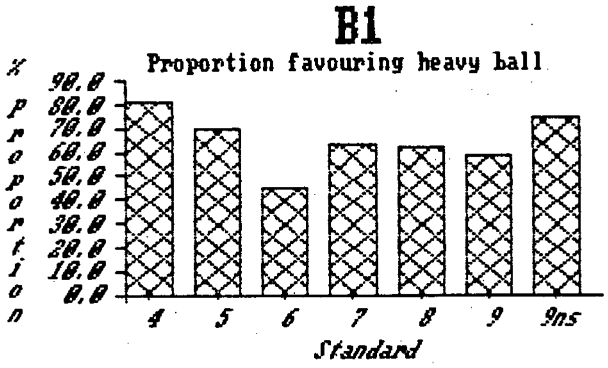

The graph clearly shows that the standard 6 pupils are "out of step" with the rest of the classes.

The graph also shows very clearly how widely held is the belief that the heavier ball will move faster than the lighter one, and that there is very little evidence from this data that exposure to science, as one would expect the standard 8 and 9 science pupils to have, does anything to reduce this belief.

It is also clear that only a very small proportion of the pupils thought that the lighter ball will move the faster of the two.

In Transkei we find that:

pupils overwhelmingly select options which indicate a believe that the heavier ball will move faster than the lighter one.

3. When we compare pupils in standards 4, 5 and 6 in schools in the Cape and Transkei we find that:

although there are differences in the frequencies with which the two groups select the different options, both groups find option d the most popular and option a the next most popular;

55% of the pupils in the Cape and 36% of the pupils in Transkei believe that the heavier ball will move twice as fast as the lighter one;

66% of the pupils in the Cape and 54% of the pupils in Transkei believe that the heavier ball will move faster than the lighter one;

23% of the pupils in Transkei select options which indicate a belief that the lighter ball will move faster than the heavier one.

4. When we compare Afrikaans-and-English-speaking pupils we find that:

   there are only small differences in the frequencies with which the two groups select options a and d;

   53% of Afrikaans-and 47% of English-speaking pupils believe that the heavier ball will move twice as fast as the lighter one;

   61% of Afrikaans-and 57% of English-speaking pupils believe that the heavier ball will move faster than the lighter one.

5. When we compare boys and girls at schools in the Cape we find that:

   there are substantial differences in the frequencies with which the two groups select options a and d;

   43% of the boys and 19% of the girls believe that the balls will be moving equally fast;

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43% of the boys and 62% of the girls believe that the heavier ball will be moving twice as fast as the lighter one;

56% of the boys and 73% of the girls believe that the heavier ball will be moving faster than the lighter one.

In Transkei we find that:

43% of the boys and 30% of the girls believe that the heavier ball will be moving twice as fast as the lighter one;

60% of the boys and 48% of the girls believe that the heavier ball will be moving faster than the lighter one;

16% of the boys and 29% of the girls believe that the lighter ball will be moving faster than the heavier one.

6. When we compare Afrikaans-speaking pupils attending schools in Cape Town and country towns we find that:

34% of the pupils in schools in Cape Town and 25% of the pupils in schools in country towns believe that the two balls will be moving equally fast;

53% of the pupils in school in Cape Town and 61% of the pupils in schools in country towns believe that the heavier ball will be moving twice as fast as the lighter one;

62% of the pupils in schools in Cape Town and 71% of pupils in schools in country towns believe that the heavier ball will be moving faster than the lighter one;

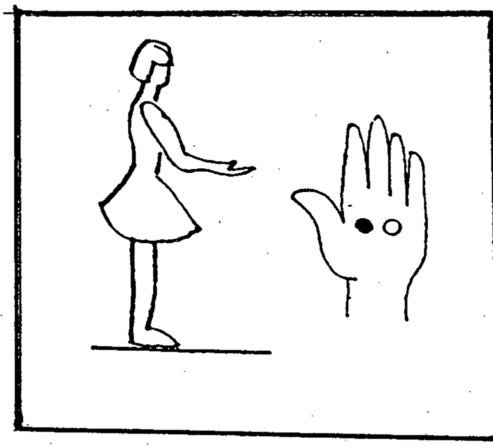
7. When we compare some of the standards we find the belief that the heavier ball will be moving faster than the lighter one to be overwhelmingly held by pupils in all of the standards. While this belief is particularly prevalent amongst pupils in

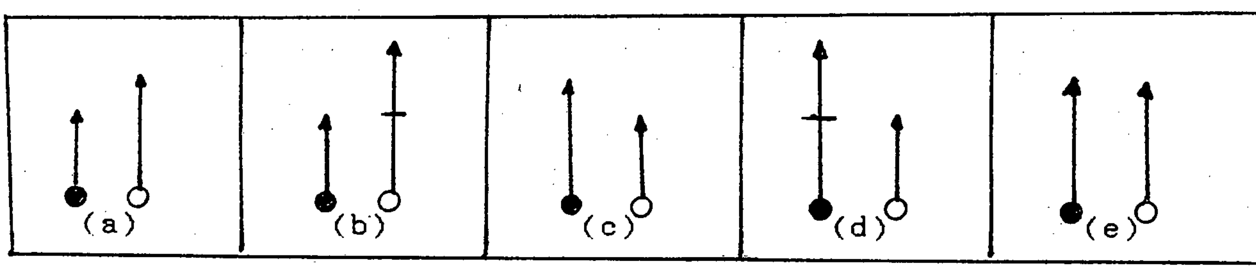
the lower standards, it is held by a remarkably high proportion of pupils in all of the standards.

8. A comparison of the frequencies with which the individual options are selected by the different standards clearly reveals the rather anomolous behaviour of the standard 6 group.

Question B 2

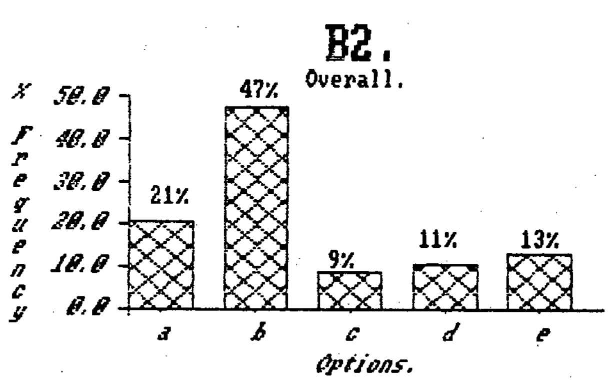
The sketch shows a girl who has two marbles in her hand. The black marble is twice as heavy as the white one. She now throws them vertically upwards. The marbles leave her hand with the same speed. The sketch which best shows the <u>heights</u> reached by the marbles, is:





(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



Note:

1. 21% of the sample select option a, the option which suggests

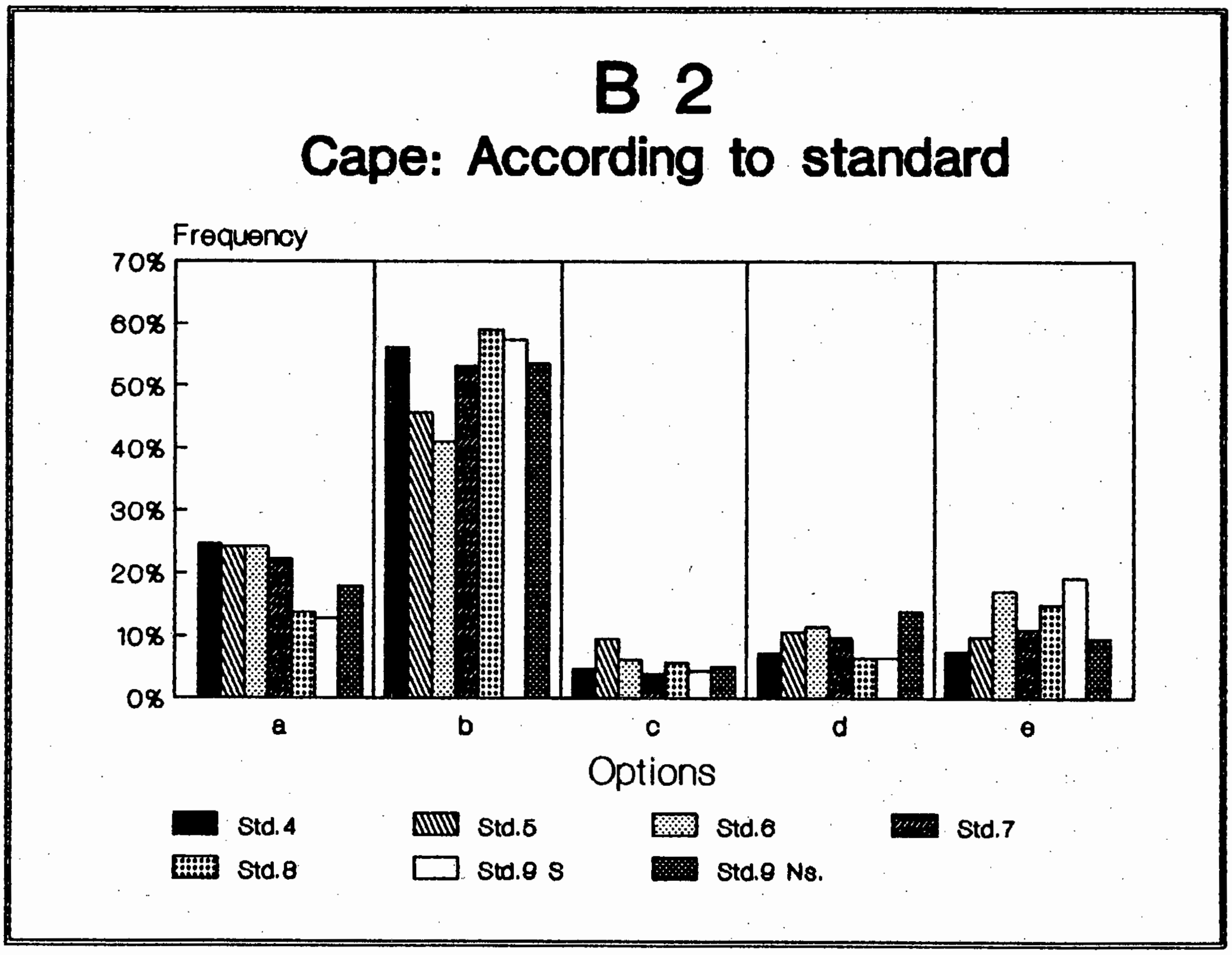
that the lighter ball will go higher than the heavier one.

2. 47% of the sample select option b, the option which suggests that the lighter ball will go twice as high as the heavier one.
3. 68% of the sample select options which suggest that the lighter ball will go higher than the heavy one.
4. 9% of the sample select option c, the option which suggests that the heavier ball will go higher than the lighter one.
5. 11% of the sample select option d, the option which suggests that the heavier ball will go twice as high as the lighter one.
6. 20% of the sample select options which suggest that the heavier ball will go higher than the lighter one.
7. 13% of the sample select option e, the option which suggests that the two balls will reach the same height.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

1. Option b receives overwhelming support from pupils in all the standards. However, pupils in standards 5 and 6 do not support it quite as keenly as pupils in the other standards do.
2. The frequencies with which option e is selected by pupils in all the standards is rather small but it is interesting to note that the standard 6 pupils and the standard 9 science

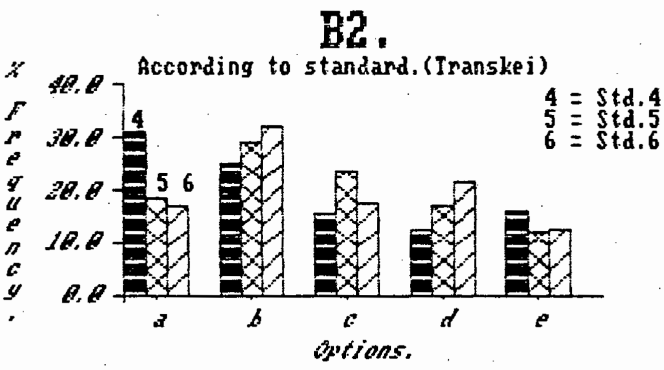
pupils select this option with higher frequencies than pupils in all of the other standards.

3. It is clear from the graph that the great majority of pupils in each of the standards favour options which suggest that the lighter ball will reach a greater height than the heavier one.

4. There is small but consistent support for options c and d by pupils in all of the standards. These options suggest that the heavier ball will reach a greater height than the lighter one.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

1. No one particular option is selected by a very large proportion of the pupils in each of the standards.

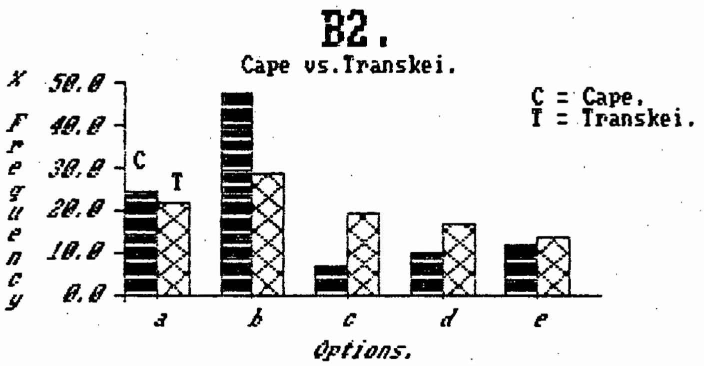
2. Option b is the most popular option with pupils in standards 5 and 6

3. Standard 4 pupils find option a much more attractive than pupils in any of the other standards.

4. There is a fair amount of support for options c and d by pupils in all of the standards.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options.



Note:

1. There are only small differences in the frequencies with which the two groups select options a and e.

2. 12% of the pupils in the Cape and 13% of the pupils in Transkei select option e.

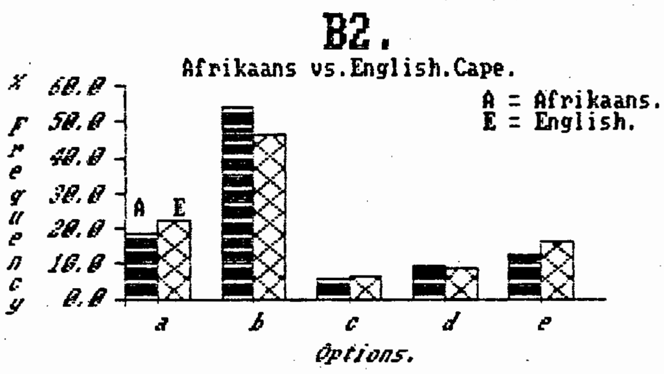
3. 24% of pupils in the Cape and 22% of pupils in Transkei select option a.

4. There are fairly large differences in the frequencies with which the two groups select the rest of the options

5. Option b is selected by 48% of pupils in the Cape and 29% of pupils in Transkei.
6. 72% of pupils in the Cape and 51% of pupils in Transkei select options which suggest that the lighter ball will reach a greater height than the heavier one.
7. 17% of pupils in the Cape and 36% of pupils in Transkei select options which suggest that the heavier ball will reach a greater height than the lighter one.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



Note:

1. There is a small difference in the frequencies with which the two groups select option b.
2. 54% of Afrikaans-and 46% of English speaking pupils select option b.

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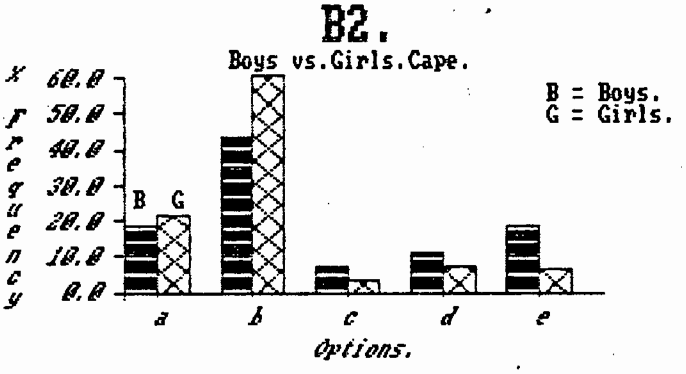
3. 72% of Afrikaans-speaking and 68% of English-speaking pupils select options which suggest that the lighter ball will reach a greater height than the heavier ball.
4. 15% of Afrikaans-and-English-speaking pupils select options which suggest that the heavier ball will reach a greater height than the lighter one.
5. 13% of Afrikaans-speaking and 17% of English-speaking pupils select option e.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

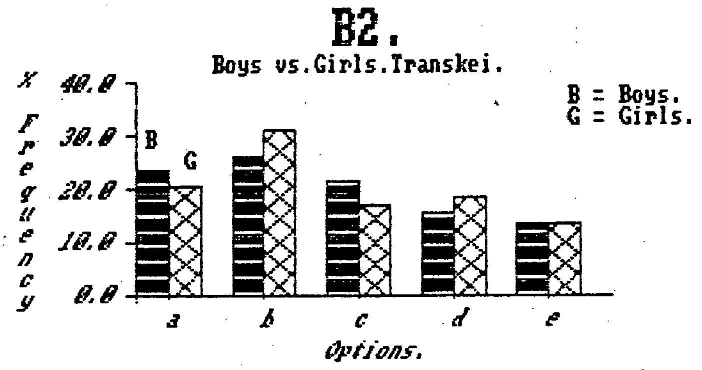


Note:

1. There are fairly large differences in the frequencies with which the two groups select options b and e.
2. 44% of the boys and 61% of the girls select option b.
3. 62% of the boys and 73% of the girls select options which suggest that the lighter ball will reach a greater height than the heavier one.
4. 19% of the boys and 6% of the girls select option e.
5. 19% of the boys and 11% of the girls select options which suggest that the heavier ball will reach a greater height than the lighter one.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

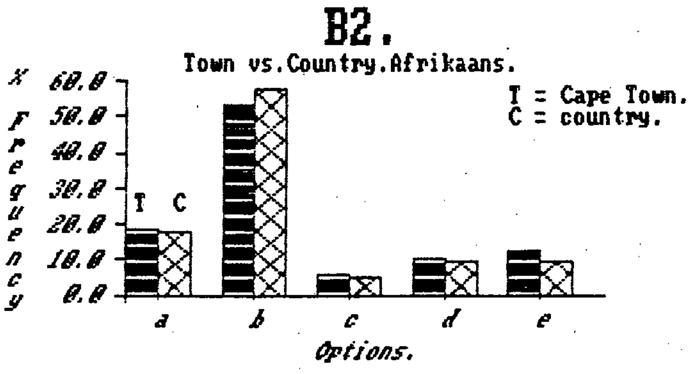


Note:

1. There are only small differences in the frequencies with which the two groups select options a, b, c, and d.
2. 26% of the boys and 31% of the girls select option b.
3. 49% of the boys and 51% of the girls select options which suggest that the lighter ball will reach a greater height than the heavier one.
4. 37% of the boys and 35% of the girls select options which suggest that the heavier ball will reach a greater height than the lighter one.
5. 13% of both boys and girls select option e.

(f) Comparing Town and Country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils attending schools in Cape Town and country towns select the different options.



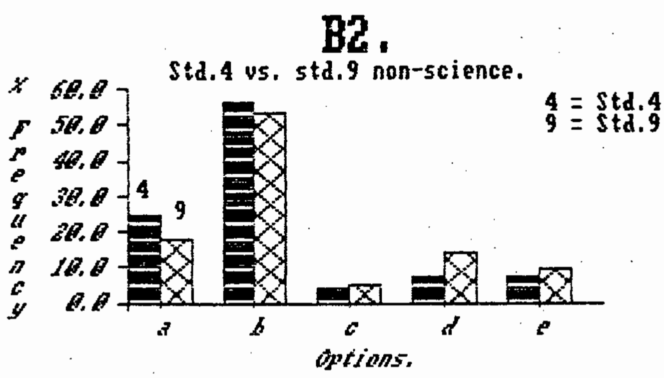
Note:

1. The different options are selected with very similar frequencies by the two groups. There are small differences in the frequencies with which the two groups select options b and e.
2. 53% of pupils from Cape Town and 58% of pupils from country towns select option b.
3. 71% of pupils from Cape Town and 76% of pupils from country towns select options which suggest that the lighter ball will reach a greater height than the heavier one.
4. 13%,of pupils from Cape Town and 9% of pupils from country towns select option e.
5. About 15% of the pupils from both groups select options which suggest that the heavier ball will reach a greater height than the lighter one.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science at school select the different options.

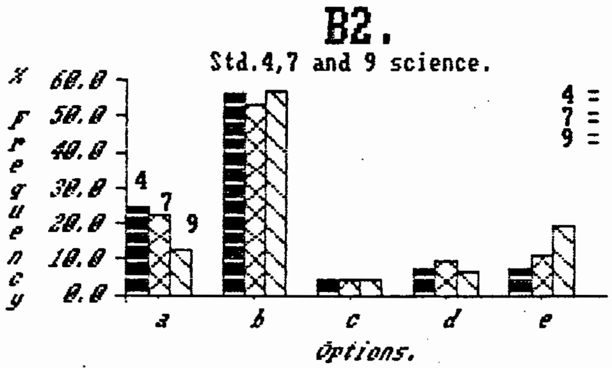


Note:

1. There are small differences in the frequencies with which the two groups select options a, b and d.
2. 81% of the pupils in standard 4 and 72% of the pupils in the standard 9 group select options which suggest that the lighter ball will reach the greater height.
3. 12% of the standard 4 and 19% of the standard 9 pupils select options which suggest that the heavier ball will reach a greater height than the lighter one

2. Standard 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standards 4, 7 and 9 pupils who do science at school select the different options.



Note:

1. The frequencies with which option b is selected by all three of the groups is the outstanding feature of this graph. Although the frequencies with which option e is selected increases steadily with the higher standards, this increase is small and probably too small to enable us to draw any important conclusions.
2. The proportion of pupils who select options which suggest that the heavier ball will reach the greater height is remarkably similar in all three of the standards.

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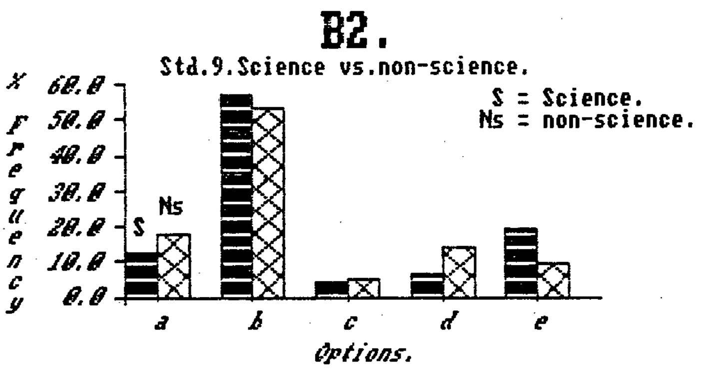
3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.



Note:

1. There are small differences in the frequencies with which the two groups select most of the options.
2. 70% of the science and 71% of the non-science pupils select options which suggest that the lighter ball will reach a greater height than the heavier one.
3. 19% of the science and 10% of the non-science pupils select option e.
4. 11% of the science and 19% of the non-science pupils select options which suggest that the heavier ball will reach a greater height than the lighter one.

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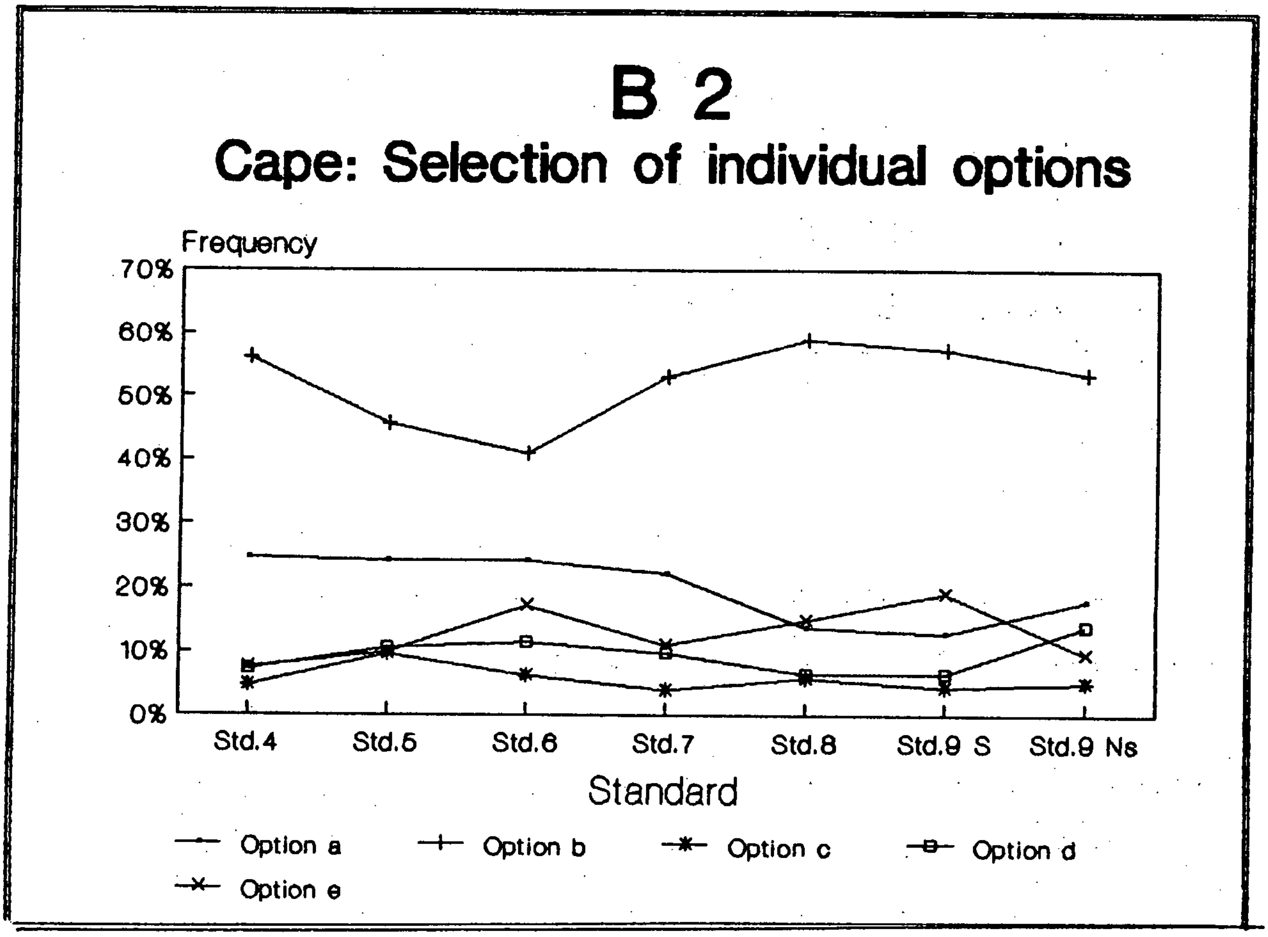
(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by the different standards.



Note:

1. Option b is a popular choice with pupils in all of the standards, but it reaches a minimum with the standard 6 pupils.
2. There are peaks at standards 6 and 9 in the proportion of pupils who select option e
3. There is small but consistent support for options c and d by pupils in all of the standards

Summary:

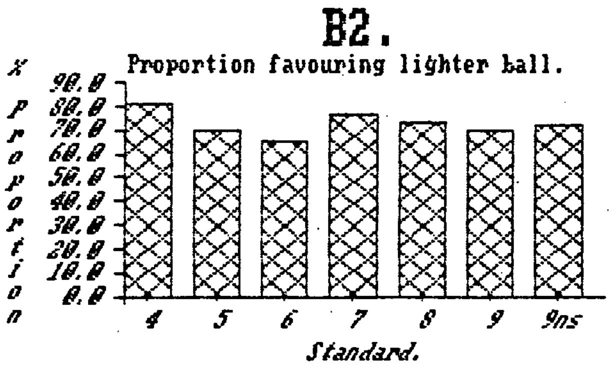
1. When we examine the overall picture we find that:

   13% of the sample believe that the balls will reach the same height;
   68% of the sample believe that the lighter ball will reach a greater height than the heavier one while 47% of the sample believe that the lighter ball will actually reach twice the height of the heavier one;
   20% of the sample believe that the heavier ball will reach the greater height.

2. When we compare the frequencies with which pupils in the different standards in schools in the Cape select the different options, we find that:

   by far the greater majority of pupils in each of the standards believe that the lighter ball will reach twice the height of the heavier one. However, although this notion was also very popular with the pupils in standards 5 and 6, it is not quite as popular with these pupils as it is with pupils in the other standards.

The following graph compares the proportion of the pupils in each of the standards who select options indicating a belief that the lighter ball will reach a greater height than the heavier one.



The graph clearly shows that the greater majority of pupils in each of the standards share this belief. However, it is not as widely held by pupils in standards 5 and 6 as in the other standards.

A small but consistent proportion of pupils in each of the standards believe that the heavier ball will reach a greater height than the lighter one.

In Transkei we find that:

no one particular option is selected overwhelmingly, but inspite of this, the majority of the pupils believe that the lighter ball will reach a greater height than the heavier one;

there was a fairly substantial proportion of the pupils in each of the standards who believe that the heavier ball will reach a greater height than the lighter one.

3. When we compare the Cape and Transkei we find that:

   while only 51% of the pupils in Transkei believe that the lighter ball will reach a greater height than the heavier one, 72% of the pupils in the Cape hold this belief. Furthermore, 48% of the pupils in the Cape believe that the lighter ball will reach twice the height of the heavier one. This belief was shared by only 29% of the pupils in Transkei.
   17% of the pupils in the Cape and 36% of the pupils in Transkei believe that the heavier ball will reach the greater height.

4. When we we compare Afrikaans-and-English-speaking pupils at school in the Cape we find that:

   72% of Afrikaans-and 68% of English-speaking pupils believe that the lighter ball will reach the greater height. The belief that the lighter ball will reach twice as high as the heavier one was held by 54% of Afrikaans-and 46% of English-speaking pupils.
   13% of Afrikaans-and 17% of English-speaking pupils believe that the balls will reach the same height.

5. When we compare boys and girls at school in the Cape, we find that:

   62% of the boys and 73% of the girls believe that the lighter ball will reach the greater height. The belief that the lighter ball will reach twice the height of the heavier one

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was held by 44% of the boys and 61% of the girls;

19% of the boys and 6% of the girls believe that the balls will reach the same height;

19% of the boys and 11% of the girls believe that the heavier ball will reach the greater height.

In Transkei we find that:

49% of the boys and 51% of the girls believe that the lighter ball will reach the greater height. 26% of the boys and 31% of the girls believe that the lighter ball will reach twice the height of the heavier one.

6. When we compare Afrikaans-speaking pupils at schools in Cape Town and country towns, we find that:

71% of pupils at school in Cape Town and 76% of pupils at school in country towns believe that the lighter ball will reach the greater height. 53% of pupils in Cape Town and 58% of pupils in country schools believe that the lighter ball will reach twice the height of the heavier one.

13% of pupils in Cape Town and 9% of pupils in country schools believe that the balls will reach the same height.

7. When we compare some of the standards we find that the belief that the lighter ball will reach the greater height to be so prevalent that pupils who hold other beliefs form only a small proportion of the standard. There is some evidence that the belief becomes less popular with pupils in the higher standards but not dramatically so.

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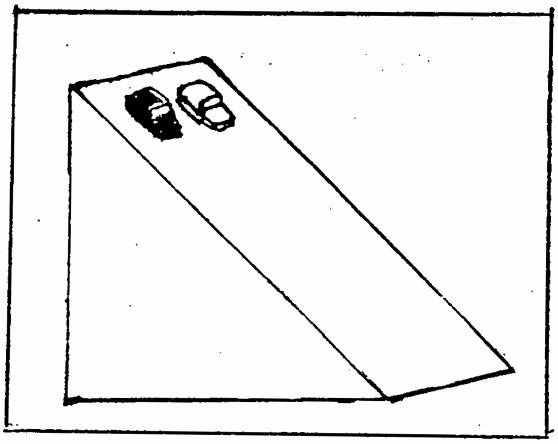
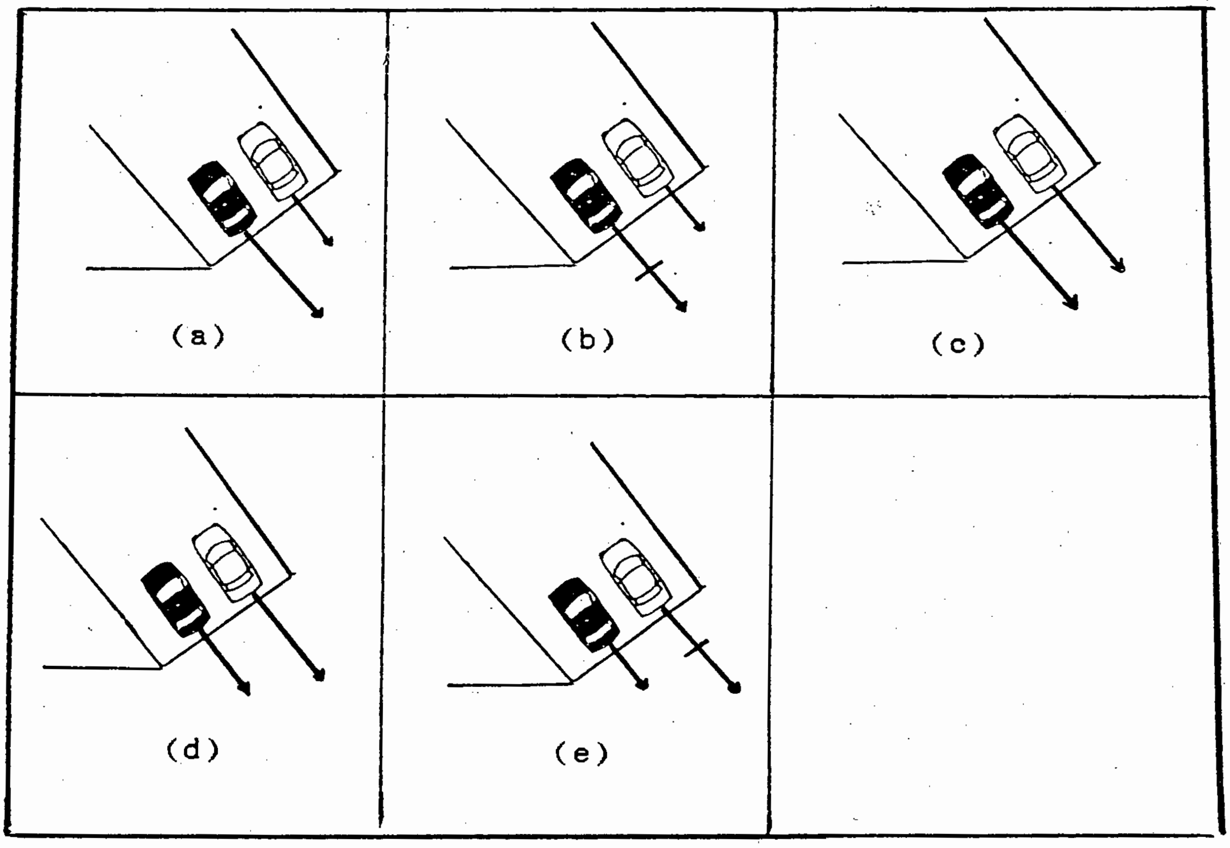
8. A comparison of the selection of the individual options across the different standards clearly indicates the popularity of of the belief that the lighter object will reach twice the height of the heavier one.

Question B 3

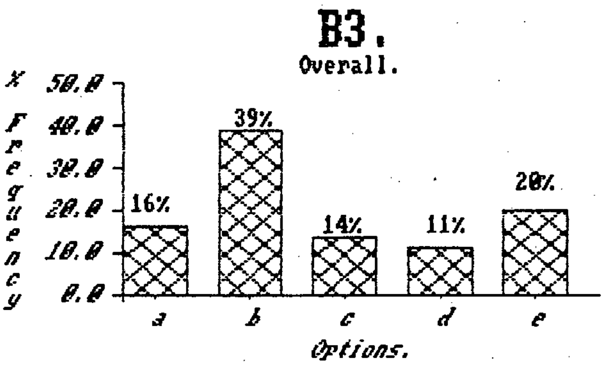
The sketch shows two little cars placed on an incline or ramp by a boy who is racing them against each other. The black car is twice as heavy as the white one. He lets them go from the same point on the incline and at the same time. The sketch which best shows the relative <u>speeds</u> with which the cars reach the bottom of the incline, is:





(a) **The overall picture:**

The following graph shows the frequencies with which the whole sample select the different options.



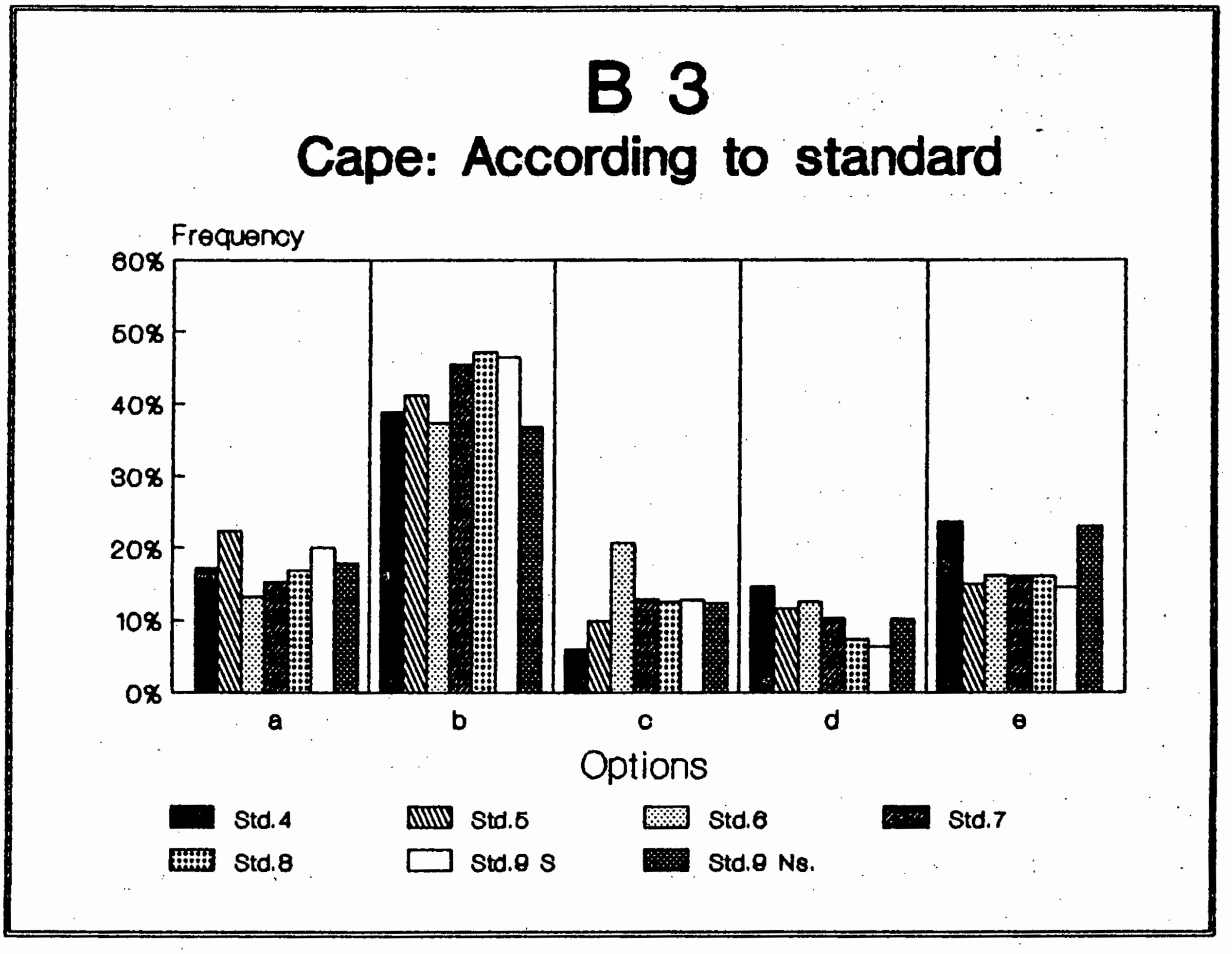
Note:

1. 16% of the sample select option a, the option which suggests that the heavier car will have the greater speed.
2. 39% of the sample select option b, the option which suggests that the heavier car will be moving twice as fast as the lighter one.
3. 55% of the sample select options which suggest that the heavier car will have the greater speed.
4. 14% of the sample select option c, the option which suggests that the two cars will have the same speed.
5. 20% of the sample select option e, the option which suggests that the lighter car will be moving twice as fast as the heavier one.
6. 31% of the sample select options which suggest that the lighter car will have the greater speed.

(b) According to standard:

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

1. Option b is the most popular option with pupils in all of the standards but, the standard 6 group find it a little less attractive than the other groups.

2. The standard 6 group also find option a a little less attractive than the other groups.

3. Of all of the groups the standard 6 group find option c the most attractive and the standard 4 group find it the least

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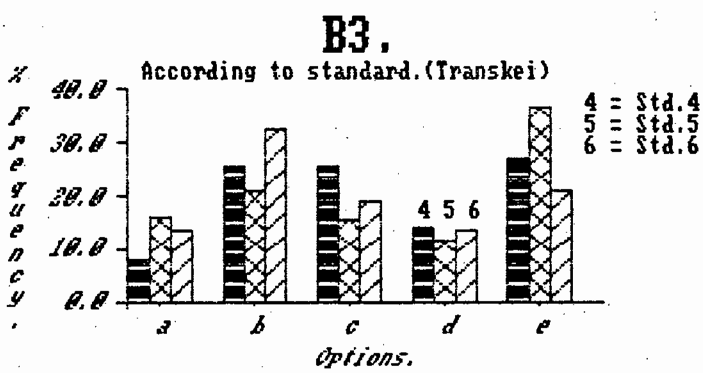
attractive.

4. Of all of the groups the standard 4 and standard 9 non-science group find option e the most attractive.

5. There is consistent support from all of the standards for options d and e.

2. <u>In Transkei:</u>

The following graph shows the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

1. No single option stands out as the firm favourite with pupils in all of the classes

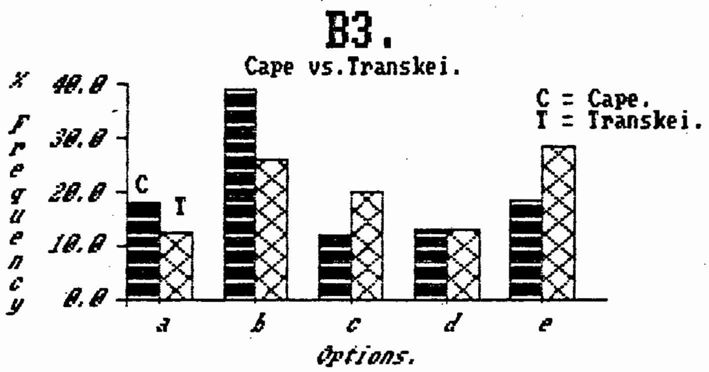
2. The standard 4 group are fairly evenly divided over options b, c and e.

3. The standard 5 group prefer option e.

4. The standard 6 group prefer option b.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options.



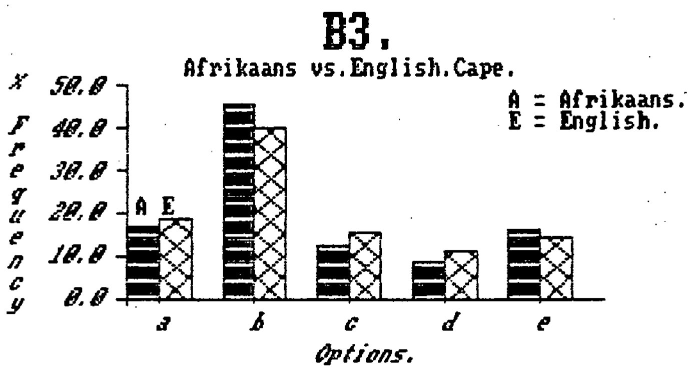
Note:

1. There are fairly large differences in the frequencies with which the two groups select options a, b, c, and e.
2. 13% of the pupils in both groups select option d.
3. 18% of Cape and 13% of Transkei pupils select option a.
4. 39% of Cape and 26% of Transkei pupils select option b.
5. 57% of Cape and 39% of Transkei pupils select options which suggest that the heavier car will have the greater speed.
6. 12% of Cape and 20% of Transkei pupils select option c.
7. 18% of Cape and 29% of Transkei pupils select option e
8. 31% of Cape and 42% of Transkei pupils select options which suggest that the lighter car will have the greater speed.
9. The majority of Transkei pupils select options which suggest that the lighter car will have the greater speed while the

majority of Cape pupils select options which suggest that the heavier car will have the greater speed.

(d) **Comparing language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



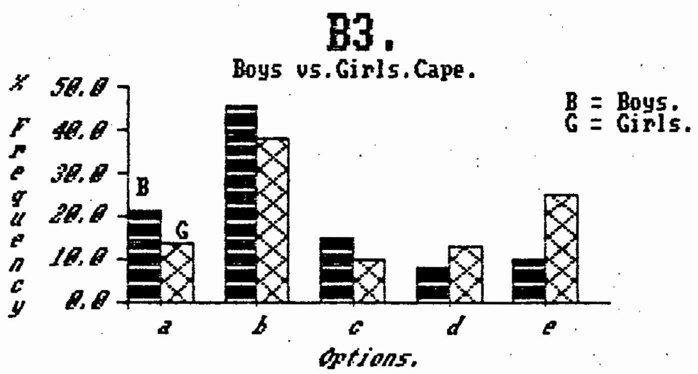
Note:

1. 46% of Afrikaans-and 40% of English-speaking pupils select option b.
2. 63% of Afrikaans-and 59% of English-speaking pupils select options which suggest that the heavier car will have the greater speed.
3. 12% of Afrikaans-and 16% of English-speaking pupils select option c.
4. About 25% of pupils in both the groups select options which suggest that the lighter car will have the greater speed.

(e) Comparing the sexes:

1. <u>In the Cape</u>:

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

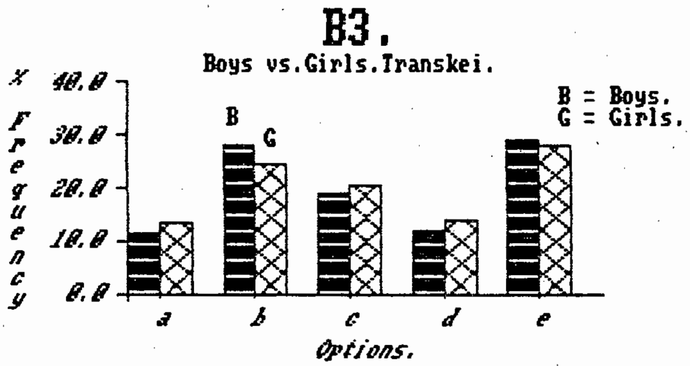


Note:

1. There are obvious differences in the frequencies with which the two groups select all of the options.
2. 21% of the boys and 14% of the girls select option a.
3. 46% of the boys and 38% of the girls select option b.
3. 67% of the boys and 52% of the girls select options which suggest that the heavier car will have the greater speed.
4. 15% of the boys and 10% of the girls select option c.
5. 10% of the boys and 25% of the girls select option e.
6. 18% of the boys and 38% of the girls select options which suggest that the lighter car will have the greater speed.

2. <u>In Transkei</u>:

The following graph compares the frquency with which boys and girls in schools in Transkei select the different options.

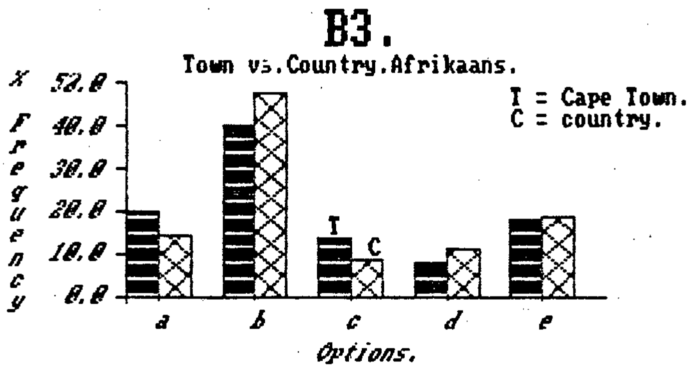


Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.
2. About 39% of both groups select options which suggest that the heavier car will have the greater speed.
3. About 41% of both groups select options which suggest that the lighter car will have the greater speed.

(f) Comparing Town and Country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils who attend schools in Cape Town and country towns select the different options.



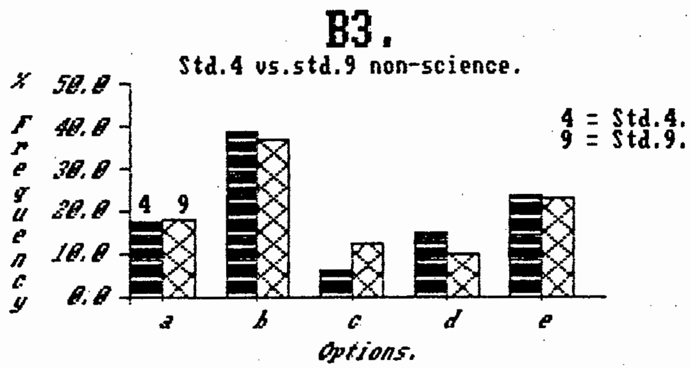
Note:

1. There are only small differences in the frequencies with which the two groups select options a, b and c.
2. 20% of the pupils from Cape Town and 14% of the pupils from country towns select option a.
3. 40% of the pupils from Cape Town and 48% of the pupils from country towns select option b.
4. 60% of the pupils from Cape Town and 62% of the pupils from country towns select options which suggest that the heavier car will have the greater speed.
5. 13% of the pupils from Cape Town and 8% of the pupils from country towns select option c.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science at school select the different options.

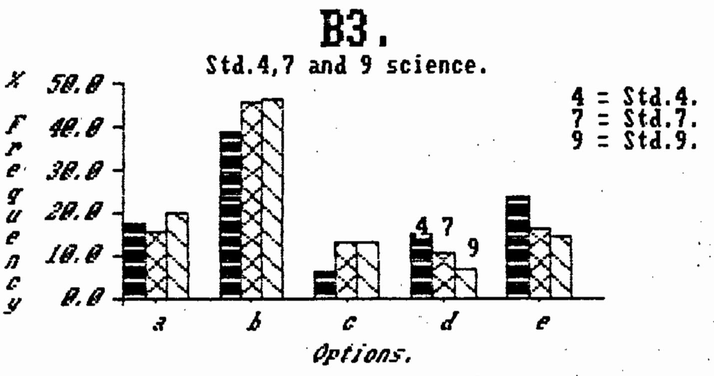


Note:

1. There is no noteworthy difference in the proportion of pupils from the two groups who select options which suggest that the heavier car will have the greater speed.
2. 6% of the pupils in standard 4 and 12% of the pupils in standard 9 select option c.
3. 38% of the pupils in standard 4 and 33% of the pupils in standard 9 select options which suggest that the lighter car will have the greater speed.

2. <u>Standards 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which standards 4, 7 and 9 pupils who do science at school select the different options.

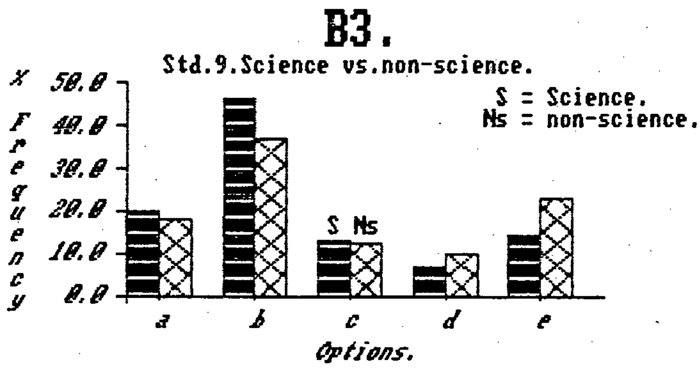


Note:

1. While the majority of the pupils in each of the standards select options which suggest that the heavier car will have the greater speed, there is an interesting decrease in the proportion of pupils who select options suggesting that the lighter car will have the greater speed. These options, options d and e, are selected by 38% of the standard 4, 26% of the standard 7 and 21% of the standard 9 science pupils.

3. Standard 9 science and non-science pupils:

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.

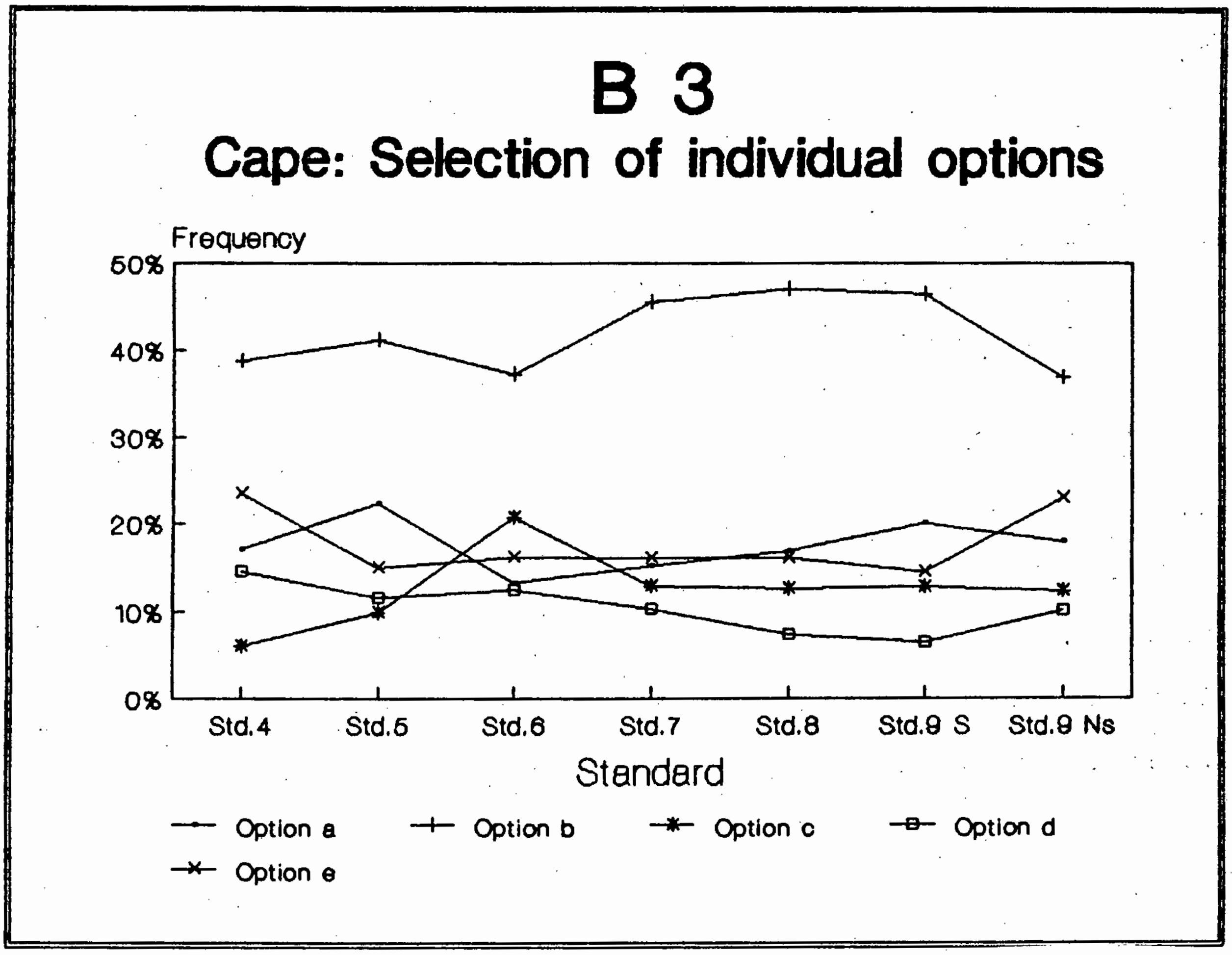


Note:

1. 46% of the science and 37% of the non-science pupils select option b.
2. 66% of the science and 55% of the non-science pupils select options which suggest that the heavier car will have the greater speed.
3. There is no difference in the frequencies with which the two groups select option c.
4. 21% of the science and 33% of the non-science group select options which suggest that the lighter car will have the greater speed.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by the different standards.



Note:

1. Option b is popular with all of the groups but its popularity reaches a minimum with the standard 6 group.
2. There is a peak in the selection of option c with the standard 6 group.

Summary:

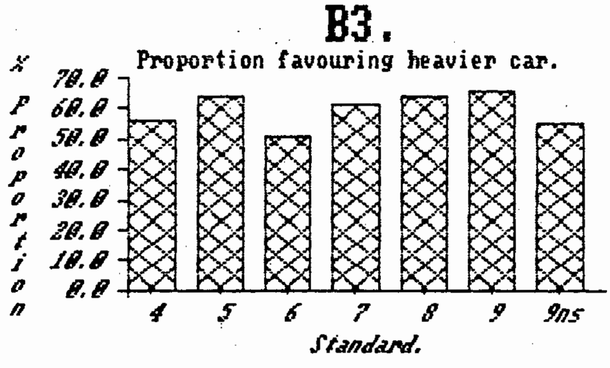
1. When we examin the overall picture we find that:

   55% of the sample believe that the heavier car will be moving the faster than the lighter car. 39% of the sample believe that the heavier car will actually be moving twice as fast as the lighter one.

   31% of the sample believe that the lighter car will be moving the faster than the heavier one. 20% believe that the lighter car will actually be moving twice as fast as the heavier car.

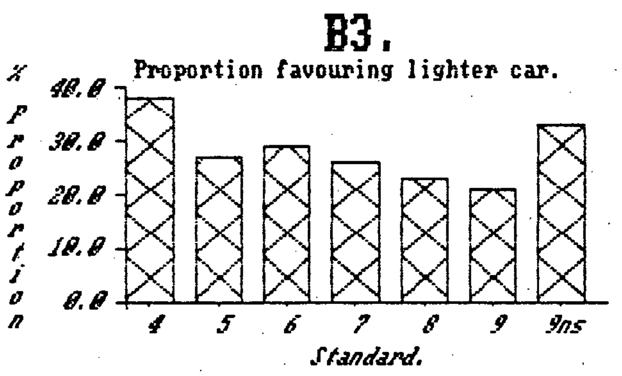
2. When we compare the pupils in different standards at schools in the Cape we find that:

   although the majority of pupils in all of the standards believe that the heavier car will move twice as fast as the lighter one, this belief is not held by quite as large a proportion of the standard 6 pupils. The following graph, which compares the proportion of pupils in each of the standards who share this belief, illustrates this clearly.



In all of the classes there is a fairly large proportion of the pupils who believe that the lighter car will move the faster of the two. This belief is much more popular with pupils in standard 4 and in the standard 9 non-science group than with pupils in the other standards, but the belief is nevertheless shared by a substantial proportion of the pupils in all of the classes.

The following graph compares the proportion of pupils in each of the standards who believe that the lighter car will be moving the faster of the two.



It is interesting to notice that the proportion of pupils who hold this belief decreases across the standards to reach a minimum with the standard 9 science pupils.

In Transkei we find that pupils in each of the different standards favoured a different belief by a relatively small margin. The standard 6 pupils favoured the belief that the heavier car will move twice as fast as the lighter one. The standard 5 pupils, again, believe that the lighter car will move twice as fast as the heavier one and the standard 4 pupils shared these two beliefs with a belief that the cars will be moving equally fast.

3. When we compare pupils in standards 4, 5 and 6 in schools in the Cape and Transkei we find that:

   while the majority of pupils in the Cape, (57%) believe that the heavier car will move the faster of the two, the majority of the pupils in Transkei, (42%) believe that the lighter car will move the faster of the two;
   39% of the pupils in the Transkei share the belief that the heavier car will move the faster of the two while 31% of the pupils in the Cape believe that the lighter car will move the faster of the two.

4. When we compare Afrikaans-and-English-speaking pupils we find that:

   63% of Afrikaans-and 59% of English-speaking pupils believe that the heavier car will move the faster of the two, with 46% of Afrikaans-and 40% of English-speaking pupils believing that it would actually be moving twice as fast as the lighter one; about 25% of pupils in both groups believe that the lighter car will move the faster of the two.

5. When we compare boys and girls at schools in the Cape, we find that:

67% of the boys and 52% of the girls believe that the heavier car will be moving the faster of the two, with 46% of the boys and 38% of the girls believing that it will be moving twice as fast as the lighter car;
18% of the boys and 38% of the girls believe that the lighter car will be moving the faster of the two, with 10% of the boys and 25% of the girls believing that it will be moving twice as fast as the heavier car.

In Transkei we find no real difference in the frequencies with which boys and girls select the different options, with about 39% of the pupils in both of the groups believing that the heavier car will be moving the faster of the two and about 41% believing that the lighter car would be moving the faster of the two.

6. When we compare Afrikaans-speaking pupils from schools in Cape Town and country towns we find that:

60% of the pupils from schools in Cape Town and 62% of pupils from schools in country towns believe that the heavier car will be moving the faster of the two. 40% of the pupils from schools in the city and 48% of the pupils from schools in the country believe that the heavier car will be moving twice as fast as the lighter one.

7 When we compare pupils from some of the standards we find that:

there was really no difference between the proportion of standard 4 pupils and standard 9 non-science pupils who believe that the heavier car will be moving the faster of the two but that 38% of the stanndard 4 group and 33% of the standard 9 group believe that the lighter car will be moving the faster of the two.

66% of standard 9 pupils who do and 55% who do not do science believe that the heavier car will be moving the faster of the two with 46% of the science group and 37% of the non-science group believing that it will be moving twice as fast as the lighter one.

21% of the science group and 31% of the non-science group believe that the lighter car will actually be moving the faster of the two.

8. A comparison of the frequencies with which the individual options are selected by pupils in the different standards clearly shows the popularity of option b and as well as the small peak in the frequencies with which option c is selected by pupils in standard 6.

Chapter 9

Relative speed on overtaking

Overview

Introduction:

Towbridge and McDermott (1980) have reported that about 33% of the students in their sample confused the concepts of speed and position. They believed that when two objects were next to each other, then they were travelling at the same speed. Some students believed that to be ahead means to have the greater speed.

Results:

In our investigation we find that:

1. 26% of our total sample believe that at the moment of overtaking the two objects have the same speed.
   6% believe that the object initially in front has the greater speed. The sketch used may actually suggest that the girl is slightly ahead of the boy. These results are in agreement with the work reported by Towbridge and McDermott.

2. In schools in the Cape the belief that the bodies are travelling with the same speed is much more popular with the pupils in standards 4 and 5. Interestingly, the belief is less widely held by pupils in standards 6, 7 and 8 but then increased in popularity with pupils in standard 9.

   In Transkei there is some evidence that the belief is less popular with the standard 6 pupils than with standard 4 and 5

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pupils.

3. The belief that the body initially in front has the greater speed is much more widely held in Transkei by pupils in standards 4, 5 and 6 than in the Cape. Pupils in this group in the Cape tend to believe that the bodies have the same speed.

4. 23% of both Afrikaans-and-English-speaking pupils believe that the two bodies have the same speed upon overtaking while 3% of the pupils in both groups believe that the body initially ahead has the greater speed.

5. The belief that the two objects have the same speed is held by a larger proportion of girls than boys in schools in the Cape.

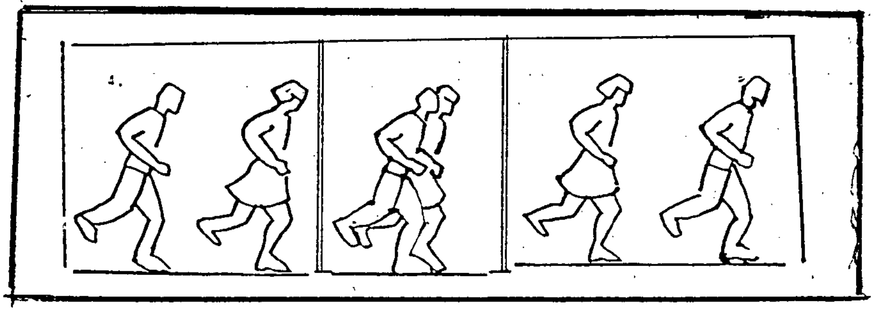
   In Transkei there is no difference between boys and girls as far as this belief is concerned.

6. The belief that the bodies have the same speed upon overtaking is slightly more prevalent amongst Afrikaans-speaking pupils in country than in Cape Town schools.

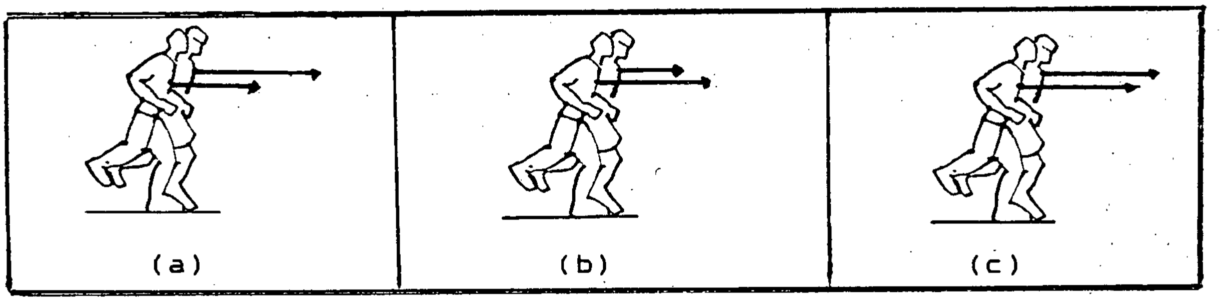
Relative speeds on overtaking:

We used the following situation to investigate the ideas which our pupils have about the relative speeds with which two bodies are moving when the one overtakes the other.

Question B 4

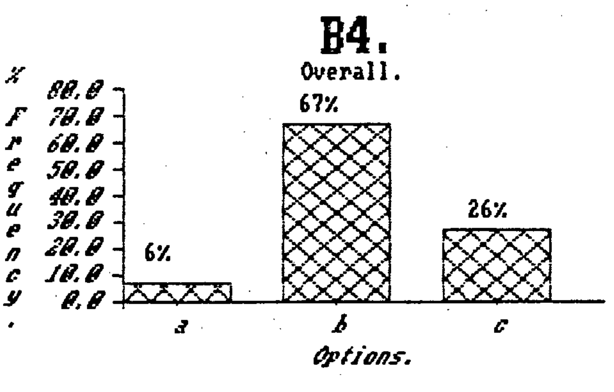


The sketches show a boy running after, catching up with and passing a girl in a race. The sketch which best compares their speeds at the moment the boy is next to the girl, is:



(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample



Note:

1. 6% of the sample select option a, the option which suggests that the girl is running faster than the boy.
2. 67% of the sample select option b, the option which suggests that the boy is running faster than the girl.
3. 26% of the sample select option c, the option which suggests that they are running equally fast.

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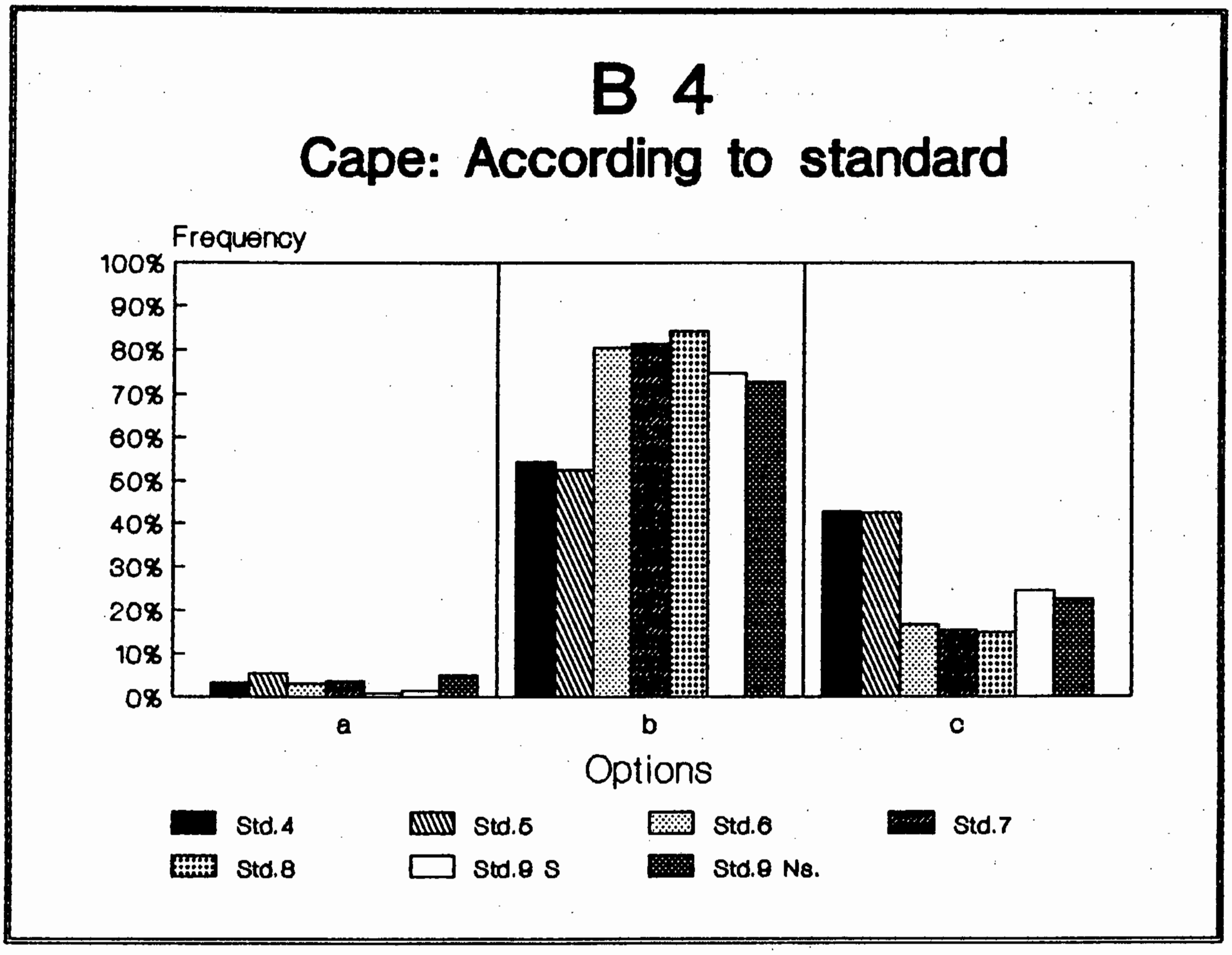
(b) According to standard:

1. In the Cape:

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

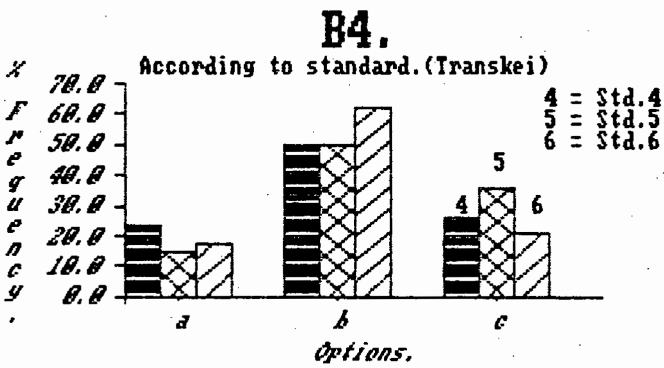
1. Option a receives very little support from pupils in all of the standards.
2. While option b is the most popular choice with pupils in all of the standards, standards 4 and 5 pupils do not select it with as high a frequency as do pupils in the other standards.
3. Standards 6, 7 and 8 pupils find option b more attractive than standard 9 pupils.

4. Option c receives fair support from pupils in all of the standards but fairly large support from standards 4 and 5 pupils.

5. Standard 9 pupils find option c more attractive than pupils in standards 6, 7 and 8.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

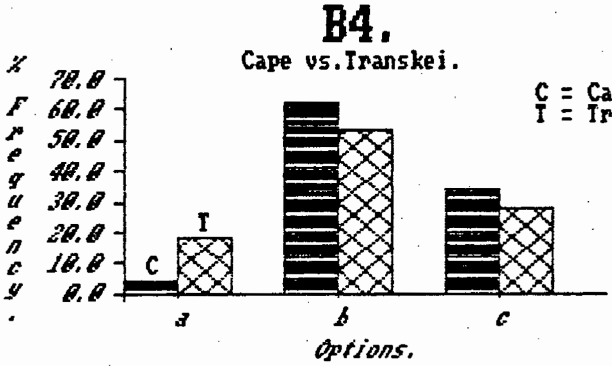
1. While option b is the most popular option with pupils in all of the standards, the other two options received fair support from all of the standards as well.

2. Option b is the most popular option with the pupils in standard 6.

3. Pupils in standards 4 and 5 find option c more attractive than those in standard 6.

(c) Comparing the Cape and Transkei:

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.

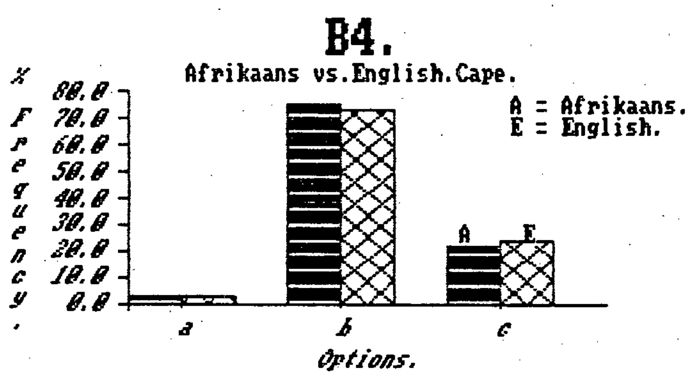


Note:

1. There are differences in the frequencies with which the two groups select each of the three options
2. 4% of the pupils in schools in the Cape and 18% of pupils in schools in Transkei select option a.
3. 62% of pupils in schools in the Cape and 54% of pupils in schools in Transkei select option b.
4. 34% of pupils in schools in the Cape and 28% of pupils in schools in Transkei select option c.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



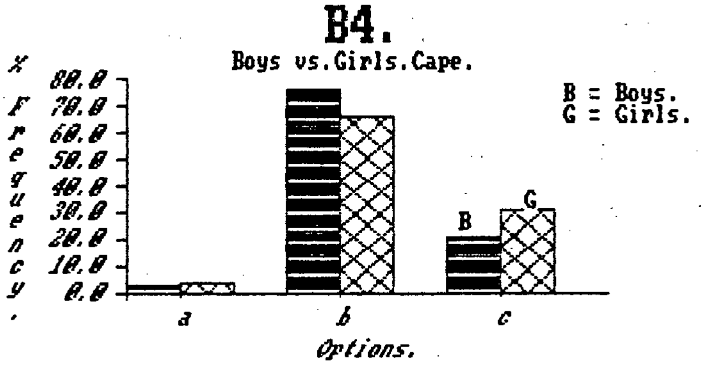
Note:

1. There is no noteworthy differences in the frequencies with which the two groups select the different options.
2. About 3% of the pupils in both groups select option a.
3. About 74% of the pupils in both groups select option b.
4. About 23% of the pupils in both groups select option c.

(e) Comparing the sexes:

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls at schools in the Cape select the different options.

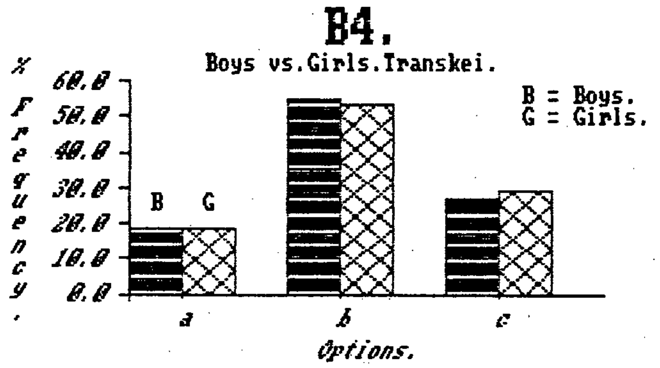


Note:

1. There are fairly large differences in the frequencies with which the two groups select options b and c.
2. 76% of the boys and 66% of the girls select option b.
3. 21% of the boys and 31% of the girls select option c.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls at schools in Transkei select the different options.



Note:

1. There are no noteworthy differences in the frequencies with which the two groups select the different options.

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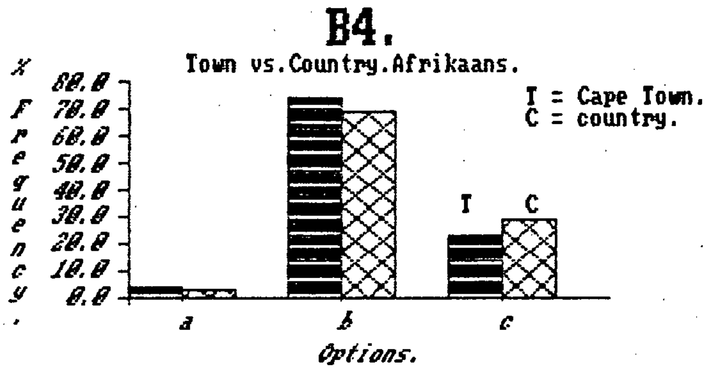
(f) Comparing pupils from Town and country areas:

The following graph compares the frequencies with which Afrikaans-speaking pupils attending schools in Cape Town and country towns select the different options.



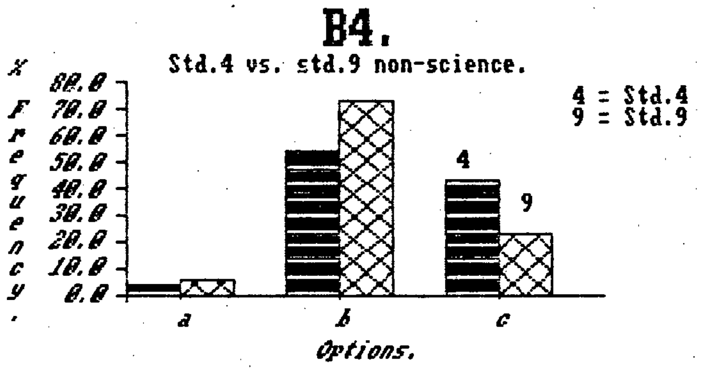
Note:

1. There are only small differences in the frequencies with which the two groups select options b and c.
2. 74% of pupils in Cape Town and 69% of pupils in country towns select option b.
3. 22% of pupils in Cape Town and 28% of pupils in country towns select option c.

(h) Comparing some standards:

1. Standard 4 and standard 9 non-science pupils.

The following graph compares the frequencies with which standards 4 and 9 non-science pupils select the different options.

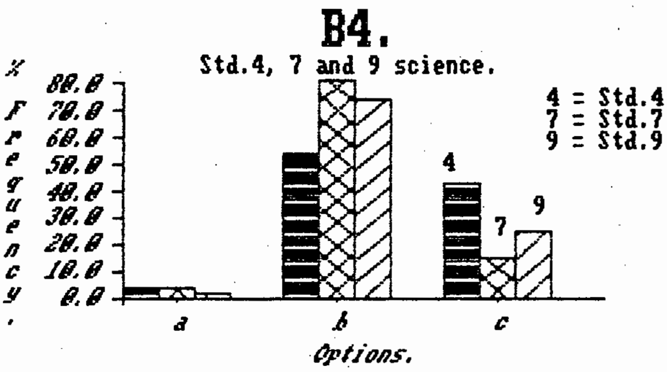


Note:

1. There are fairly large differences in the frequencies with which the two groups select options b and c.
2. 54% of standard 4 and 73% of standard 9 pupils select option b.
3. 43% of standard 4 and 22% of standard 9 pupils select option c.

2. Standard 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.

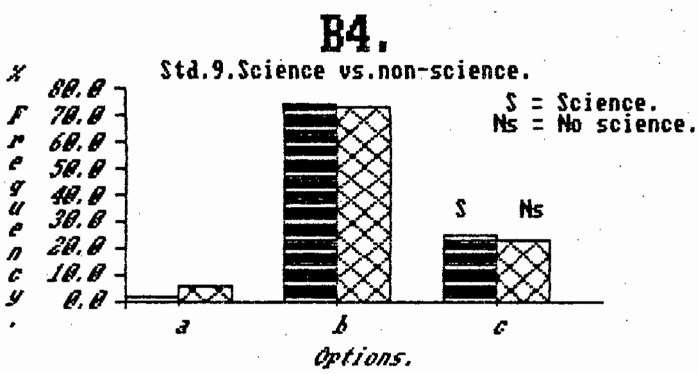


Note:

1. Option a received very little support from all three groups.
2. The standard 4 group is fairly evenly divided between option b and c
3. Although both the standard 7 and 9 groups find option b the most popular, the standard 7 pupils find it somewhat more popular than the standard 9 group.
4. Interestingly, 24% of the standard 9 science pupils select option c, as opposed to only 15% of the standard 7 pupils.

3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.

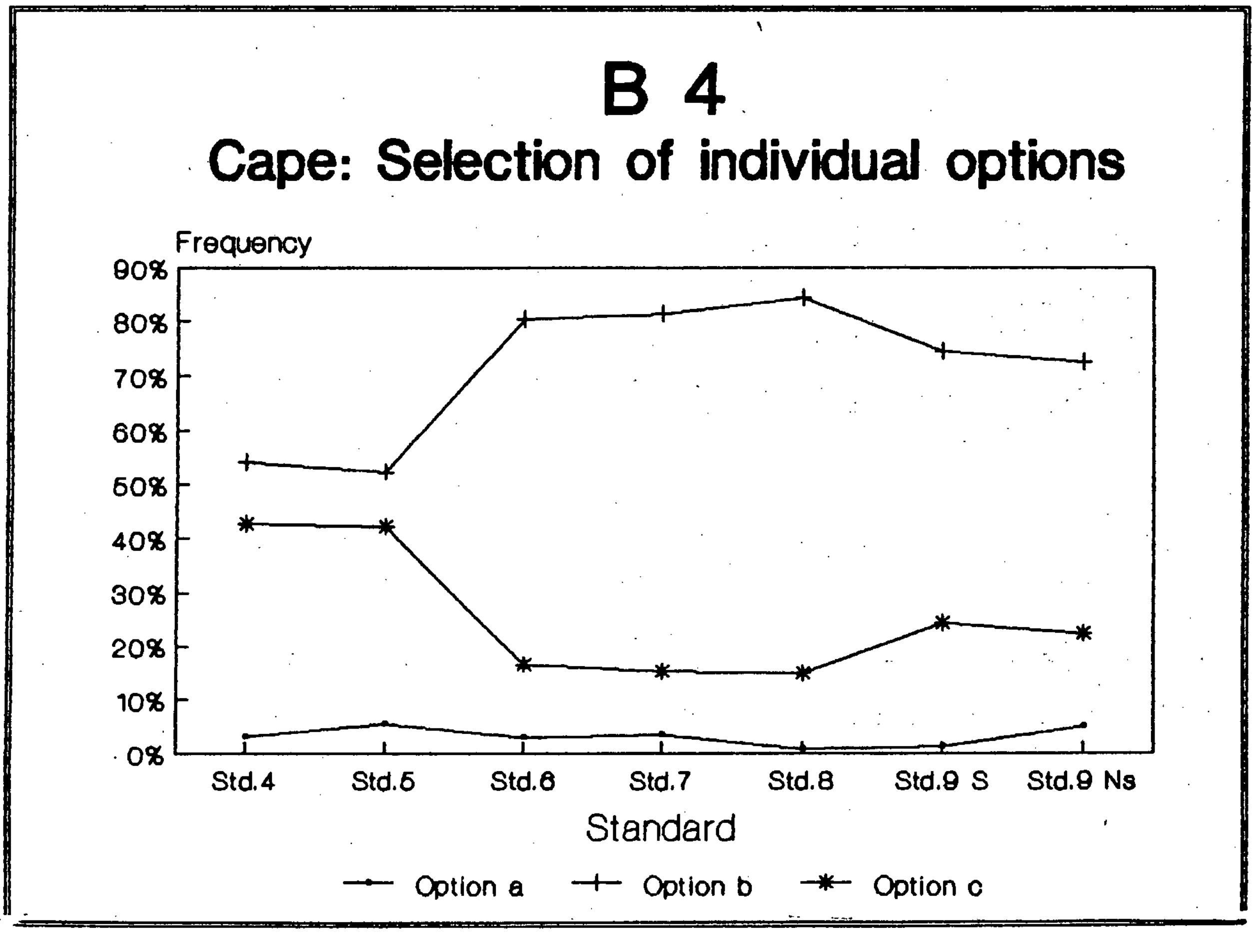


Note:

1. There is no noteworthy differences in the frequencies with which the two groups select the different options.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by pupils in the different standards.



Note:

1. The small difference in the frequencies with which option b and c are selected by pupils in standard 4 and 5.
2. The increase in frequencies with which option b is selected across standards 6, 7 and 8 and a decrease to the standard 9 groups.

Summary:

1. When we examine the overall picture we find that at the moment when the two bodies are opposite each other during the act of overtaking:

   6% of our sample believe that the body being overtaken has the greater speed;

   67% of the pupils in our sample believe that the overtaker has the greater speed;

   26% of the pupils in our sample believe that the speed of the two bodies is equal.

2. When we compare the frequencies with which pupils in the different standards in schools in the Cape select the different options, we find that:

   a very small proportion of the pupils in all of the classes believe that the girl is running faster than the boy when he overtakes her;

   the majority of pupils in each of the standards believe that the boy is running faster than the girl, but this belief is supported by a smaller proportion of standard 4 and 5 pupils than by pupils in the rest of the standards. It is also interesting to note that the pupils in the two standard 9 groups do not hold this belief quite as widely as the standard 6, 7 and 8 pupils.

   quite a large proportion of standard 4 and 5 pupils believe that the boy and the girl are running equally fast when he is next to her. This belief is held by a much smaller proportion of standard 6, 7 and 8 pupils but the pupils in the two standard 9 groups find it more attractive.

In Transkei we find that:

the majority of pupils in each of the classes believe that the boy is running faster than the girl, but the two other options received fair support as well;
the belief that the speeds are equal is more widely held by pupils in standard 4 and 5;
a greater proportion of standard 6 pupils than standard 4 and 5 pupils believe that the boy is running faster than the girl.

3. When we compare standard 4, 5 and 6 pupils at schools in the Cape and Transkei, we find that:

4% of the pupils in schools in the Cape and 18% of pupils in schools in Transkei believe that the girl is running faster than the boy;
62% of the pupils in the Cape and 54% of the pupils in Transkei believe that the boy is running faster than the girl;
34% of the pupils in the Cape and 28% of the pupils in Transkei believe that the boy and girl are running equally fast.

4. When we compare Afrikaans-and English-speaking pupils, we find that:

the two groups do not differ in the frequencies with which the pupils select the different options;

23% of the pupils in each of the two groups believe that the boy and girl are running equally fast when they are opposite each other;

3% of the pupils in each of the groups believe that the girl is running faster than the boy.

5. When we compare boys and girls in the Cape, we find that:

   76% of the boys and 66% of the girls believe that the boy is running faster than the girl;

   21% of the boys and 31% of the girls believe that the boy and girl are running equally fast.

   In Transkei we find no noteworthy difference between the two groups.

6. When we compare Afrikaans-speaking pupils from Town and country areas, we find that:

   74% of Town and 69% of country pupils believe that the boy is running faster than the girl;

   22% of the Town and 28% of the country pupils believe that the boy and girl are running equally fast.

7. When we compare the pupils in some of the standards, we find that:

   54% of standard 4 and 73% of standard 9 non-science pupils believe that the boy is running faster than the girl;

   43% of the standard 4 and 22% of the standard 9 non-science pupils believe that the boy and girl are running equally fast when he overtakes her;

the belief that the boy and girl are running equally fast is held by 24% of the pupils in both the standard 9 groups. This is about 10% more than the proportion of standard 7 pupils who believe this.

8. The graph which shows the selection of the individual options across the standards clearly illustrates the popularity of option b with all of the classes as well as the decrease in popularity of this option from the standard 8 group to the two standard 9 groups. This trend is mirrored in the selection of option c.

Chapter 10

Circular motion:

Overview:

Introduction:

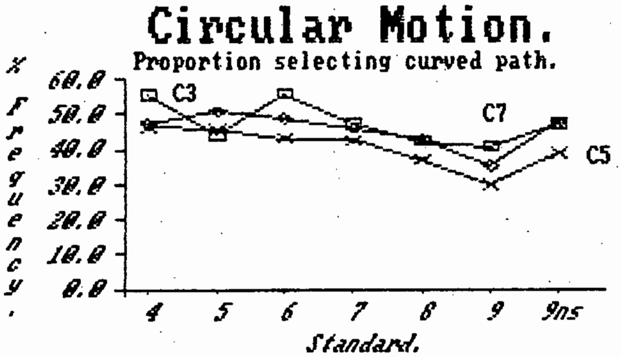
We used three situations depicted in questions C3, C5 and C7 in order to investigate the beliefs which our pupils hold about the path along which an object, which is initially travelling in a circle, will travel once the object is released and moving freely. Once again we are particularly interested in any context-related responses and so the three situations, while conceptually similar, are not so from a contextual point of view. C5 involves a child being swung in a circle by its father and then released. We think that any child who has experienced this game will have felt the enormous pull inwards on his or her arms and that this might encourage a belief that he or she might travel radially outwards once released. We are therefore particularly interested to see the effect on the responses when a human is part of the system.

In the investigations into the beliefs which students hold about the path along which a body, which is initially moving in a circle, or along a curve, will move when the constraining force is removed, McCloskey et al (see p 92) find that a high proportion of students in their sample exhibit a belief that the object would carry on moving on a curved path. The proportion of students who share this belief seemed to be dependent on the context of the question. In particular, they find that if the object is seen to have spent a longer time travelling along a curve or if it is forced to travel in a tighter curve then the proportion of students selecting a curved path for the object after its release is greater.

Of importance for us is McCloskey *et al's* results on objects which moved in a circle before being released. They find that 30% of their sample indicate that the object will move along a curve, 6% that it will move radially outwards and a further 6% that it will move along a straight line at an angle to the radius of the circle. Their sample consisted of undergraduate university students and as we will present evidence that the belief in the continuation of a curved path appears to be related to the age of the pupils, we feel that the results of our standard 9 science pupils should be compared with those of McCloskey et al. Thus, for example on the question of a man swinging a ball around his head before releasing it, we find that 41% of our standard 9 pupils who do science select the option which indicates a curved path for the ball after its release, 23% indicate that it will travel radially outwards while 29% indicate that it will travel along a straight line at an angle to the radius of the original circle. These results differ substantially from those of McCloskey.

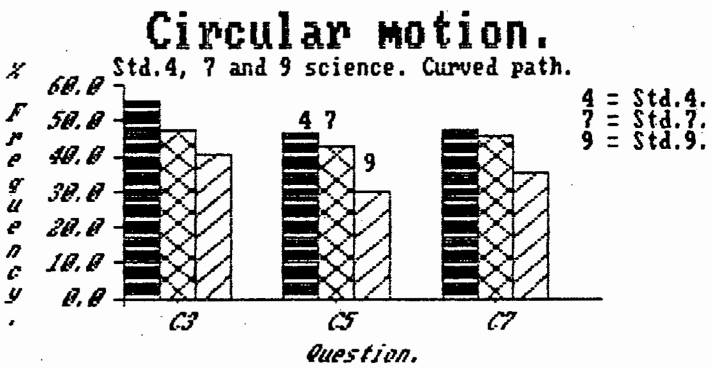
Results:

1. In all three of the situations investigated, we find that the majority of the pupils in our sample believe that the path along which the object will travel after it is released, is a curve. However, the proportion of the pupils selecting a curved path appears to be dependent on the situation presented. Thus for a ball being swung in a circle before release 46% and 45% of the pupils select a curved path on C3 and C7 respectively whereas for a girl being swung in a circle before being released only 41% select a curved path. The fact that the proportion of pupils who select a curved path depends on the situation presented to them as well as the standard which they are in, is clearly illustrated in the following graph which compares the proportion of pupils selecting a curved path with the standard which they were in.

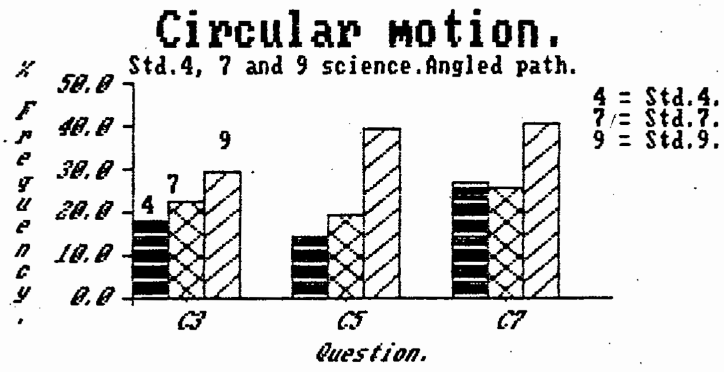


2. We find that the proportion of pupils who select a curved path depends on the standard which they are in. In all cases we find that a larger proportion of the pupils in the lower

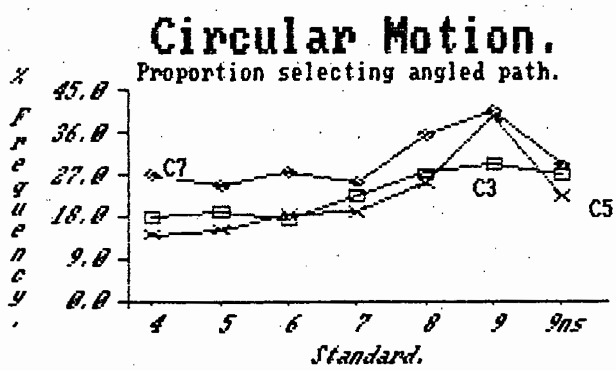
standards prefer curved paths when compared to the standard 9 science pupils. The following graph compares the frequency with which standards 4, 7 and 9 science pupils select curved paths in the situations presented to them.



It is quite clear from the graph that a smaller proportion of standard 9 science pupils than standard 4 or standard 7 pupils prefer a curved path. The reason for this is not at all clear. What is interesting is the change in preference for a path which is along a straight line at an angle to the radius of the original circle. The following graph compares the same three groups with respect to the frequency with which they select this option.



It is clear that the proportion of standard 9 science pupils who select this path is consistently higher than that of the standard 4 and 7 pupils. There is some evidence that the popularity of this choice increases across the three groups. The following graph clearly illustrates that the proportion of pupils who prefer an angled path depends on the situation presented to them as well as the standard which they are in.



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It is clear from the results obtained from pupils in the Cape that the belief that the object when released will travel at a tangent to the circle is an extremely unpopular one with pupils in all of the standards on questions C3 and C7. Interestingly, there is very little variation in the frequency with which it is selected by pupils in any of the standards.

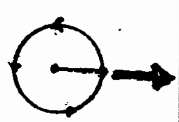
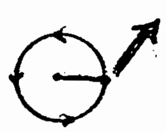
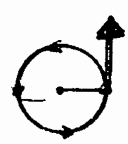
By introducing a child being swung in a circle and released we were providing what we believe to be a particularly appropriate opportunity for pupils to select a radial path. This question, C5, did effect the responses differently as the graphs already presented clearly show, but not in the way that we expected. On this question the tangential path is very popular with all of the standards. As a matter of fact, it is the next most popular choice for the pupils in all of the groups with the exception of the standard 9 science group. This option is now selected by up to 30% of the pupils in some of the standards.

With pupils in schools in Transkei, we find that the most popular belief is that the ball will travel in a curve after being released. The responses to the questions seem to be very dependent on the situation presented. In C3 the next most popular choice by pupils in all of the standards is a tangential path while on C5 and C7 it is a radial one. The situation involving the girl induced the pupils to select a radial path with a frequency of up to 36%.

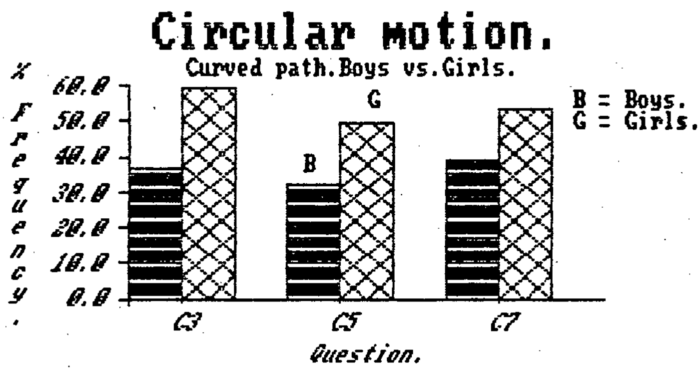
3. When we compare pupils in standards 4, 5 and 6 attending schools in the Cape and Transkei we find that in all three the

situations presented a greater proportion of pupils in Cape schools believe that the object when released will continue on a curved path. On two of the situations, C5 and C7, a much larger proportion of pupils in Transkei than in Cape schools believe that the object will travel radially outwards. Interestingly in C3, a situation which one imagines must be fairly well known to children in Transkei, this is not the case. Here the proportion of pupils from the two groups selecting a radial path is about equal, but the proportion of Transkei pupils who believe that the object will travel tangentially is much larger than that in the Cape. In this situation it is the next most popular option in Transkei.

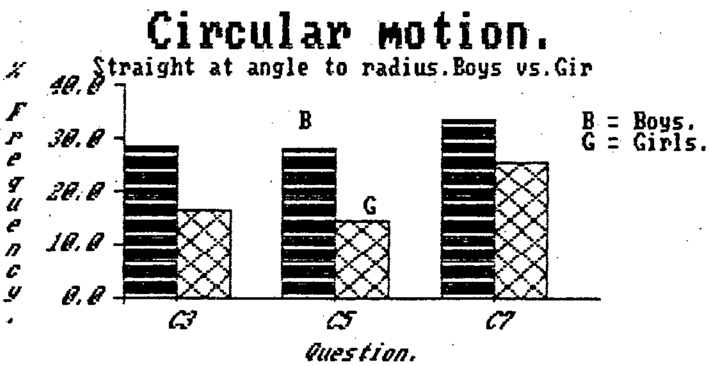
4. In all three of the situations presented we find no appreciable differences in the proportion of English-and Afrikaans-speaking pupils who hold similar beliefs about the path the objects will travel along upon being released. We find that the proportion of pupils who select a particular option to depend upon the situation presented. The following table shows this clearly.

Question	Path selected			
				
C3.	23%	23%	8%	46%
C5.	10%	23%	27%	40%
C7.	8%	30%	16%	45%

5. We find that there are fairly large differences between the beliefs of boys and girls attending schools in the Cape. The following graph compares the proportion of boys and girls who select a curved path for the object in the different situations presented to them.



It is quite clear that a greater proportion of girls than boys hold the the belief that the object will travel along a curved path. As the following graph shows, a greater proportion of boys than girls prefer a straight line path at an angle to the radius. It appears that the notion that the object moves along a straight line path is one which is better developed in boys than girls. One can only speculate about the reasons for this.



It is clear that in each of the situations presented a substantially greater proportion of boys than girls select the path at an angle to the radius.

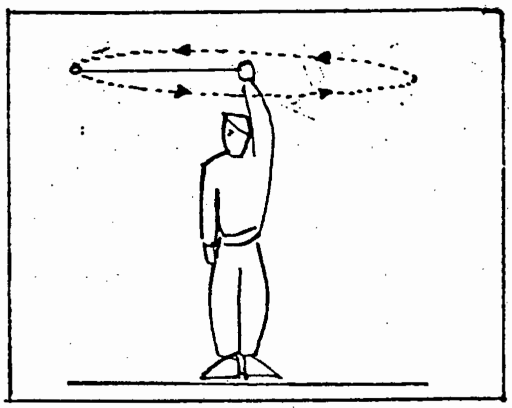
In Transkei we find that the belief that the object will continue to move along a curved path is held by a slightly larger proportion of boys than girls in two of the situations presented to them.

6. We find that there is no noteworthy difference between the proportion of Afrikaans-speaking pupils who share the different beliefs and who attend schools in Cape Town and in country towns.

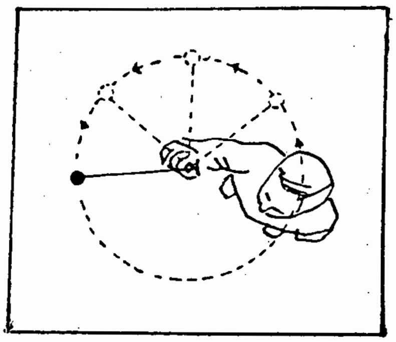
7. We have shown quite clearly that the proportion of pupils who select a particular path will depend on the standard they are in and the situation presented to them. There is very clear evidence that older pupils prefer a path which is at an angle to the radius for an object once it has been released.

Question C 3

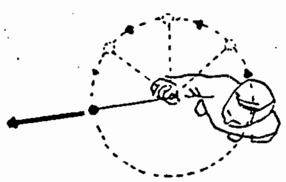
The sketch shows a boy who is swinging a ball, which is attached to a string, horizontally around his head.



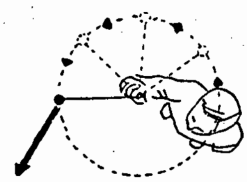
Seen from above it would look like this:



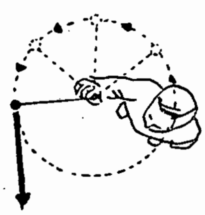
He lets the string go when the ball is at A. The path the ball will travel along after he has released it, is:



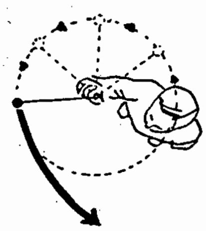
(a)



(b)



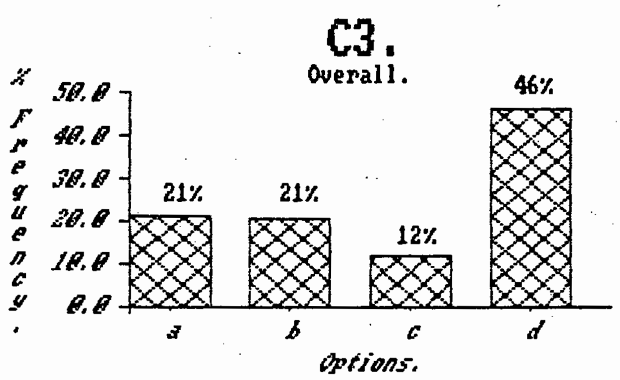
(c)



(d)

(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the pupils in the whole sample.



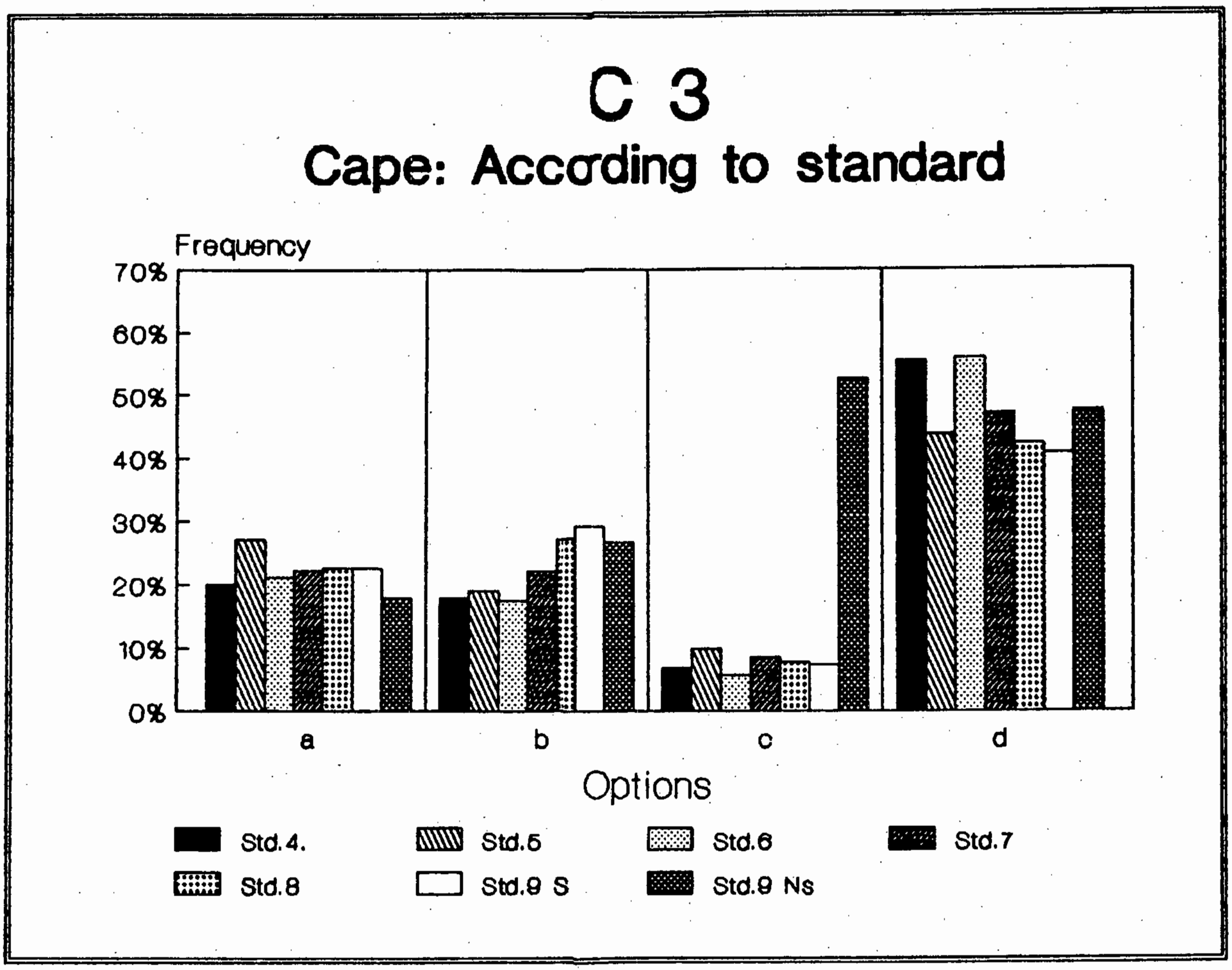
Note:

1. 21% of the pupils in our whole sample select option a, the option which suggests that the ball will move radially outwards.
2. 21% of the pupils select option b, the option which suggests that the ball will move in a straight line at an angle to the radius.
3. 12% of the pupils select option c, the option which suggests that the ball will move at a tangent to the circle.
4. 46% of the pupils select option d. the option which suggests that the ball will keep on moving in a curved path.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which the different options are selected by pupils in the different standards in schools in the Cape.



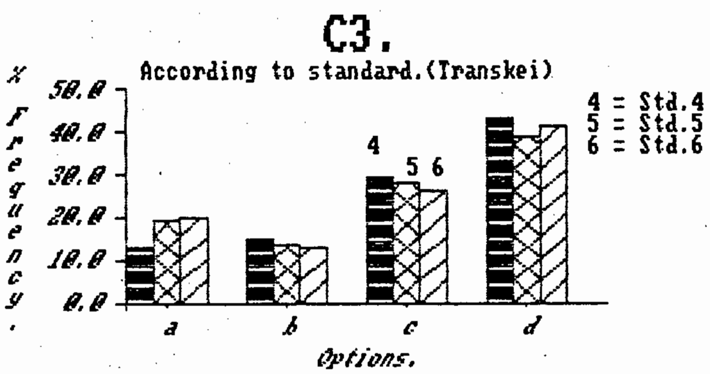
Note:

1. Option d is the favourite option with pupils in all of the standards and especially so with pupils in standards 4 and 6.
2. Option c is by far the least popular with pupils in all of the standards and the proportion of pupils in each of the standards who select it is very constant across the standards.

3. Option b is more attractive to pupils in standards 8 and 9.
4. Option a is selected by about the same proportion of pupils in each of the standards except the standard 5 group, who select it with a frequencies which is slightly higher than that of the other standards.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

1. Option d is the favourite option with the pupils in each of the standards.
2. Option c is the next most popular with the pupils and is selected by a fairly high proportion of pupils, with little variation across the standards.
3. Options a is a little more popular with the pupils in standards 4 and 5.
4. Option b is the least popular with the pupils in all of the standards

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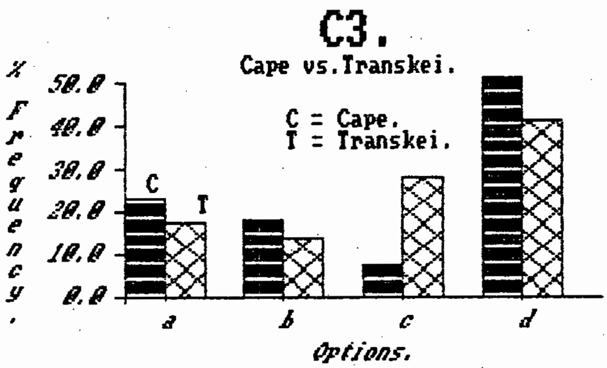
(c) Comparing the Cape and Transkei:

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.

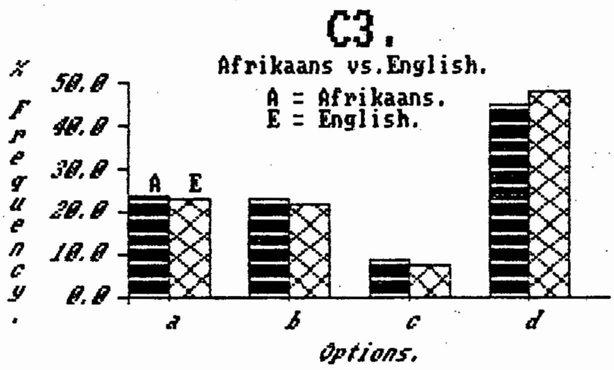


Note:

1. There are differences in the frequencies with which the pupils in the two groups select all of the options. In the case of options c and d the differences are quite large and in the case of c markedly so.
2. 23% of the pupils in the Cape and 17% of the pupils in Transkei select option a.
3. 18% of the pupils in the Cape and 14% of the pupils in Transkei select option b.
4. 8% of the pupils in the Cape and 28% of the pupils in Transkei select option c.
5. 52% of the pupils in the Cape and 41% of the pupils in Transkei select option d.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



Note:

1. There are no noteworthy differences in the frequencies with which pupils from the two groups select options a, b and c.
2. 23% of the pupils select option a.
3. 23% of the pupils select option b.
3. 8% of the pupils select option c.
4. 45% of Afrikaans-speaking and 48% of English-speaking pupils select option d.

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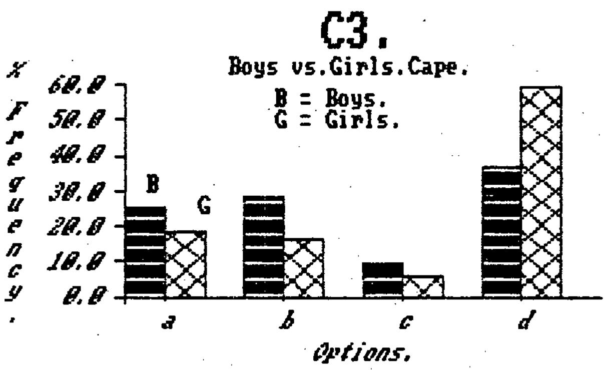
(d) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.



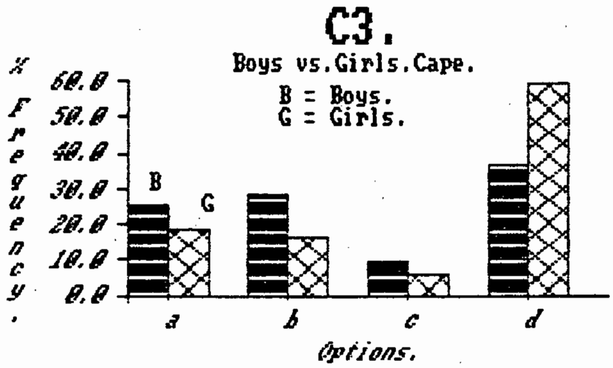
Note:

1. There are differences in the frequencies with which pupils from the two groups select the different options. In the case of options a, b and d these differences are appreciable.
2. 26% of the boys and 19% of the girls select option a.
3. 28% of the boys and 16% of the girls select option b.
4. 10% of the boys and 6% of the girls select option c.
5. 37% of the boys and 59% of the girls select option d.

(d) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

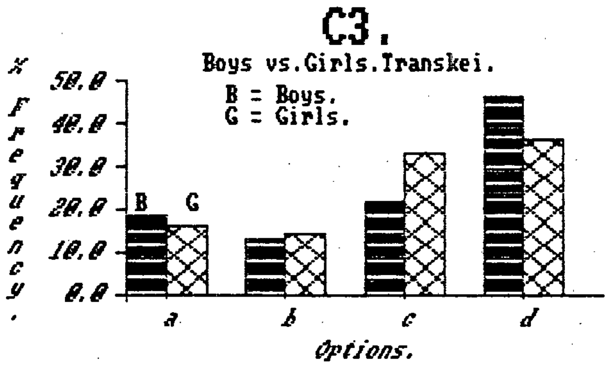


Note:

1. There are differences in the frequencies with which pupils from the two groups select the different options. In the case of options a, b and d these differences are appreciable.
2. 26% of the boys and 19% of the girls select option a.
3. 28% of the boys and 16% of the girls select option b.
4. 10% of the boys and 6% of the girls select option c.
5. 37% of the boys and 59% of the girls select option d.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

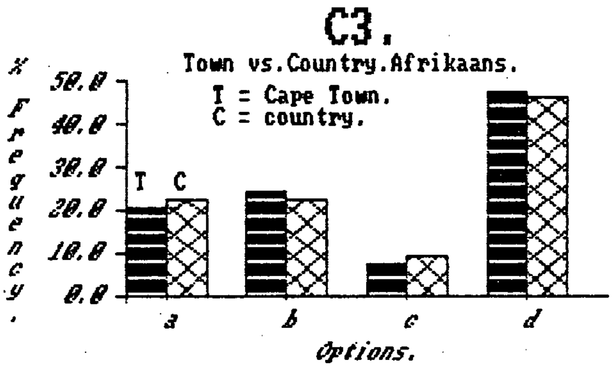


Note:

1. There are differences in the frequencies with which the pupils from the two groups select options a, c and d. In the case of options c and d the differences were appreciable.
2. 19% of the boys and 16% of the girls select option a.
3. 14% of the pupils select option b.
4. 22% of the boys and 33% of the girls select option c.
5. 46% of the boys and 37% of the girls select option d.

(e) Comparing Town and country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils who attend schools in Cape Town and country towns select the different options.



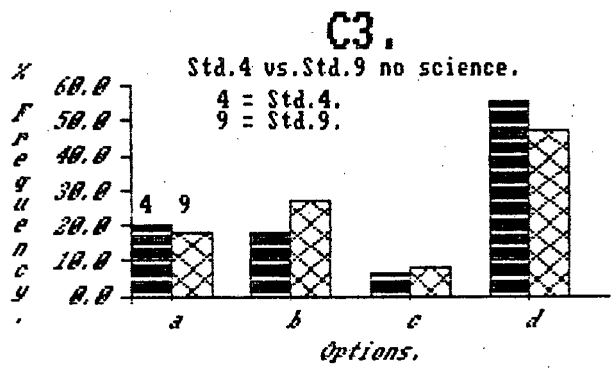
Note:

1. The pupils from the two groups select the different options with very similar frequencies.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science:

The following graph compares the frequencies with which pupils in standard 4 and standard 9 who do not do science select the different options.

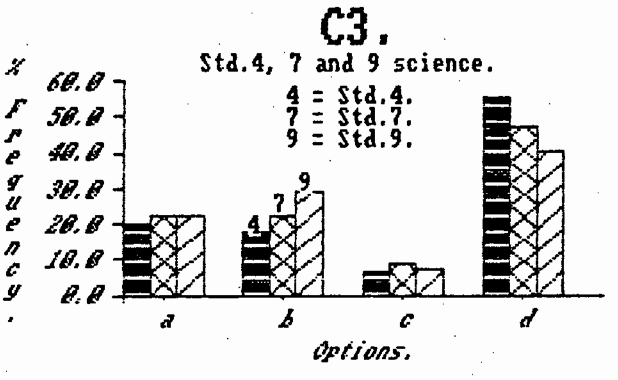


Note:

1. There are small differences in the frequencies with which pupils from the two groups select options a, b and d.
2. 20% of standard 4 and 18% of standard 9 pupils select option a.
3. 18% of standard 4 and 27% of standard 9 pupils select option b.
4. 7% of the pupils in both groups select option c.
5. 55% of standard 4 and 48% of standard 9 pupils select option d.

2. <u>Standards 4, 7 and 9 science:</u>

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.

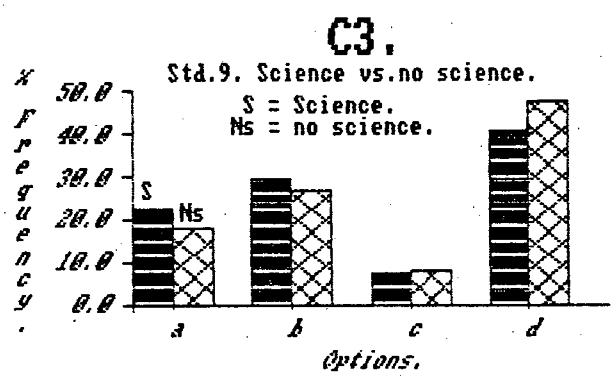


Note:

1. Option a is selected by about the same proportion of pupils in each of the standards.
2. There is a steady increase in the popularity of option b from standard 4 through to standard 9.
3. Option c is selected by about the same small proportion of pupils in each of the standards.
4. There is a steady decrease in the frequencies with which the pupils select option d from standard 4 through to standard 9.

3. Standard 9 science and non-science:

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.

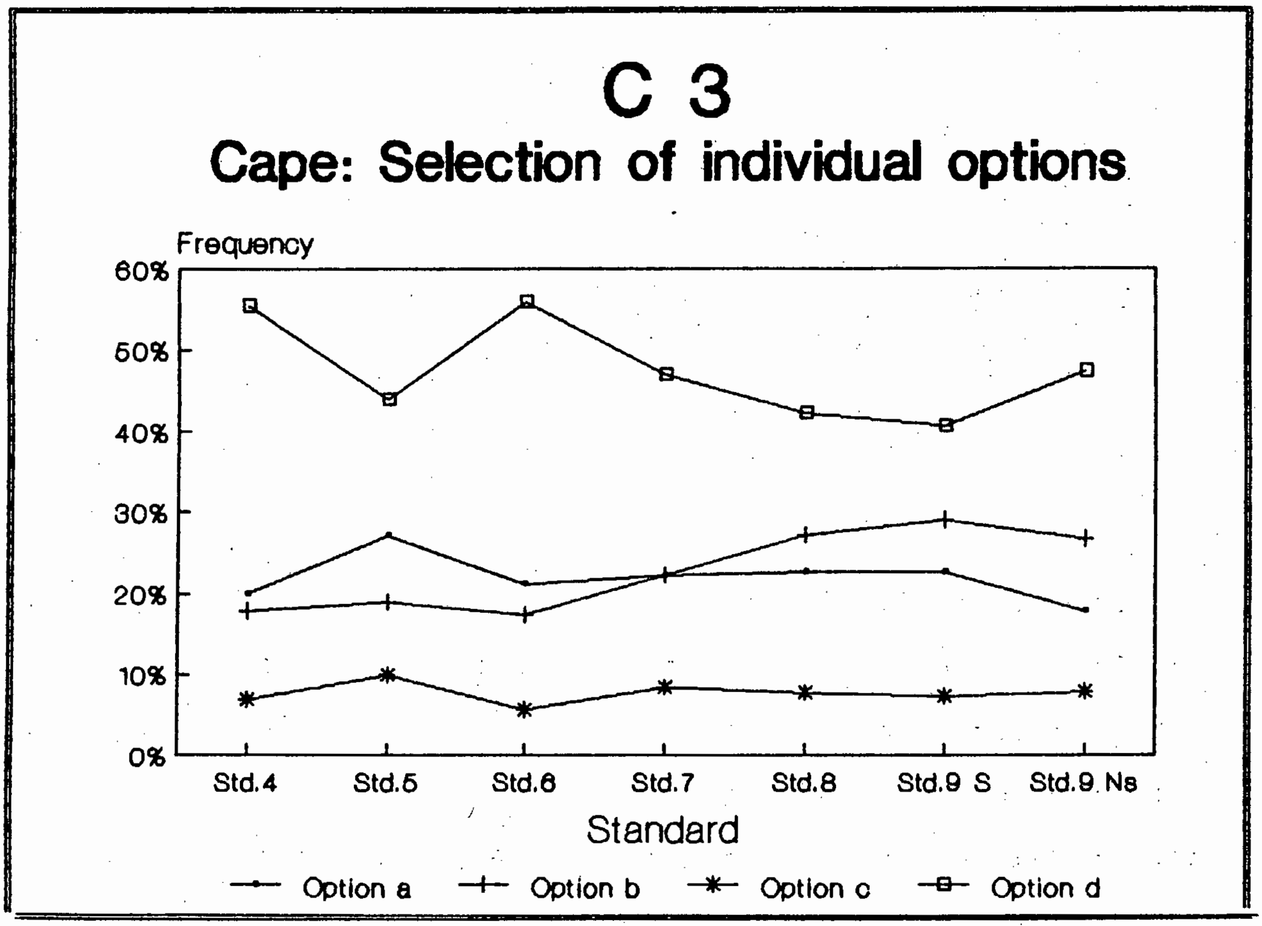


Note:

1. There are small differences in the frequencies with which pupils from the two groups select options a, b and d.
2. 23% of science and 18% of non-science pupils select option a.
3. 29% of science and 27% of non-science pupils select option b.
4. 41% of science and 48% of non-science pupils select option d.

(h) **Selection of individual options:**

The following graph compares the frequencies with which the individual options are selected by pupils across the standards.



Note:

1. There is a gradual decrease in the popularity of option d to a minimum with the standard 9 science pupils. It would appear that the standard 5 group are "out of step" as this group appears to be selecting this option with too low a frequency.
2. There is a gradual increase in popularity of option b to a maximum with the standard 9 science group.
3. There are small peaks in the curves for options a and c over the standard 5 group.

Summary:

1. When we examine the overall picture we find that:

   21% of all the pupils believe that the ball will travel along a radial path when released;
   21% of all the pupils believe that the path of the ball will be along a straight line at an angle to the radius;
   12% of the pupils believe that the ball will travel at a tangent to the circle;
   46% of the pupils believe that the ball will travel along a curve once released;

2. When we compare the frequencies with which the pupils in the different standards in schools in the Cape select the different options we find that:

   the majority of pupils in each of the standards believe that the ball will travel along a curve once released. This belief is more widely held by standard 4 pupils.
   a small but consistent proportion of the pupils in each of the standards believe that the ball will travel at a tangent to the circle;
   a slightly greater proportion of standard 8 and 9 science pupils believe that the ball will travel in a straight line at an angle to the radius;
   a remarkably consistent proportion of the pupils in all of the standards believe that the ball will travel radially outwards once released.

In Transkei we find that:

most of the pupils in each of the standards believe that the ball will travel along a curve once released;
the next most widely held belief is that the ball will travel at a tangent to the circle.

3. When we compare pupils in standards 4, 5 and 6 at schools in in the Cape and Transkei we find that:

23% of pupils in the Cape and 17% of pupils in Transkei believe that the ball will travel radially outwards;
18% of the pupils in the Cape and 14% of the pupils in Transkei believe that the path of the ball will be along a straight line at an angle to the radius;
8% of the pupils in the Cape and 28% of the pupils in Transkei believe that the ball will travel along a tangent to the circle;
52% of the pupils in the Cape and 41% of the pupils in Transkei believe that the ball will travel along a curved path once released.

4. When we compare Afrikaans-and-English-speaking pupils in schools in the Cape we find that the proportion of pupils in each of the two groups who share similar beliefs to be very similar. A small majority of English speaking pupils believe that the ball will travel along a curved path.

5. When we compare boys and girls in schools in the Cape we find that:

   26% of the boys and 19% of the girls believe that the ball will travel radially outwards;
   28% of the boys and 16% of the girls believe that the path will be along a straight line at an angle to the radius;
   10% of the boys and 6% of the girls believe that the path will be a tangent to the circle;
   37% of the boys and 59% of the girls believe that the ball will travel on a curve after release.

   In Transkei we find that:

   19% of the boys and 16% of the girls believe that the ball will travel radially outwards;
   22% of the boys and 33% of the girls believe that the ball will travel at a tangent to the circle;
   46% of the boys and 37% of the girls believe that the ball will travel on a curve after release.

6. When we compare Afrikaans-speaking pupils attending schools in Cape Town and country towns we find that the proportion of pupils in each of the two groups who share similar beliefs to be almost the same.

7. When we compare the pupils in some of the standards we find that:

   18% of standard 4 and 27% of standard 9 non-science pupils believe that the ball will travel along a straight line at an angle to the radius:

55% of the standard 4 and 48% of the standard 9 non-science pupils believe that the ball will continue along a curve once released;

there is an increase in the proportion of pupils who believe that the ball will move at an angle to the radius from standard 4 through to standard 9 science pupils;

there is a decrease in the proportion of pupils who believe that the ball will travel along a curve from standard 4 through to standard 9 science pupils;

23% of science and 18% of non-science pupils in standard 9 believe that the ball will travel radially outwards;

41% of the standard 9 science and 48% of the non-science pupils believe that the ball will continue along a curve once released.

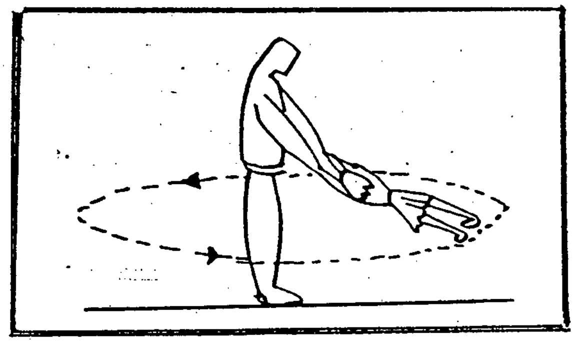
8. The graph which compares the frequencies with which the individual options are selected across the standards shows that:

the proportion of pupils who share the belief that the ball will travel along a curve decreases from standard 4 through to the standard 9 science pupils, but the standard 5 group appear to be "out of step";

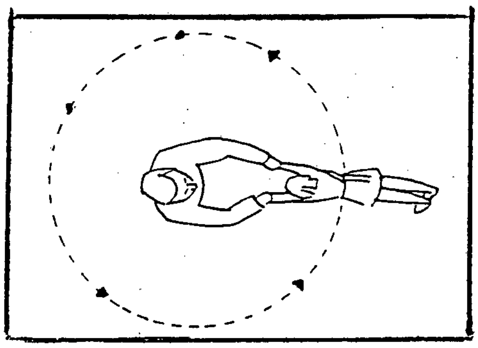
the proportion of pupils who believe that the ball will travel along a straight line at an angle to the radius increases from standard 4 through to a maximum with the standard 9 science pupils.

Question C 5

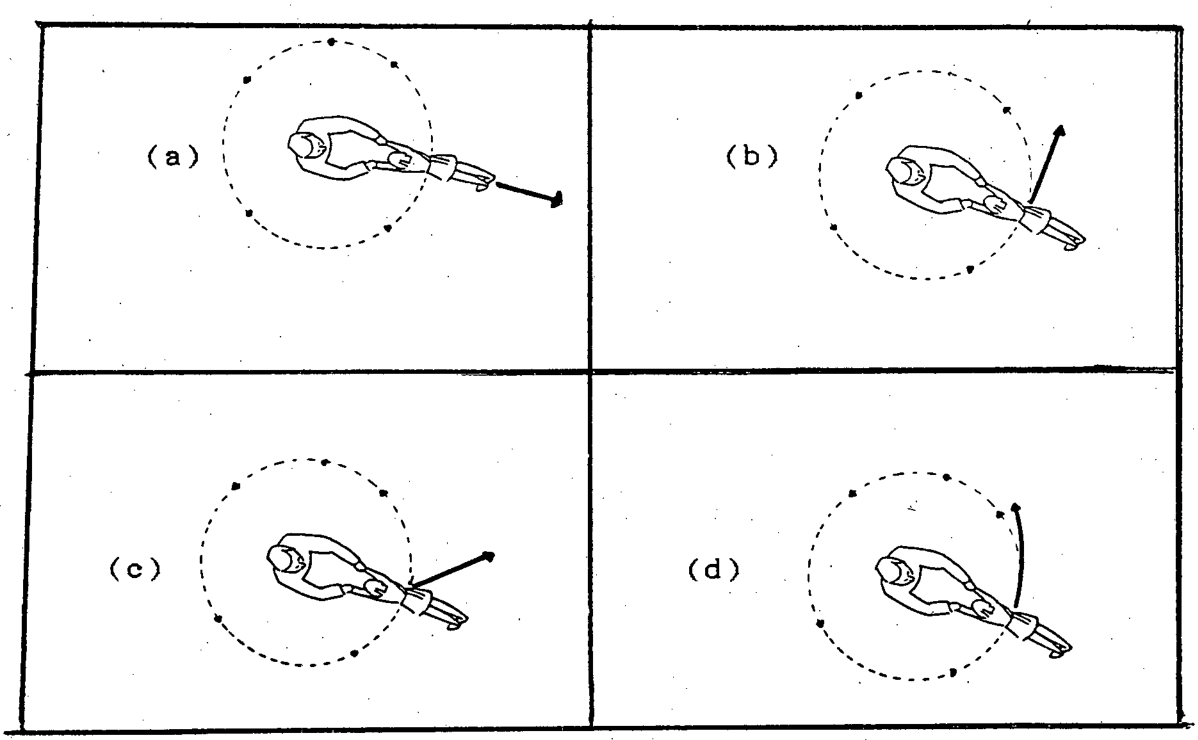
The sketch shows a girl who is being playfully swung in a circle by her father.



Seen from above it would look like this :

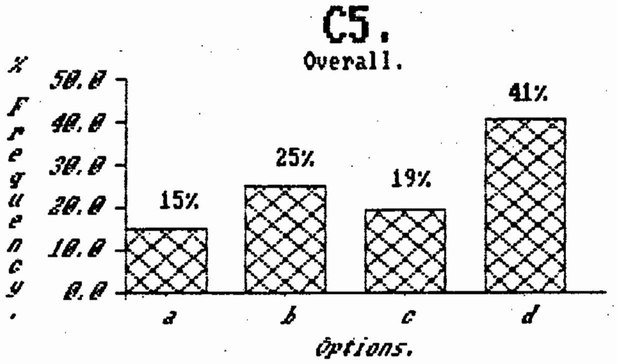


The father releases the girl when she is at A. The path she will travel along after being released , is best shown as :



(a) **The overall picture:**

The following graph compares the frequencies with which pupils in the whole sample select the different options.



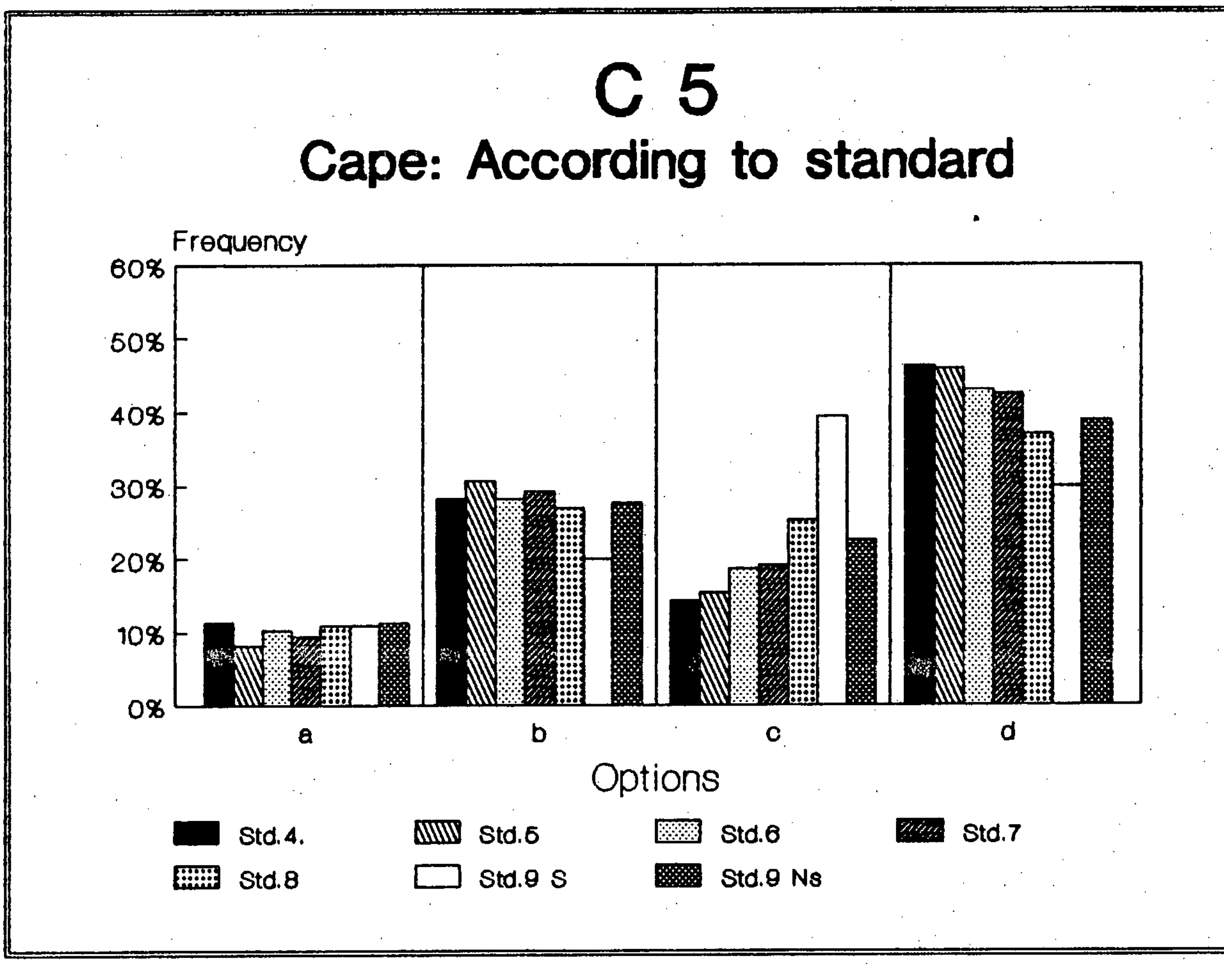
Note:

1. 15% of the pupils in the whole sample select option a, the option which suggests that the girl will travel radially outwards.
2. 25% of the pupils select option b, the option which suggests that the girl will travel at a tangent to the circle.
3. 19% of the pupils select option c, the option which suggests that the girl will travel along a straight line at an angle to the radius.
4. 41% of the pupils select option d, the option which suggests that the girl will continue on a curve after being released.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in the Cape select the different options.



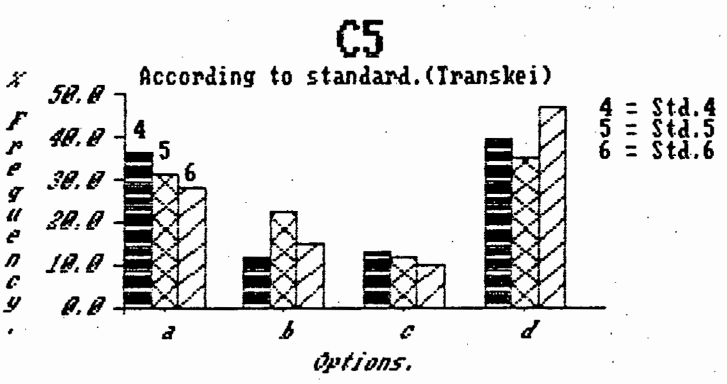
Note:

1. With the exception of the standard 9 science pupils, the majority of the pupils in the other standards favour option d.
2. Option c increases in popularity to a maximum with the standard 9 science pupils who find it the most popular option.

3. Option b is the next most popular option with pupils in all of the standards except the standard 9 science pupils.
4. Option a is selected by a small but remarkably consistent proportion of pupils in all of the standards.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in Transkei select the different options.

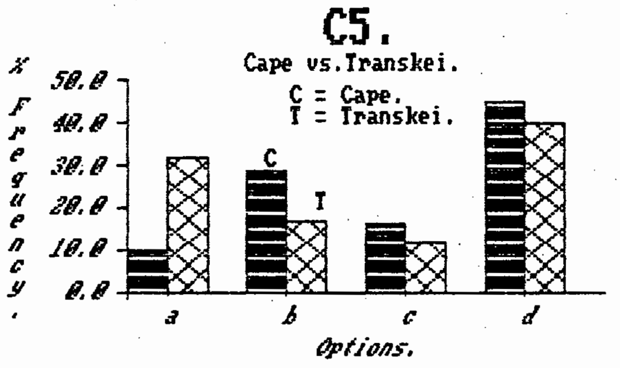


Note:

1. Option d is the most popular option for pupils from all of the standards, but more so for standard 6 pupils.
2. Option c is the least popular option with the pupils in all of the standards.
3. Option b is not popular with any of the standards, but the standard 5 pupils find it more attractive than pupils from any of the other standards.
4. Option a is very popular with pupils from all of the standards and only a little less popular than option d.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.

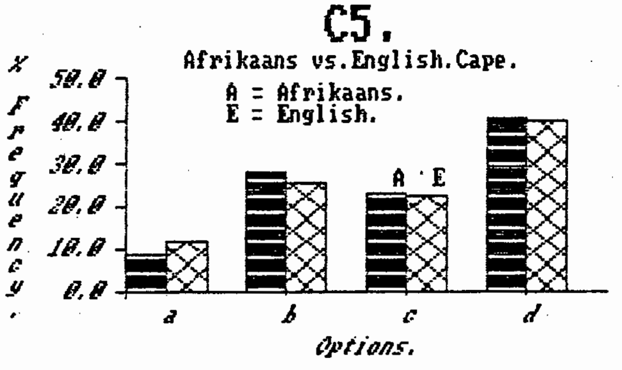


Note:

1. There are differences in the frequencies with which the pupils from the two groups select all of the options. In the case of options a and b the differences are large.
2. 10% of the pupils from the Cape and 32% of the pupils from Transkei select option a.
3. 29% of the pupils from the Cape and 17% of the pupils from Transkei select option b.
4. 16% of the pupils from the Cape and 11% of the pupils from Transkei select option c.
5. 45% of the pupils from the Cape and 40% of the pupils from Transkei select option d.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



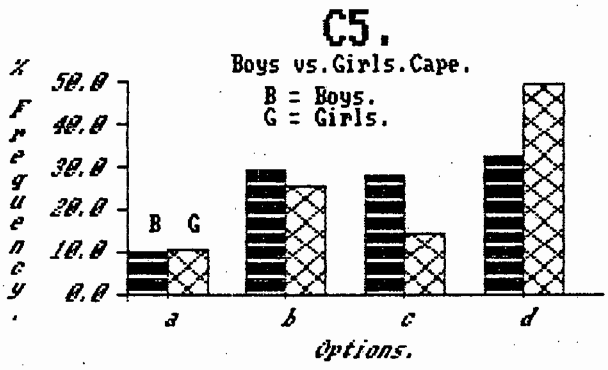
Note:

1. There are small differences in the frequencies with which pupils from the two groups select options a, b and d.
2. 9% of Afrikaans-and 12% of English-speaking pupils select option a.
3. 28% of Afrikaans-and 26% of English-speaking pupils select option b.
4. 23% of the pupils from both groups select option c.
5. 40% of the pupils from both groups select option d.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

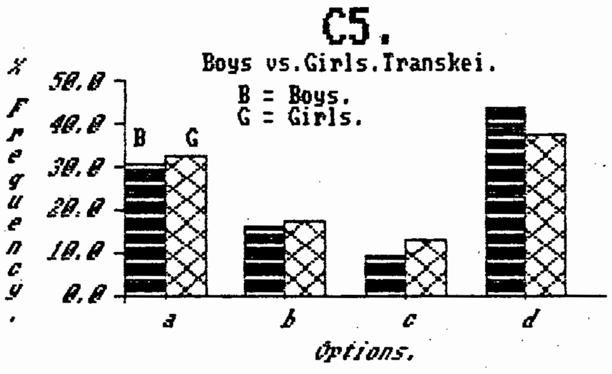


Note:

1. There are large differences in the frequencies with which boys and girls select options c and d.
2. 30% of the boys and 25% of the girls select option b.
3. 28% of the boys and 15% of the girls select option c.
4. 33% of the boys and 50% of the girls select option d.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

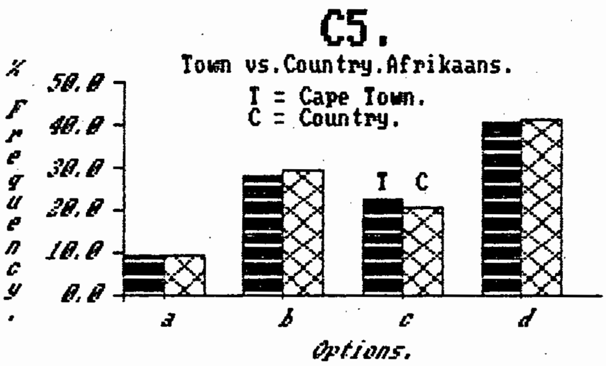


Note:

1. There are small differences in the frequencies with which boys and girls select option c and d.
2. 9% of the boys and 13% of the girls select option c
3. 44% of the boys and 37% of the girls select option d.

(f) **Comparing Town and country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans- speaking pupils who attend schools in Cape Town and country towns select the different options.



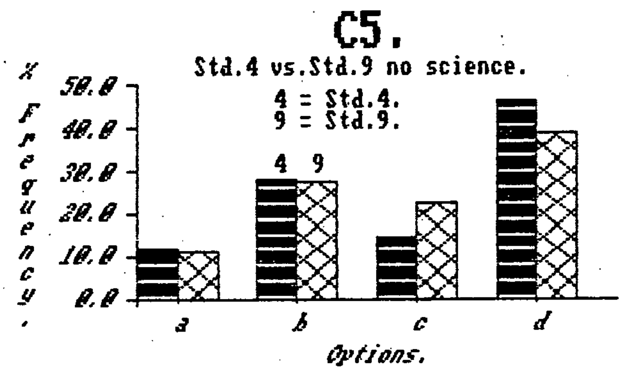
Note:

1. There are clearly no noteworthy differences in the frequencies with which the different options are selected by the pupils from the two groups.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science select the different options.



Note:

1. There are differences in the frequencies with which pupils from the two groups select options c and d.
2. 14% of the standard 4 and 23% of the standard 9 non-science pupils select option c.
3. 46% of the standard 4 and 39% of the standard 9 non-science group select option d.

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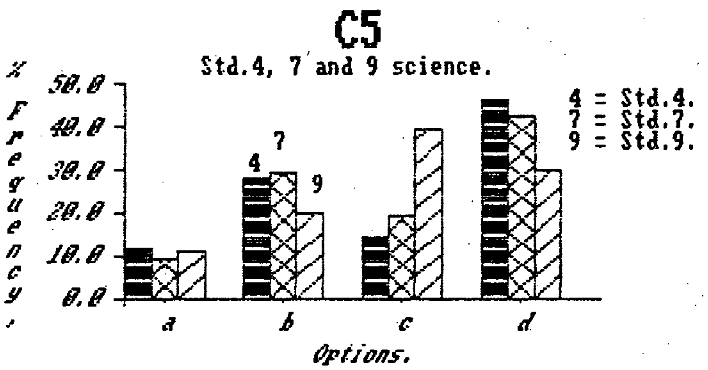
2. <u>Standard 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which standards 4, 7 and 9 pupils who do science select the different options.

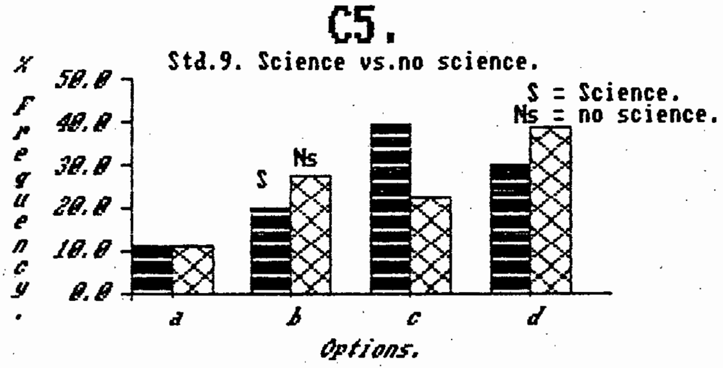


Note:

1. Standard 9 science pupils find option b relatively unpopular.
2. There is an increase in the popularity of option c from standard 4 through to standard 9 science pupils.
3. There is a steady decrease in popularity of option d from standard 4 through to standard 9 science pupils.
4. Option a is selected by about the same proportion of pupils in each of the three standards.

3. Standard 9 science and non-science pupils:

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.

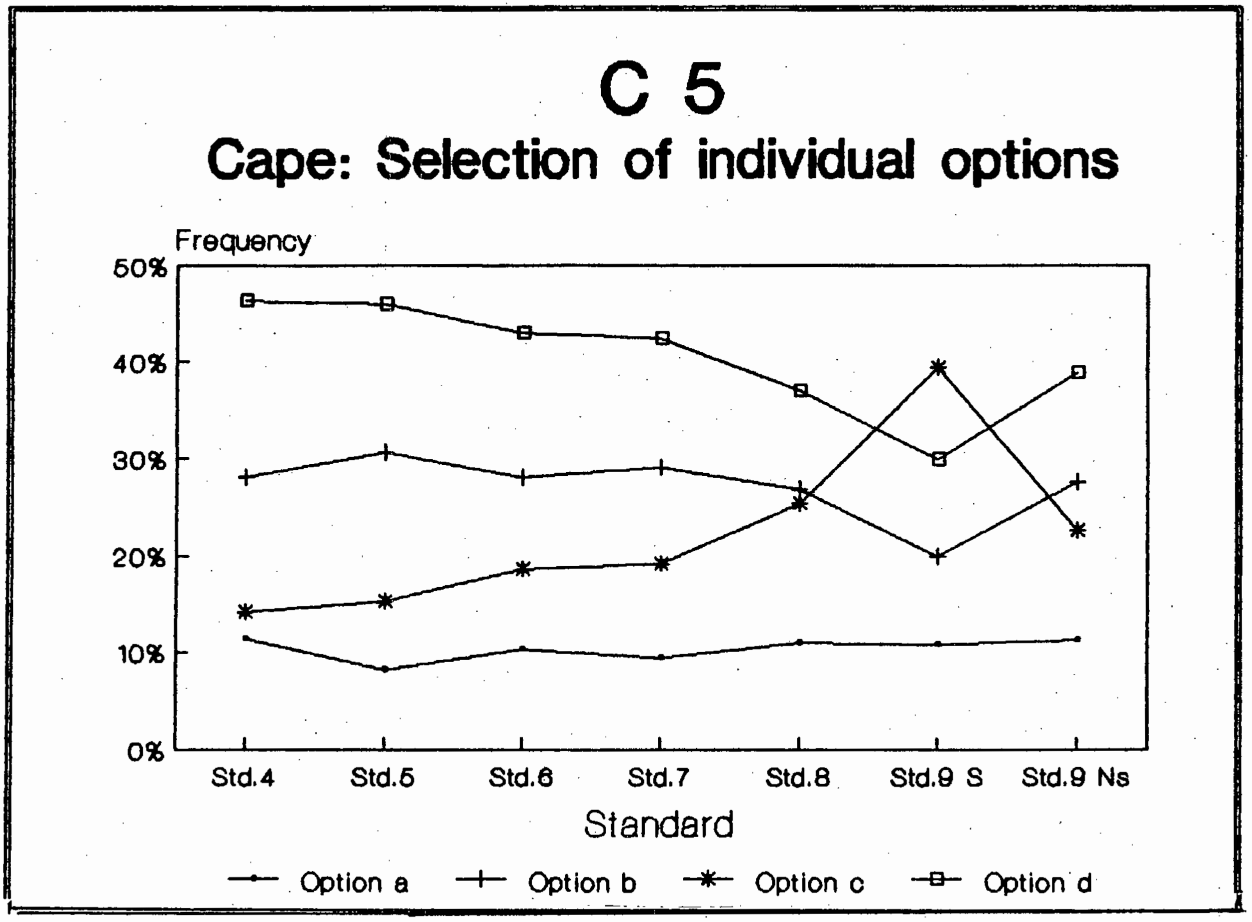


Note:

1. There are differences in the frequencies with which the pupils in the two groups select options b, c and d.
2. 20% of science and 28% of non-science pupils select option b.
3. 39% of science and 23% of non-science pupils select option c.
4. 30% of science and 39% of non-science pupils select option d.

(h) **Selection of individual options:**

The following graph shows how the individual options are selected by the pupils across the standards.



Note:

1. There is a gradual decrease in the popularity of option d to a minimum with the standard 9 science group.
2. There is an increase in the popularity of option c to a maximum with the standard 9 science group.
3. With the exception of the standard 9 science group, option b is selected by a relatively high and stable proportion of pupils in each of the other standards.
4. Option a is selected by a small but consistent proportion of

pupils in all of the standards.

Summary:

1. When we look at the overall picture we find that, after the girl had been released:

   15% of the pupils believe that she will move radially outwards;
   25% of the pupils believe that she will move at a tangent to the circle;
   19% of the pupils believe that she will move in a straight line at an angle to the radius;
   41% of the pupils believe that she will move on a curve;

2. When we compare the frequencies with which the pupils in the different standards in the Cape select the different options we find that:

   with the exception of the standard 9 science pupils the majority of the pupils in the other standards believe that the girl will continue to travel in a curve once released;
   the belief that the girl will travel in a straight line at an angle to the radius increases across the standards to a maximum with the standard 9 science pupils, for whom this is the most popular belief;
   the next most popular belief with the pupils in all of the standards except the standard 9 science pupils, is that the girl will travel at a tangent to the circle;
   about 10% of the pupils in each of the standards believe that the girl will move radially outwards.

In Transkei we find that:

the majority of the pupils in each of the standards believe that the girl will travel on a curve after being released;
a slightly smaller proportion of the pupils believe that she will travel radially outwards after being released.

3. When we compare pupils in standards 4, 5 and 6 in schools in the Cape and Transkei we find that:

   10% of the pupils in the Cape and 32% of the pupils in Transkei believe that the girl will travel radially outwards after being released;
   29% of the pupils in the Cape and 17% of the pupils in Transkei believe that the girl will travel at a tangent to the circle after being released;
   45% of the pupils in the Cape and 40% of the pupils in Transkei believe that she will travel on a curve after being released.

4. When we compare Afrikaans-and-English-speaking pupils we find that the proportions of pupils in the two groups who share the different beliefs to be very similar.

5. When we compare boys and girls at schools in the Cape we find that:

   30% of the boys and 25% of the girls believe that the girl will travel at a tangent to the circle after being released;
   28% of the boys and 15% of the girls believe that the girl will travel in a straight line at an angle to the radius after being released;

33% of the boys and 50% of the girls believe that the girl will continue on a curve after being released;

In Transkei we find that 44% of the boys and 37% of the girls believe that the girl will continue on a curve after being released.

6. When we compare Afrikaans-speaking pupils attending schools in Cape Town and country towns we find that the proportions of pupils in each of the groups who share the same belief to be very similar.

7. When we compare the pupils in some standards we find that:

14% of standard 4 and 23% of standard 9 non-science pupils believe that the girl will move in a straight line at an angle to the radius after being released;
46% of the standard 4 and 39% of the standard 9 non-science pupils believe that the girl will move on a curve after being released;
there is an increase in the proportion of pupils who believe that the girl will move in a straight line at an angle to the radius from standard 4 through to the standard 9 science group;
there is a decrease in the proportion of pupils who believe that the girl will move on a curve from standard 4 through to standard 9 science pupils;
20% of standard 9 science and 28% of non-science pupils believe that the girl will move at a tangent to the circle;
39% of standard 9 science and 23% of non-science pupils

believe that the girl will travel on a straight line at an angle to the radius;

30% of standard 9 science and 39% of non-science pupils believe that the girl will continue on a curve after being released.

8. An examination of the graph indicating how the individual options are selected across the standards shows that:

the proportion of pupils who believe that the girl will continue on a curve after being released gradually decreases across the standards to a minimum with the standard 9 science pupils;

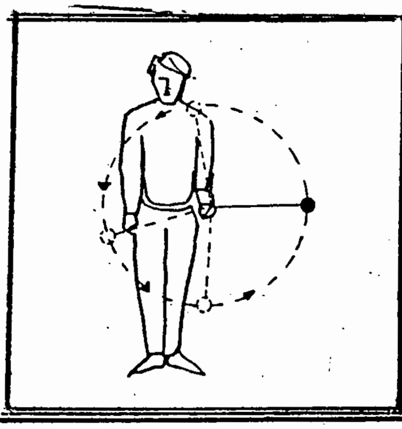
the proportion of pupils who believe that she will move in a straight line at an angle to the radius gradually increases to a maximum with the standard 9 science pupils.

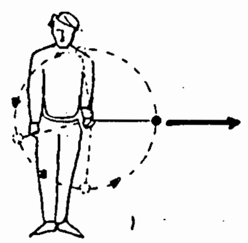
the belief that she will travel at a tangent to the circle is held by a fairly large proportion of pupils in all of the standards;

a small but remarkably stable proportion of pupils in each of the standards believe that she will move radially outwards.

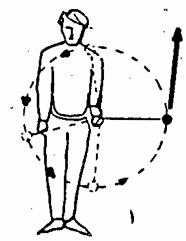
Question C 7

The sketch shows a man who is swinging a ball which is attached to a string vertically in front of him. He lets the string go when the ball is at A. The path the ball will travel along after he has released it, is:

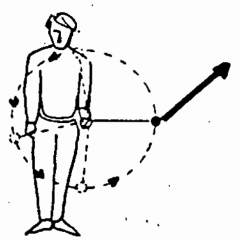




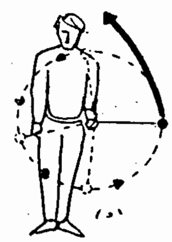
(a)



(b)



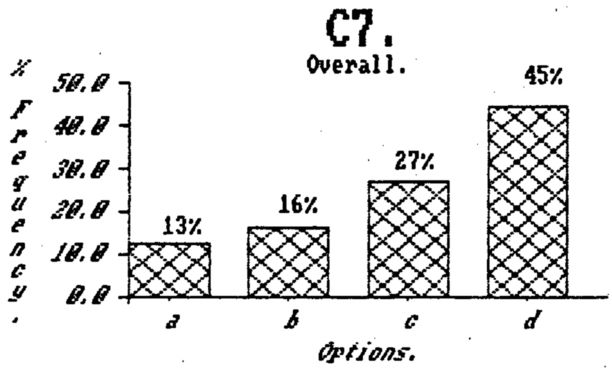
(c)



(d)

(a) **The overall picture:**

The following graph shows the frequencies with which the different options are selected by the whole sample.



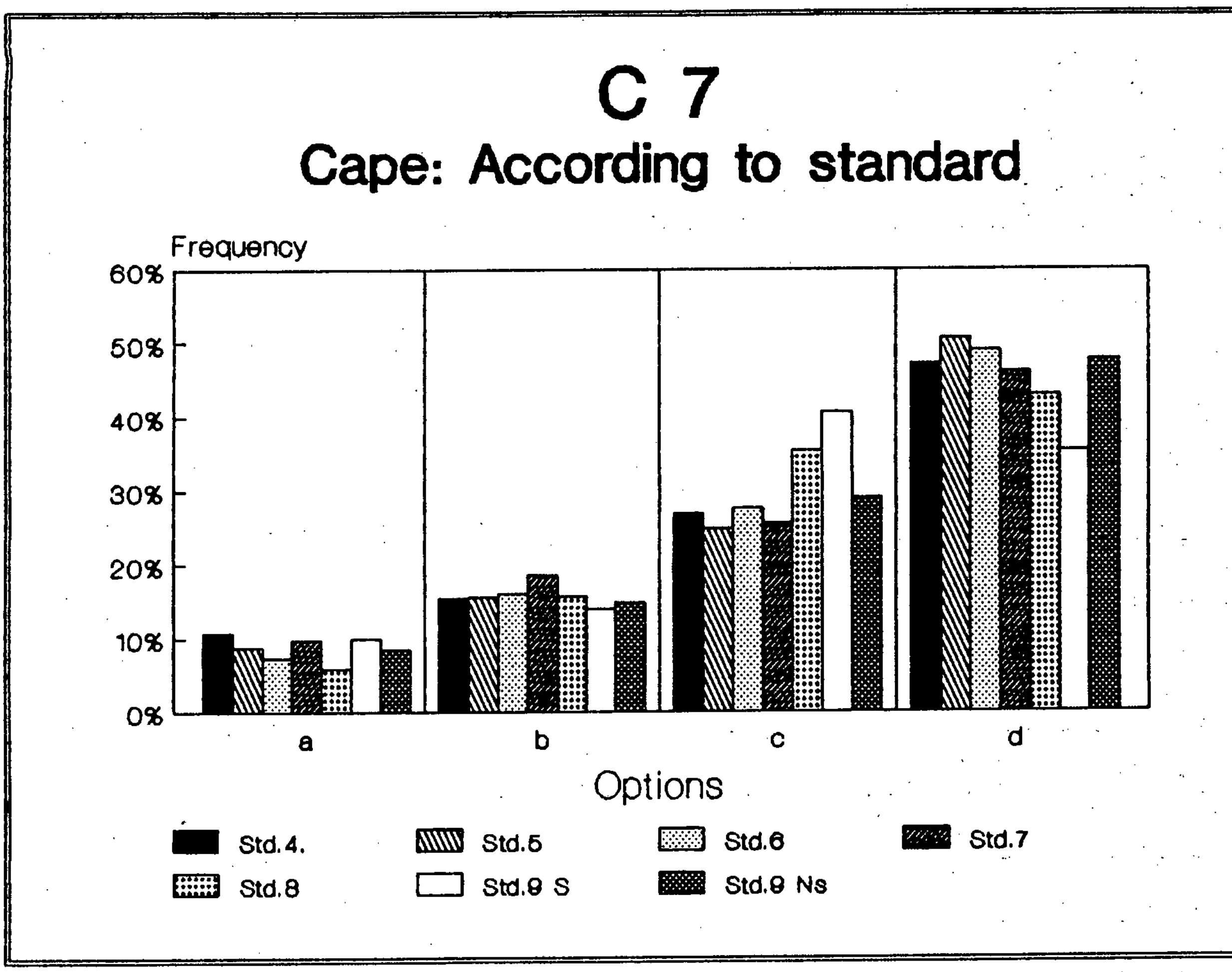
Note:

1. 13% of the pupils in our whole sample select option a, the option which suggests that the ball will travel radially outwards.
2. 16% of the pupils select option b, the option which suggests that the ball will travel at a tangent to the circle.
3. 27% of the pupils select option c, the option which suggests that the ball will travel in a straight line at an angle to the radius.
4. 45% of the pupils select option d, the option which suggests that the ball will travel on a curve when released.

(b) According to standard:

1. In the Cape:

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

1. With the exception of the standard 9 science pupils, option d is the most popular option with the pupils in all standards.

2. The standard 9 science group found option c the most attractive. Pupils in the other standards found this option the next most attractive.

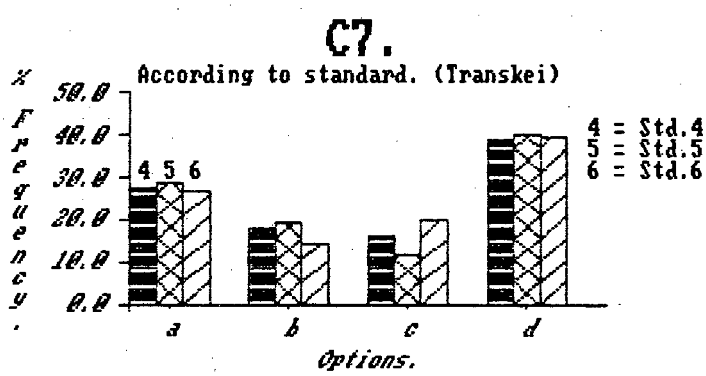
3. Option b is selected by a very consistent proportion of

pupils in all of the different standards.

4. Option a is selected by a small but consistent proportion of pupils in all of the standards.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

1. Option d is the most, and consistently chosen, popular option with the pupils in all three standards
2. Option a is the next most popular option and is selected by the same proportion of pupils in all three standards.
3. Options b and c are selected by appreciably smaller proportions of pupils in each of the standards.

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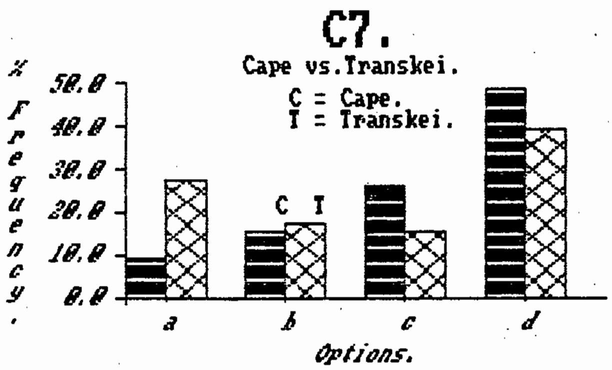
(c) Comparing the Cape and Transkei:

The following graph compares the frequencies with which standard 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options.

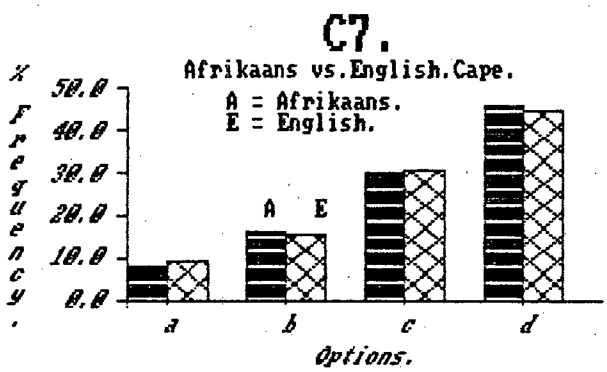


Note:

1. The pupils in the two groups differ in the frequencies with which they select options a, c and d.
2. 9% of pupils in the Cape and 28% of pupils in Transkei select option a.
3. About 16% of the pupils in both groups select option b.
4. 26% of the pupils in the Cape and 16% of the pupils in Transkei select option c.
5. 49% of the pupils in the Cape and 39% of the pupils in Transkei select option d.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



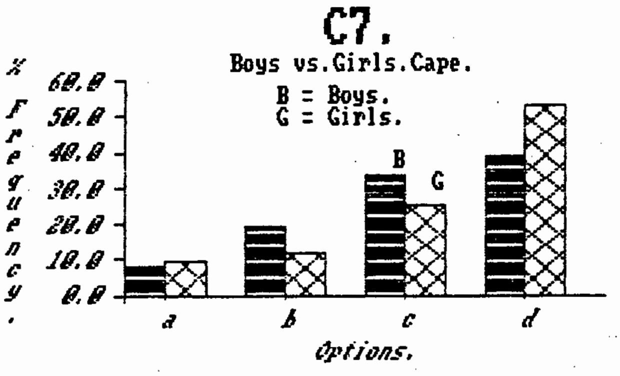
Note:

1. It is clear that the different options are selected by very similar proportions of pupils from the two groups.
2. 8% of the pupils select option a.
3. 16% of the pupils select option b.
4. 30% of the pupils select option c.
5. 45% of the pupils select option d.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

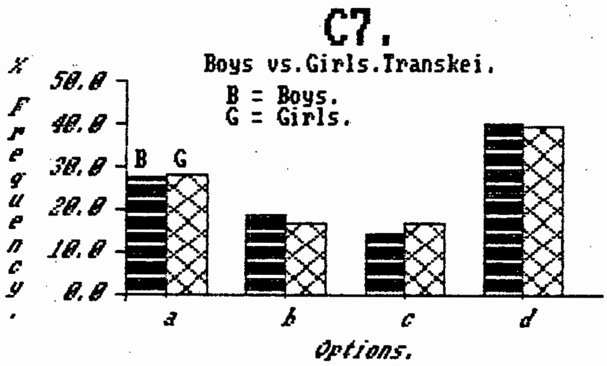


Note:

1. There are appreciable differences in the frequencies with which boys and girls select options b, c and d.
2. About 9% of both boys and girls select option a.
3. 20% of the boys and 12% of the girls select option b.
4. 34% of the boys and 26% of the girls select option c.
5. 39% of the boys and 53% of the girls select option d.

2. In Transkei:

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

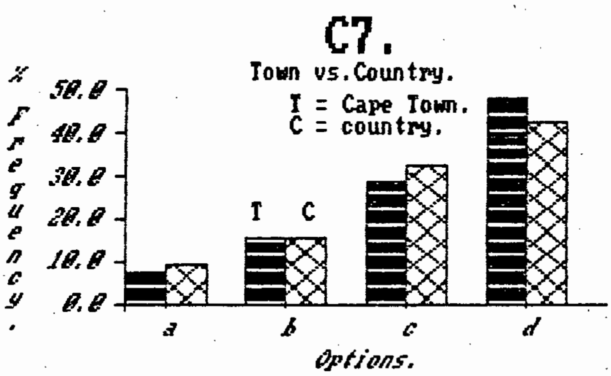


Note:

1. The different options are selected by very similar proportions of boys and girls.

(f) **Comparing Town and country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans-speaking pupils attending schools in Cape Town and country towns select the different options.



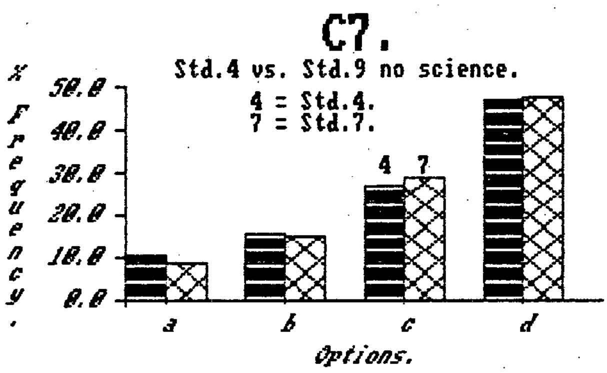
Note:

1. There are small differences in the frequencies with which pupils from the two groups select options a, c and d.
2. 7% of pupils from Cape Town and 9% of pupils from country schools select option a.
3. 15% of the pupils from both areas select option b.
4. 29% of the pupils from Cape Town and 33% of the pupils from country towns select option c.
5. 48% of the pupils from Cape Town and 42% of the pupils from country towns select option d.

(g) Comparing some standards:

1. Standard 4 and 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science at school select the different options.

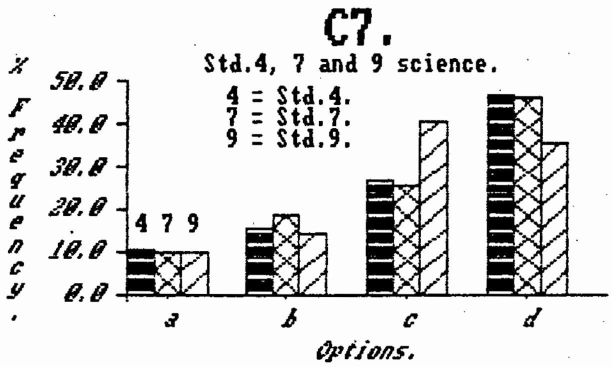


Note:

1. It is clear that the pupils from the two groups select the different options with remarkably similar frequencies.

2. Standard 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standard 4, 7 and 9 pupils who do science at school select the different options.

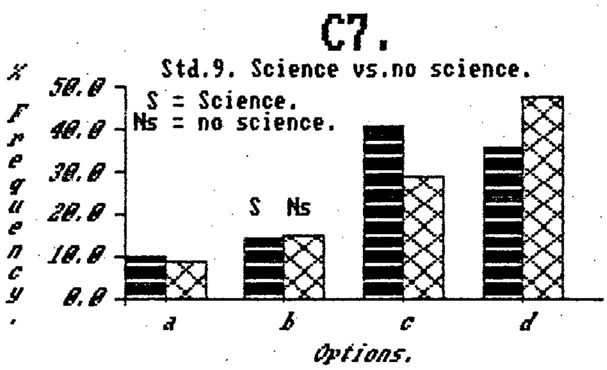


Note:

1. The pupils in the three standards select option a with very similar frequencies.
2. The different groups of pupils select option b with similar frequencies.
3. The standard 9 science pupils select option c with a noticeably higher frequency.
4. The frequency with which option d is selected by the standard 9 science pupils is low compared to the pupils in the other two standards.

3. Standard 9 science and non-science:

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.



Note:

1. There are fairly big differences in the frequencies with which pupils from the two groups select options c and d.
2. 41% of science and 29% of non-science pupils select option c.
3. 35% of science and 48% of non-science pupils select option d

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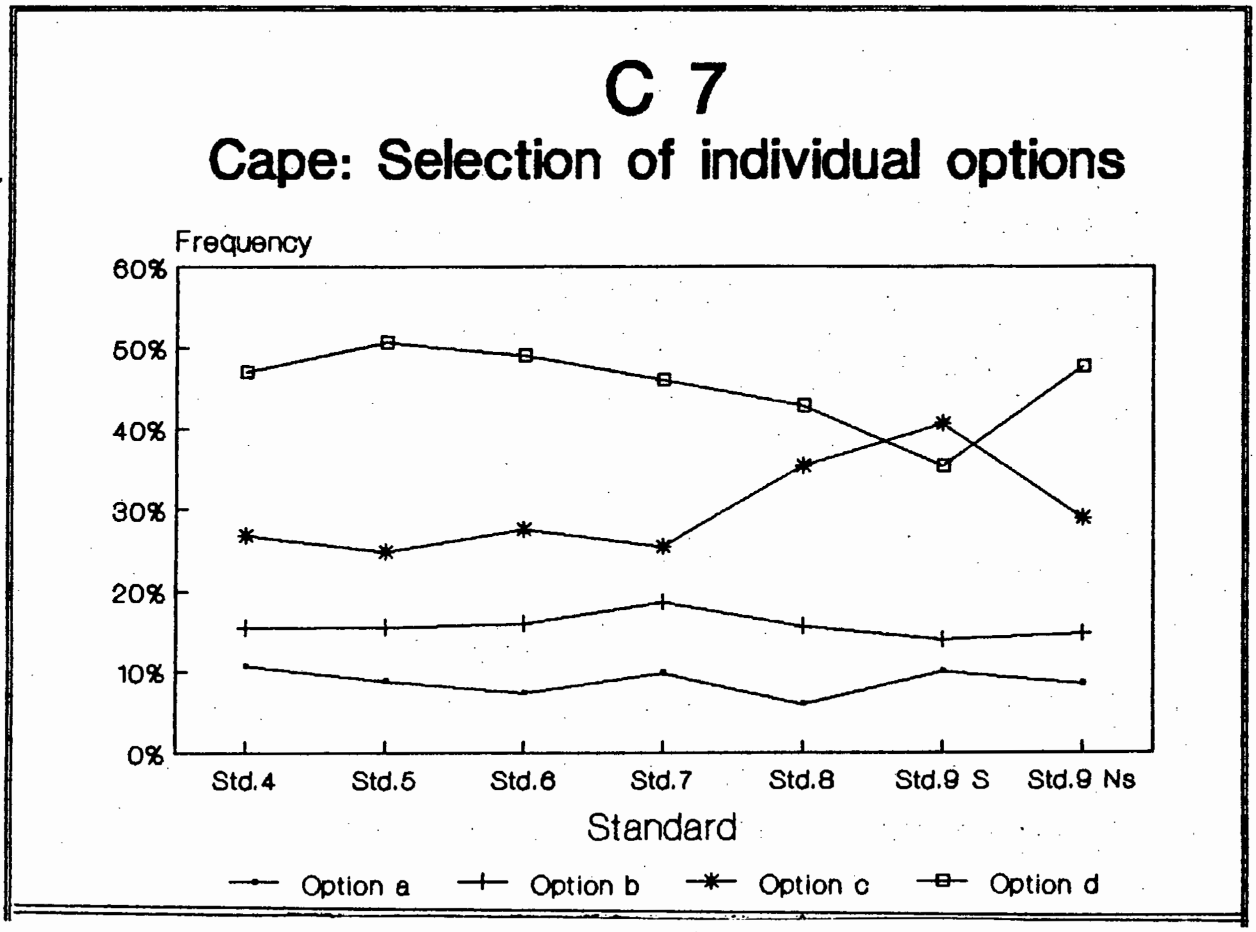
(h) **Selection of individual options:**

The following graph shows how the individual options have been selected by the pupils across the standards.



Note:

1. There is a gradual decrease in the frequencies with which option d is selected, reaching a minimum with the standard 9 science group.

2. There is an increase in the frequencies with which option c is selected from standard 7 through to the standard 9 science group.

3. Options a and b are selected with relatively small but stable frequencies by pupils in all of the standards.

Summary:

1. When we look at the overall picture we find that:

 13% of the pupils believe that the ball will travel radially outwards after being released;
 16% of the pupils believe that the ball will travel at a tangent to the circle after being released;
 27% of the pupils believe that the ball will travel in a straight line at an angle to the radius after being released;
 45% of the pupils believe that the ball will continue to move along a curve after being released.

2. When we compare the frequencies with which pupils in the different standards at schools in the Cape select the different options we find that:

 with the exception of the standard 9 science pupils the majority of pupils in each of the standards believe that the ball will travel along a curve once released;
 the majority of the standard 9 science pupils and the next largest proportion of pupils in the other standards believe that the ball will travel along a straight line at an angle to the radius after being released;
 a small but consistent proportion of the pupils in each of the standards believe that the ball will travel radially outwards from or at a tangent to the circle after being released.

 In Transkei we find that:

 the majority of pupils in each of the standards believe that the ball will travel along a curve after being released;

the next most popular belief with the pupils in all of the standards is that the ball will travel radially outwards after being released.

3. When we compare standard 4, 5 and 6 pupils at schools in the Cape and Transkei we find that:

9% of the pupils in the Cape and 28% of the pupils in Transkei believe that the ball will travel radially outwards after being released;
26% of the pupils in the Cape and 16% of the pupils in Transkei believe that the ball will travel along a straight line at an angle to the radius after being released;
49% of the pupils in the Cape and 39% of the pupils in Transkei believe that the ball will continue along a curve after being released.

4. When we compare Afrikaans-and-English-speaking pupils at schools in the Cape we find that:

the proportion of pupils from the two groups who share similar beliefs are almost the same;
8% of the pupils believe that the ball will travel radially outwards after being released;
16% of the pupils believe that the ball will travel at a tangent to the circle after being released;
30% of the pupils believe that the ball will travel along a straight line at an angle to the radius after being released;
45% of the pupils believe that the ball will continue along a curve after being released.

5. When we compare boys and girls at schools in the Cape we find that:

   20% of the boys and 12% of the girls believe that the ball will travel at a tangent to the circle after being released;
   34% of the boys and 26% of the girls believe that the ball will travel along a straight line at an angle to the radius after being released;
   39% of the boys and 53% of the girls believe that the ball will continue along a curve after being released.

   In Transkei we find that there is no noteworthy difference between the proportion of boys and girls who share similar beliefs.

6. When we compare Afrikaans-speaking pupils attending schools in Cape Town and country towns we find that:

   29% of pupils from Cape Town and 33% of pupils from country towns believe that the ball will follow a straight line at an angle to the radius after being released;
   48% of the pupils from Cape Town and 42% of pupils from country towns believe that the ball will continue along a curve after being released.

7. When we compare the pupils from some of the standards we find that:

   the proportion of standard 4 and standard 9 pupils who do not do science and who share similar beliefs are almost the same;

while similar proportions of standard 4 and 7 pupils share a belief that the ball will travel along a curve, the proportion of standard 9 science pupils who do so is considerably less; standard 9 science pupils preferred a belief that the ball will travel along a straight line at an angle to the radius after being released;

41% of standard 9 science pupils and 29% of non-science pupils believe that the ball will travel along a straight line at an angle to the radius after being released;

35% of standard 9 science pupils and 48% of non-science pupils believe that the ball will continue along a curve after being released.

8. An examination of the graph which shows the frequencies with which the individual options are selected by the pupils across the standards indicates that:

the proportion of pupils who believe that the ball will travel along a curve gradually decreases to a minimum with the standard 9 science group;

the proportion of pupils who believe that the ball will travel along a straight line at an angle to the radius increased to a maximum with the standard 9 science pupils;

Chapter 11

Projectile Motion

Overview

Introduction:

We used 4 situations to investigate the beliefs which our pupils hold about the path along which moving bodies fall. In question C6 a rapidly rolling ball falls over the edge of a table while in questions C1 and C4 an observer watches another person who is moving, drop a ball. We believe that although these situations are conceptually very similar, that the perception that a ball dropped by a running person appears to move backwards away from him, will influence the way these two questions are interpreted relative to question C6, in which this perceptual misinformation is absent.

In question C2 an observer standing in a moving vehicle has to drop a ball through a hole in the floor of the vehicle. It is clear that the same perceptual clues which may suggest that the ball should fall backwards are also present here.

Work done by Whitaker,(1983),(reviewed on p.96 above) suggests that some students believe that a force is required to keep a body moving and that when the source of this force is removed the body will fall straight down. If the object is initially part of a moving system then it will fall behind a point directly below it as that point would have moved forward relative to the initial position of the object. What is astonishing about Whitaker's results is the relatively small proportion of his sample who believe that the dropped ball will fall behind a horse and rider as there are some very strong perceptual clues which suggest that the ball is falling backwards relative to the rider. It is also interesting to note that the proportion of his sample which exhibits this belief changed markedly when the the situation used is changed. The situations depicted by our questions C1 and C4 are comparable to his questions involving the galloping horse and sailing boat while our question C2 is comparable to his question involving a boxcar.

McKloskey's work into projectile motion was reviewed on p.100 above. The situation used in our question C6 is comparable to the situation used by him in his investigation.

Halloun and Hestenes's investigation into the initial knowledge of college students was reviewed on p. 61 above. Their results are comparable to our work on questions C1 and C6, but as they used college students we should compare their results with our standard 9 science group.

Results:

Before we go into a more detailed discussion of our results we are going to present data relative to the investigations reviewed.

On his boxcar problem in which students were asked to decide where a bolt which falls freely from the ceiling of a boxcar moving at 60 miles per hour, would strike the ground relative to a hole which is immediately below the bolt, Whitaker found that of his sample 40% of students who did not study physics at high school and 33% of students who studied physics at high school thought that the bolt would hit the ground behind the hole in the floor. This option is comparable to our own option in C2 of a boy standing in front of the hole to release a stone in order that it may fall through the hole (i.e. option a). We find that 27% of the pupils in our whole sample select this option. However, if we should further try to equate the samples we must look at our standard 9 science and non-science groups, and here we find that about 31% of the pupils in each of the two groups select this option. This is in very good agreement with the reported results.

On his horse and rider problem in which his students had to decide where a ball dropped by the rider would land relative to the horse and rider, Whitaker reports that 28% of his science pupils and 17% of his non-science pupils believe that the object will fall straight down. This question is comparable to our questions C1 and C4 which involves a moving child dropping a ball or throwing it upwards. We find that 29% of the pupils in our whole sample select this option in the situation depicted in our C1 while 22% of our standard 9 science and 26% of our non-scienc pupils select this option. If one considers that a belief that the object will actually fall backwards also suggest that the object should land behind the person who has dropped it, then we should add to our results the proportion of pupils who select the option which suggests that the ball is actually falling backwards as well. We now find that 39% of our standard 9 science and 52%

of our non-science standard 9 pupils indicate a belief that the ball will land behind the running boy. These proportions are considerably larger than that reported by Whitaker for his galloping horse problem but in line with the results of his sailing boat problem where he has found that 62% of his non-science pupils and 45% of his science pupils select the option which indicate a belief that an object dropped from the top of the mast of a moving yacht will fall behind the mast of the yacht. On the situation depicted in our C4 we find that 34% of our whole sample select the option which suggests that the ball will travel straight up and down. We now find that 29% of the pupils in each of our standard 9 science and non-science groups select this option. If we add to this those who select options suggesting that the ball will actually move backwards, then we find that 64% of our science and 75% of our non-science group select options which suggest that the ball will land behind the girl.

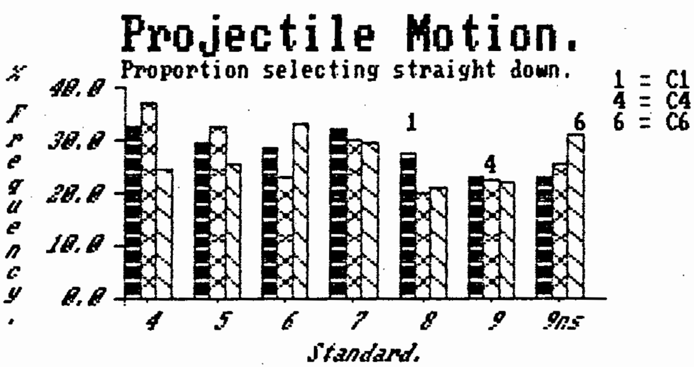
The situations covered in the work reported by McCloskey is covered by our question C6 as well as some of those in question C1. The frequencies reported for our standard 9 science pupils as compared to those reported by McCloskey and Halloun, are as follows:

Path:

McCloskey :	5%	35%	28%	32%
C6.:	1%	5%	63%	22%
C1.:	3%		48%	22%
Halloun			66%	

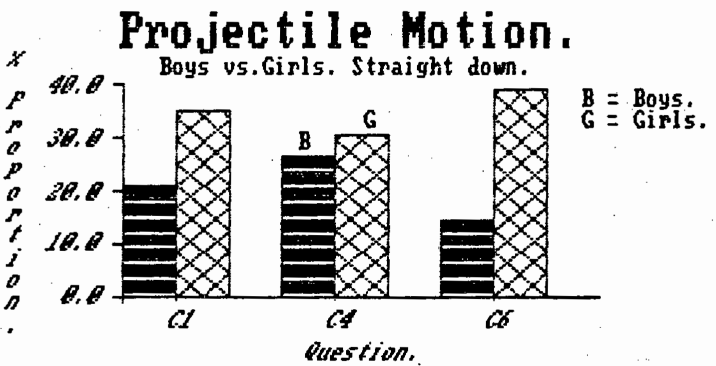
It is clear from these figures that on some of the findings we agree with McCloskey's frequencies but on others not. This is especially true for the results reported for the path which suggests that the projectile travels along horizontally and then slowly starts to curve down until it is falling vertically. On the other hand, our results agree very well with that of Halloun and Hestenes.

We find that a high proportion of the pupils in the Cape and even higher in Transkei, believe in the situations depicted in C1, C4 and C6, that the object will fall straight down once it is released. As the following graph which compares the frequencies with which pupils in the different standards in schools in the Cape select this option shows, this believe is not restricted to the pupils in some standards only but is spread over all the standards.



It is clear from the graph that pupils in standards 4 and 5 consider the behaviour of the object in questions C1 and C4 as very similar but different from that of the object in question C6. Pupils in standard 7 and the standard 9 science group consider all three of the situations to be similar while those in standard 6 appear to consider all three of the situations as being different from each other. There is some evidence here of context-dependency of the response. It is interesting that while the proportion of pupils in each of the standards who believe that the ball will fall straight down decreases to a minimum with the standard 9 science pupils, a relatively high proportion of the pupils in this group still share this belief.

We find that the belief that the ball will fall straight down is more firmly held by girls than boys in schools in the Cape. The following graph which compares the proportion of boys and girls who select the option which suggests that the object will fall straight down, shows this very clearly.



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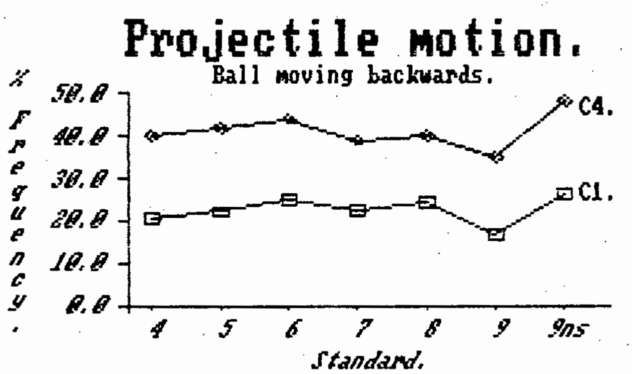
On all of the situations presented the pupils from Transkei consistently select the option which suggests that the object will move straight down with a higher frequency than their counterparts in the Cape - this was the favourite option with Transkei pupils in every situation.

The belief that a freely falling object will fall backwards is strongly rooted in pupils in schools in the Cape. The following graph compares the proportion of pupils in each of the standards in the Cape who select options suggesting that the ball will fall backwards when released by a moving person.



This is a particularly interesting pair of curves as the trends on them are remarkably similar. It would appear that the perceptual clues which suggests that the ball is falling backwards are much stronger in the case of a ball being thrown upwards.

In this case again it would appear that boys and girls in Cape schools see the path of falling objects differently. In both

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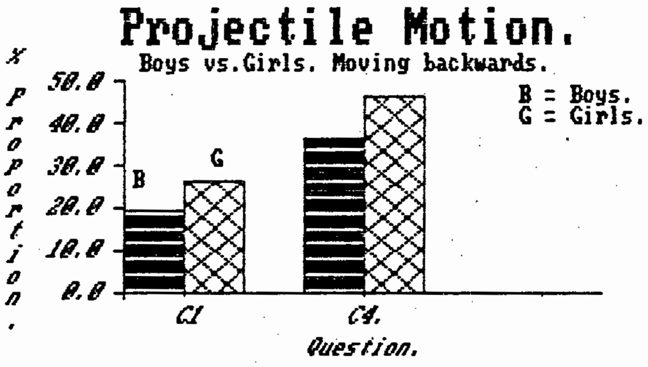
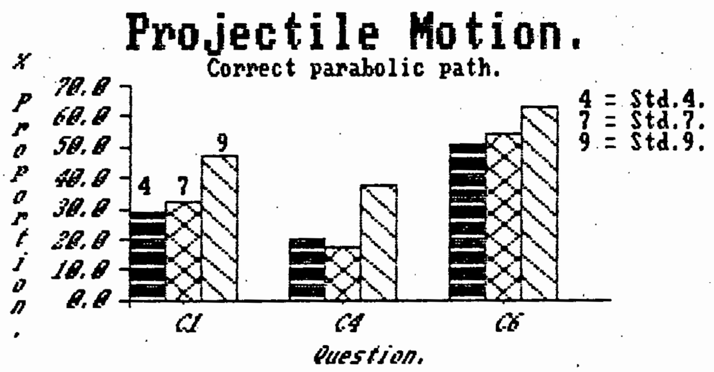
cases a greater proportion of girls select options which suggest that the dropped object will move backwards. The following graph, which compares the proportion of boys and girls who select options suggesting a backwards path, shows this clearly.



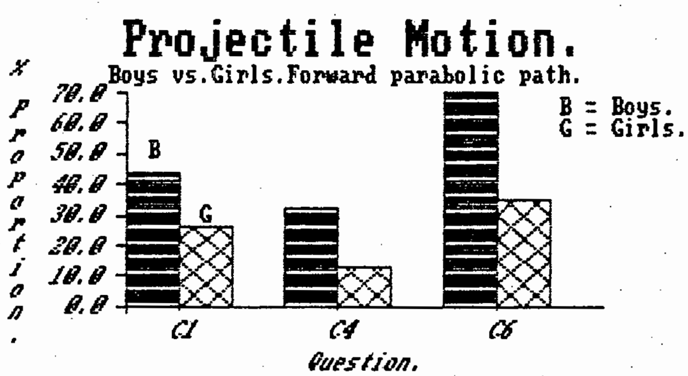
Our results also indicate that the belief that the dropped ball will move backwards is held by a slightly larger proportion of English-speaking than Afrikaans-speaking pupils, the difference being in the order of 5%.

The one aspect of the results which we find astonishing is the small proportion of pupils in each of the standards which select the correct parabolic path for the movement of the ball. The following graph compares the proportions of pupils in standards 4, 7 and 9 science group who select the correct option on questions C1, C4 and C6.



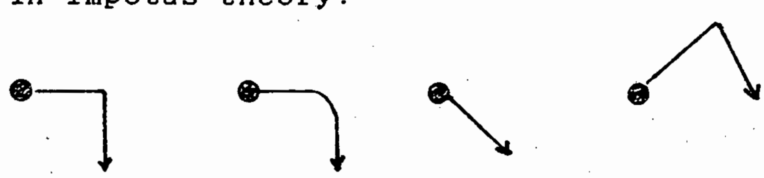
This graph clearly shows that the context of the question is a major factor in determining the proportion of pupils who select the correct answer. The ball being thrown upwards (C4) is clearly seen as a very different situation from the ball falling off the table.(C6). This one would consider to be a very everyday experience for children and although they indicate that more of them now know the path, only 63% of the standard 9 science pupils select it. In each case the proportion of standard 9 science pupils who select the correct option is higher than that for the other classes, but as the graph shows, not dramatically so. Our pupils truly do not see the world of falling objects through the same glasses as we do!

The following graph which compares the proportion of boys and girls who select the forward parabolic path for the falling balls also clearly indicates that there are fairly large differences in the way that boys and girls see falling objects.

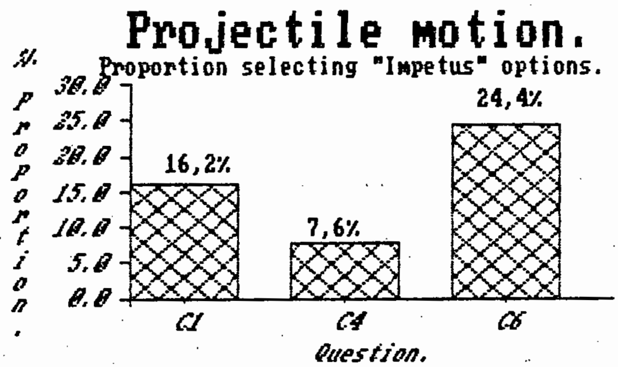


The belief that the path of the falling ball is parabolic and forward is clearly held by a much larger proportion of boys than girls. There can be no doubt that pupils in these two groups have a very different view of falling objects.

It is interesting to speculate on the kind of reasoning which leads to the selection of the different paths. McCloskey, Halloun and Hestenes identify the following paths as being the result of a belief in Impetus theory:

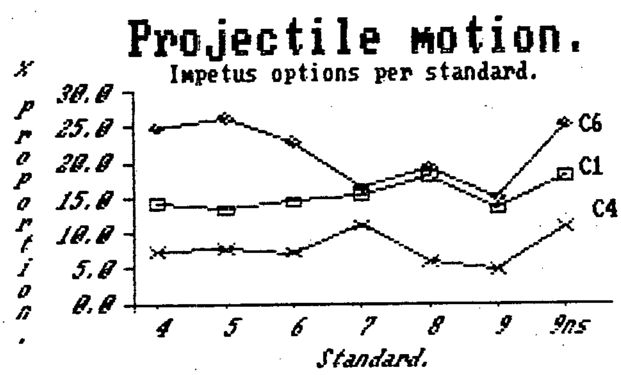


Each one of our questions contain some options which, if selected, would indicate, in the opinion of the researchers quoted above, a belief in Impetus Theory. On question C1 this would be options a and d, on question C4 option e and on question C6 options a,b and c. The following graph compares the overall frequency with which these options are selected by the whole sample on the different questions.



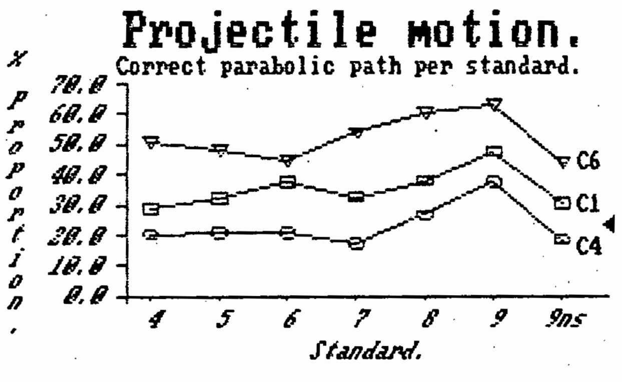
McCloskey reports that in the problem in which he asked his students to draw the path along which a rapidly moving metal ball will fall if it is pushed over the side of a cliff, about 40% of his sample select options which indicate a belief in Impetus theory. As previously stated above, this problem is very similar to our question C 6. We find that only 24% of our sample select options which indicate a belief in Impetus Theory. The graph also clearly shows that the proportion of pupils which select "Impetus" options to be dependent on the question asked. Questions C1 and C6 are similar in the sense that in both cases the object is moving forward horizontally and these two questions elicited a substantially higher proportion of pupils who select options which indicate a belief in Impetus theory. It is possible that the low frequency with which "Impetus" options are selected on question C4 is due to the fact that only one option was given which suggests the path associated with this belief.

The following graph compares the frequencies with which pupils in the different standards in Cape schools select "Impetus" options on the different questions.



The graph clearly illustrates that as far as selecting options which indicate a belief in Impetus theory, the standard 4, 5, 6 pupils and standard 9 pupils who do not do science see all of the situations presented as different from one another. Standard 7, 8 and 9 pupils see the situations presented in C1 and C6 as similar to each other and different from the situation presented in C4.

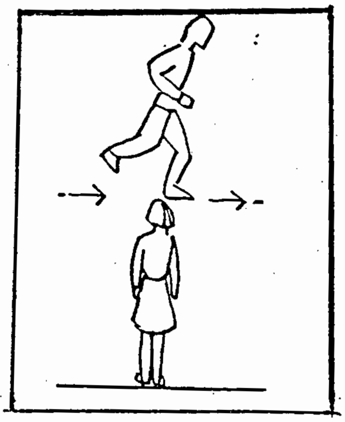
We may expect that the situation presented to the pupils by our question C6 will in everyday life present them with no false perceptual information about the motion of the falling object. We may expect that on this question the correct parabolic path will be selected with a higher frequency by pupils in all of the standards. We also expect that the perceptual mis-information present in the situation presented in C1 to be less misleading than those present in the more complex situation presented in C4 and we therefore expect that the frequency with which the correct option is selected by pupils in the different standards to be higher for C1 than for C4 and less than on C6. The following graph clearly supports this argument.

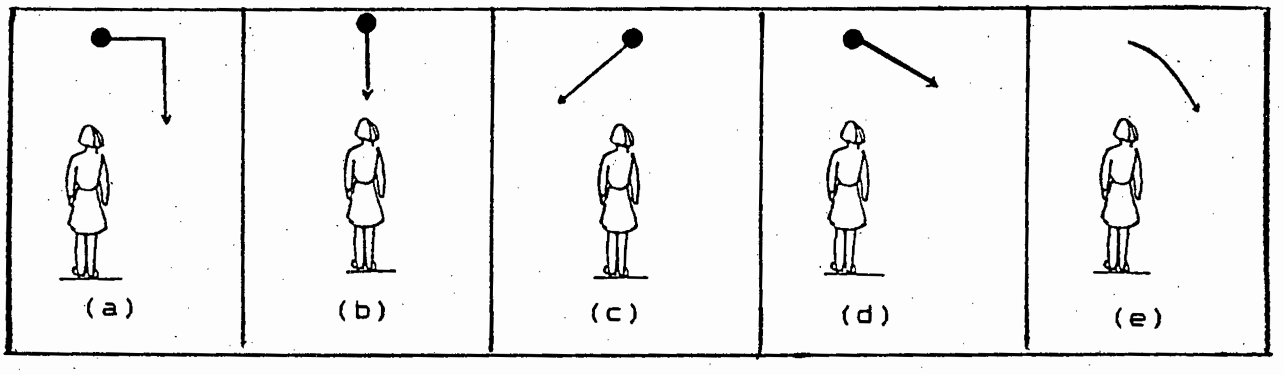


This graph as well as the graph which compares the frequencies with which the different standards select "impetus" options both indicate that the pupils see the different situations presented to them as different from each other and that the largest difference is between C6 and C4 with, as we may expect, C1 somewhat similar to both of them. Once again it is clear that the responses elicited from the pupils depend on the situation presented and the reason for this is most probably the perceptual cues associated with these situations in real life.

Question C 1

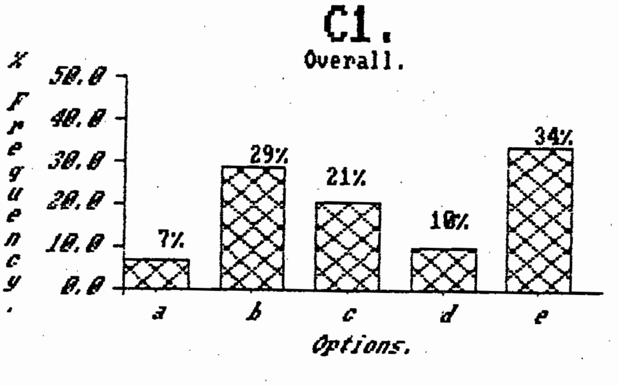
The sketch shows a boy who is running along to the right and a girl is watching him. Just as he passes her he drops a ball from his hand. The girl sees the ball fall to the ground. The sketch which best shows the path the <u>girl</u> sees the ball fall along, is:





(a) **The overall picture:**

The following graph compares the frequencies with which the different options were selected by the whole sample.



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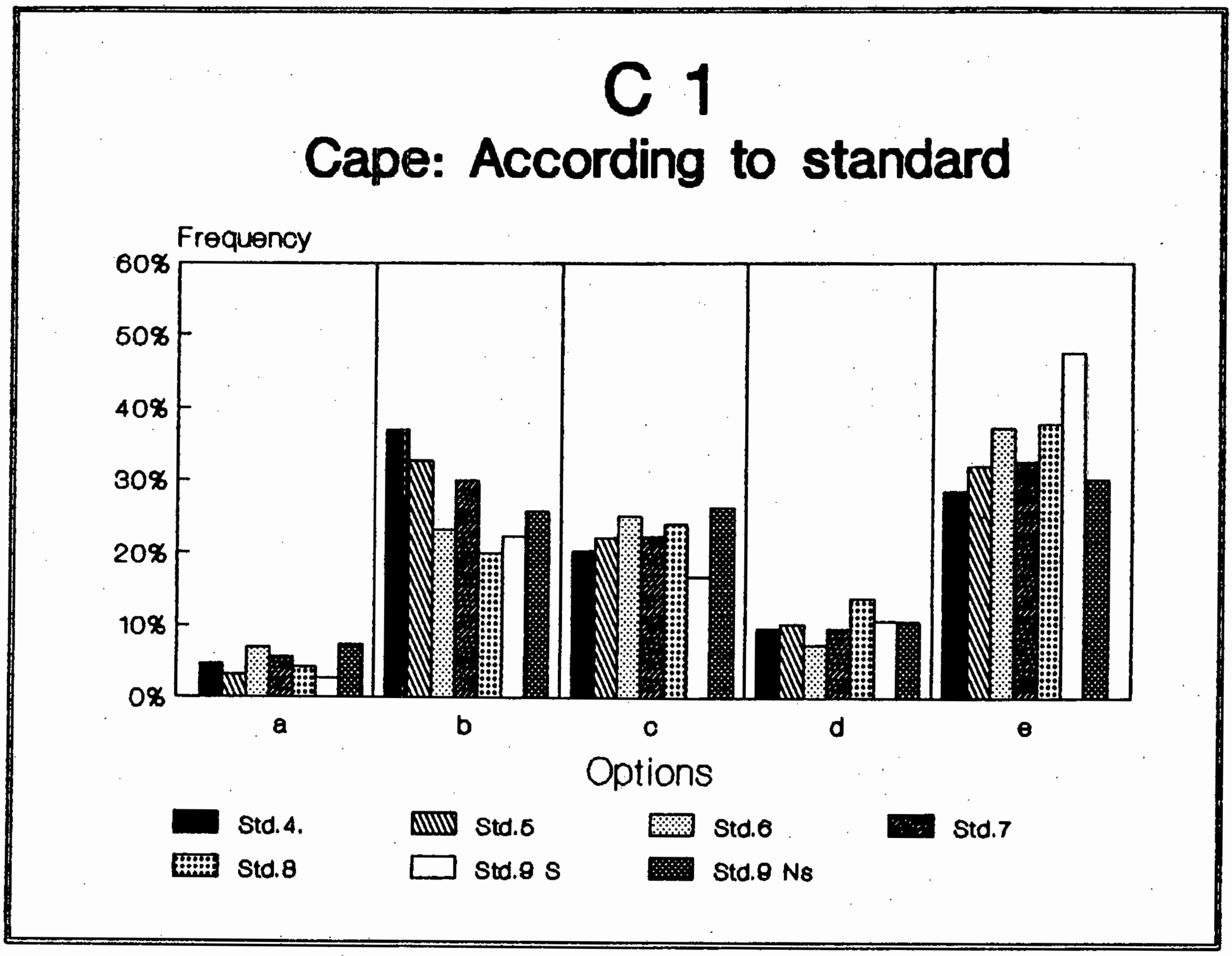
Note:

1. 7% of the sample select option a, the option which suggests that the ball travels horizontally for a while and then suddenly falls vertically.
2. 29% of the sample select option b, the option which suggests that the ball falls straight down.
3. 21% select option c, the option which suggests that the ball will fall backwards away from the person who has dropped it.
4. 10% of the sample select option d, the option which suggests that the ball falls forward but at an angle.
5. 34% of the sample select option e, the option which suggests the the ball travels forward and downwards along a parabolic path.
6. 51% of the sample select options which suggest that the ball travels forwards, 21% that it travels backwards and 29% that it falls straight down.

(b) **Comparing the standards:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

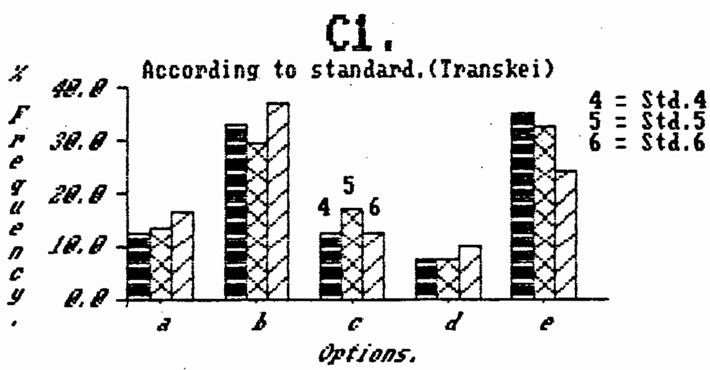
1. No single standard finds any one of the options overwhelmingly popular.
2. Option a is unpopular with pupils in all of the standards.
3. Option b is fairly popular with pupils in all of the standards but pupils in standards 4 and 5 and find it the most popular; its popularity decreased thereafter. The standard 6 pupils seem to be a little out of step here as this group does not

appear to be supporting this option quite as strongly as an extrapolation of the graph would seem to suggest.

4. Option c receives a fair amount of support from the pupils in all of the standards with the standard 9 science group according it the least support.
5. Option d is not particularly popular with pupils in any of the classes but the support it receives is consistent across all of the standards.
6. With the exception of the standard 4 and 5 pupils, option e is the most popular option with pupils in all of the other standards. Its popularity reached a maximum with the standard 9 science pupils. Again here it would seem that the standard 6 pupils find this option a little "too" popular.

2. In Transkei:

The following graph compares the frequencies with which pupils in the different standards at schools in Transkei select the different options.

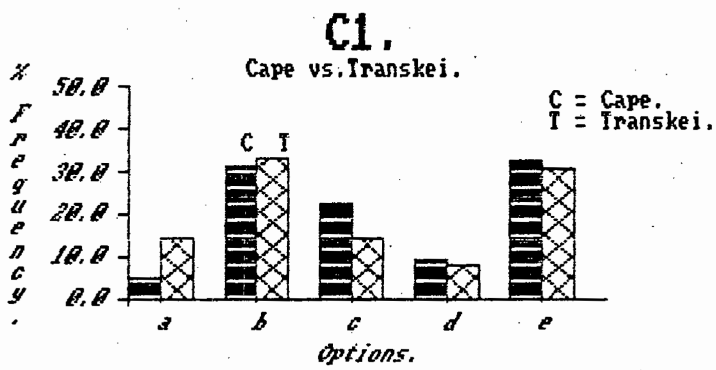


Note:

1. No single standard finds any one of the options overwhelmingly attractive.
2. All of the options receive some support from the pupils but option d is the least popular with all of the standards.
3. Option b is very popular with the standard 6 pupils while the standard 4 and 5 pupils find option e the most popular.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils at schools in the Cape and Transkei select the different options.



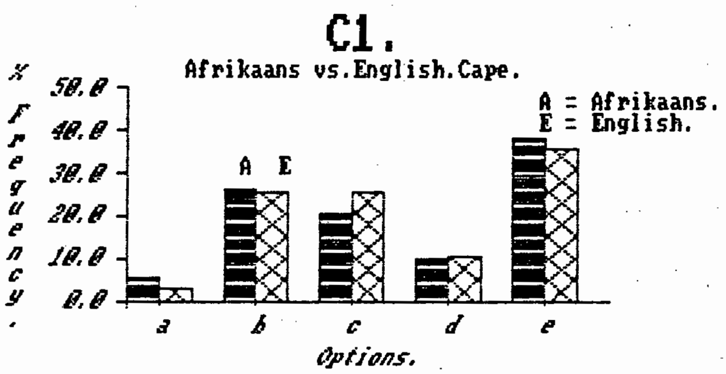
Note:

1. Pupils from the two groups select options b, d and e with very similar frequencies.
2. About 32% of the pupils in each of the groups select option b.
3. About 32% of the pupils in each of the groups select option e.

4. 5% of the pupils in the Cape and 14% of the pupils in Transkei select option a.
5. 23% of the pupils in the Cape and 14% of the pupils in Transkei select option c.
6. About 9% of the pupils in each of the groups select option d.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils at school in the Cape select the different options.



Note:

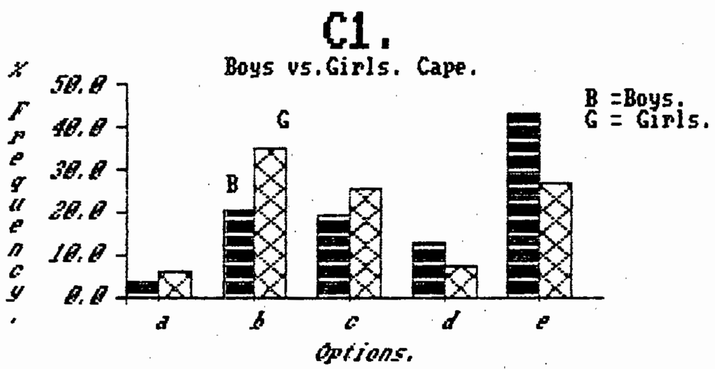
1. There is only a relatively small difference in the frequencies with which the two groups select option c.
2. 20% of Afrikaans-and 25% of English-speaking pupils select option c
3. 6% of Afrikaans-and 3% of English-speaking pupils select option a.
4. 26% of the pupils in each of the two groups select option b.
5. 10% of the pupils in both groups select option d

6. About 37% of the pupils in each of the two groups select option e.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.



Note:

1. It is clear that the two groups select all of the options with appreciably different frequencies.
2. 4% of the boys and 6% of the girls select option a.
3. 21% of the boys and 35% of the girls select option b.
4. 19% of the boys and 26% of the girls select option c.
5. 13% of the boys and 7% of the girls select option d.
6. 43% of the boys and 27% of the girls select option e.
7. 60% of the boys and 40% of the girls select options which suggest that the ball will move forward after it has been released.

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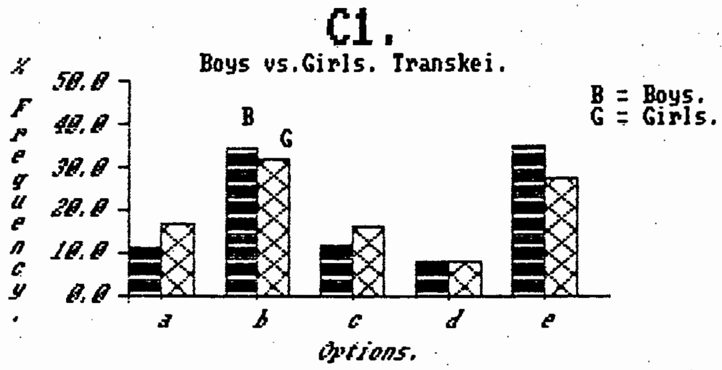
2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.



Note:

1. There are only small differences in the frequencies with which pupils in the two groups select most of the options.
2. 11% of the boys and 17% of the girls select option a.
3. 34% of the boys and 32% of the girls select option b.
4. 12% of the boys and 16% of the girls select option c.
5. 8% of the the pupils in each of the two groups select option d.
6. 35% of the boys and 27% of the girls select option e.

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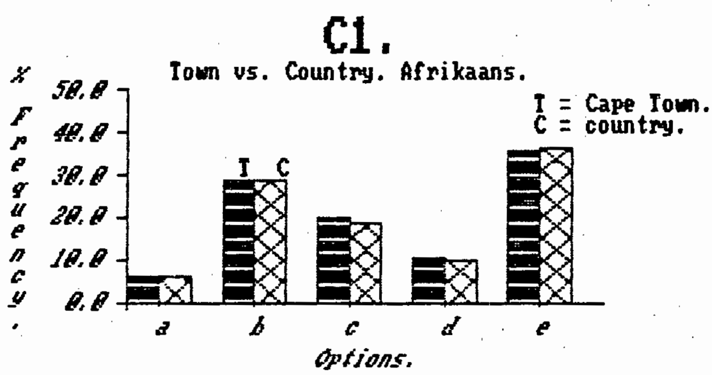
(f) Comparing pupils from Town and country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils who attend schools in Cape Town and country towns select the different options.



Note:

1. There are clearly no noteworthy differences in the frequencies with which pupils from these two groups select the different options.

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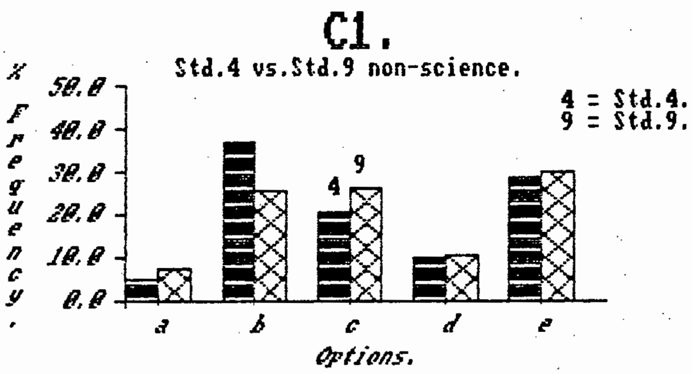
(g) **Comparing some of the standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science select the different options.

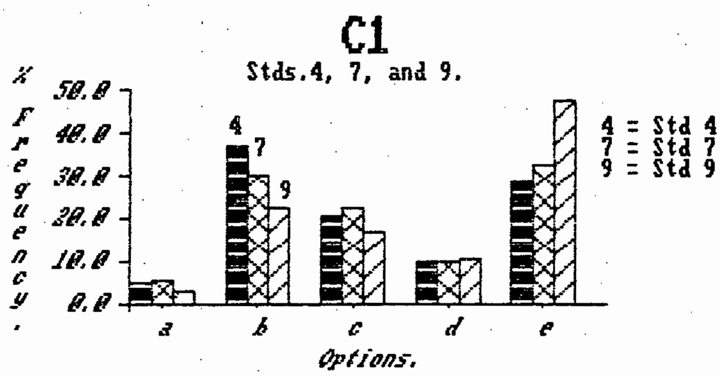


Note:

1. There are large differences in the frequencies with which the pupils in the two groups select options b and c.
2. 37% of the standard 4 and 26% of the standard 9 pupils select option b
3. 20% of the standard 4 and 26% of the standard 9 pupils select option c.
4. About 30% of the pupils in each of the two groups select option e.

2. Standard 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standard 4, 7 and 9 science pupils select the different options.

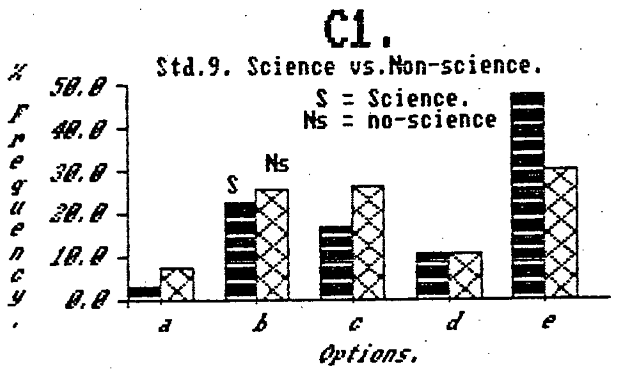


Note:

1. There is a decrease in the frequencies with which option b is selected by the pupils from standard 4 through to standard 9.
2. There is very small variation in the frequencies with which the pupils in the different standards select options a, c and d.
3. There is an increase in the frequencies with which option e is selected by the pupils from standard 4 through to standard 9.

3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science at school select the different options.

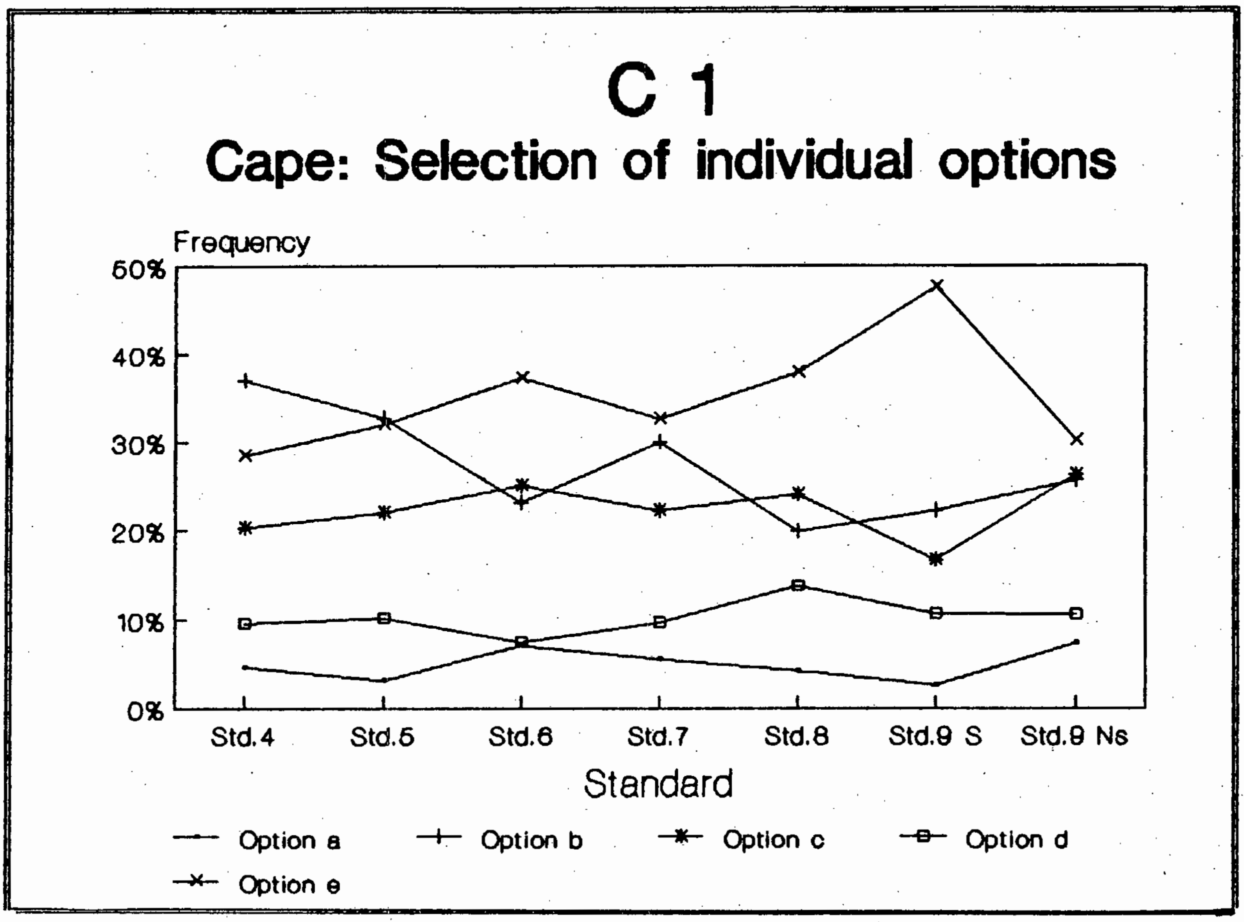


Note:

1. There are fairly large differences in the frequencies with which the pupils in the two groups select options a, b, c and e.
2. 3% of science and 7% of non-science pupils select option a.
3. 22% of science and 26% of non-science pupils select option b.
4. 17% of science and 26% of non-science pupils select option c.
5. 48% of science and 30% of non-science pupils select option e.
6. Option d is selected by 11% of the pupils in each of the two groups.

(h) **Selection of individual options:**

The following graph shows how the individual options are selected across the different standards.



Note:

1. There is a small peak in the selection of option e over the standard 6 group and a corresponding minimum in the frequency of selection of option b by the same group.
2. Options a, c and d are selected with relative constancy.

Summary:

1. When we examine the overall picture, we find that:

21% of the pupils in our whole sample believe that the ball would fall backwards away from the boy after he has released it;

29% of the pupils in our sample believe that the ball would fall straight down after the boy has released it;

51% of the pupils in our sample believe that the ball would travel forwards after release;

34% of the pupils in our sample believe that the ball would travel forwards on a parabolic path;

7% of the pupils in our sample believe that the ball would travel along horizontally and then suddenly drop straight down.

2. When we examine the frequencies with which pupils in the different standards in schools in the Cape select the different options, we find that:

the belief that the ball will first travel horizontally and then vertically is not popular with any of the standards but it receives small but consistent support from all of the standards;

the majority of pupils in standards 4 and 5 believe that the ball will fall straight down. This is a popular belief with pupils in all of the standards but it decreased in popularity across the standards.

the belief that the ball will fall backwards is held by a fairly large proportion of pupils in all of the standards, the standard 9 science group being the group which held this belief less widely than any of the other;

a small but consistent proportion of the pupils in all of the standards believe that the ball will travel forward but at an angle to the ground;

with the exception of standard 4 and 5 pupils the majority of pupils in the other standards believe that the ball will follow a parabolic path on its way to the ground. This belief increased in popularity across the standards to a maximum with the standard 9 science pupils.

there is some evidence that the standard 6 pupils, when compared to the pupils in standard 4, 5 and 7, may be behaving a little differently from what might be expected.

In Transkei we find that:

no one of the individual options is overwhelmingly popular. The pupils were divided between all of the different options with options b and e being the most popular.

the majority of standard 6 pupils believe that the ball will fall straight down;

the majority of standards 4 and 5 pupils believe that the ball will follow a parabolic path to the ground.

3. When we compare pupils from the Cape and Transkei we find that:

32% of the pupils in each of the two groups believe that the ball will fall straight down;

32% of the pupils in each of the two groups believe that the

ball will fall along a parabolic path;
23% of pupils in the Cape and 14% of the pupils in Transkei believe that the ball will fall backwards.

4. When we compare Afrikaans-and-English-speaking pupils in schools in the Cape we find that:

20% of Afrikaans-and 25% of English-speaking pupils believe that the ball will fall backwards;
26% of the pupils in each of the groups believe that the ball will fall straight down
37% of the pupils in each of the two groups believe that the ball will fall along a parabolic path.

5. When we compare boys and girls in schools in the Cape we find that:

21% of the boys and 35% of the girls believe that the ball will fall straight down;
19% of the boys and 26% of the girls believe that the ball will fall backwards;
43% of the boys and 27% of the girls believe that the ball will fall along a parabolic path;
60% of the boys and 40% of the girls believe that the ball will travel forwards after it had been released.

In Transkei we find that:

12% of the boys and 16% of the girls believe that the ball will travel backwards;
35% of the boys and 26% of the girls believe that it will

travel on a parabolic path.

6. When we compare Afrikaans-speaking pupils attending schools in Cape Town and country towns we find that there is no appreciable difference in the proportion of pupils in the two groups who select the different options.

7. When we compare pupils in some of the standards we find that:

37% of standard 4 and 26% of standard 9 pupils who do not do science believe that the ball will fall straight down;
20% of the standard 4 and 26% of the standard 9 pupils believe that the ball will fall backwards;
30% of the pupils in the two groups believe that the ball will fall along a parabolic path.
the proportion of pupils who believe that the ball will fall straight down decreases across the standards from standard 4 through to the standard 9 science pupils;
the proportion of pupils who believe that the ball will fall along a parabolic path increases across the standards from standard 4 through to the standard 9 science pupils;
22% of standard 9 pupils who do science and 26% of the pupils who do not do science believe that the ball will fall straight down;
17% of the science pupils and 26% of the non-science pupils believe that the ball will fall backwards;
48% of the science and 30% of the non-science pupils believe that the ball will fall along a parabolic path;
62% of the science and 48% of the non-science pupils believe

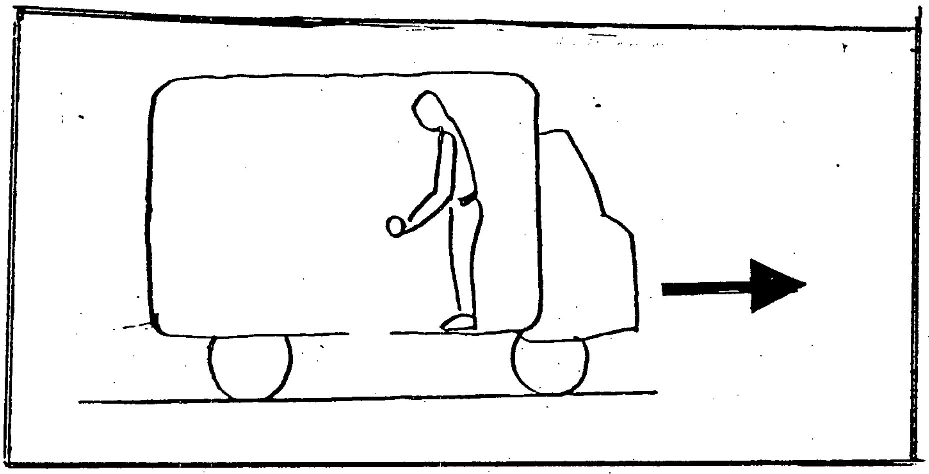
that the ball will travel forward.

8. An examination of the curve which compares the selection of similar options shows that:

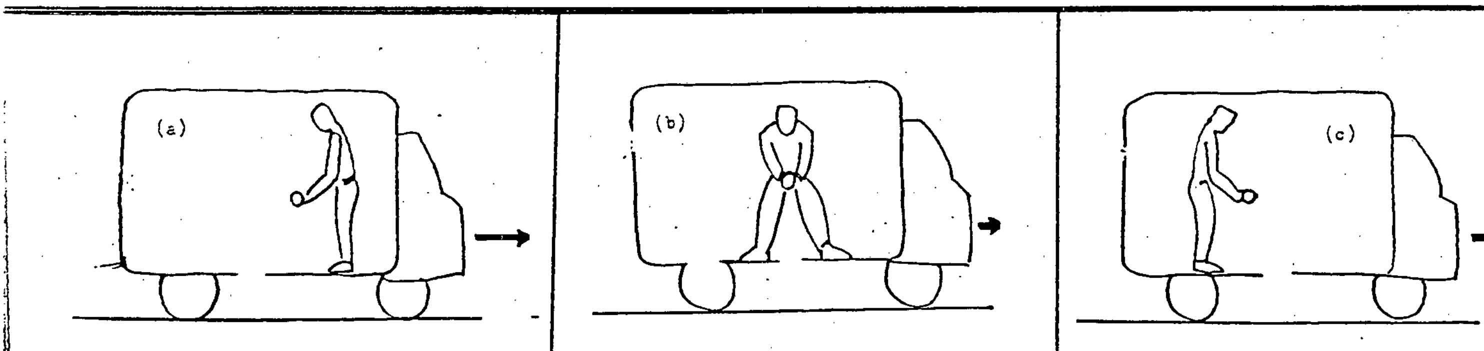
   option e is in general the most popular option with all of the standards, the standard 4 group being an exception;

   options a, d and e are selected by very consistent proportions of the pupils in each of the standards.

Question C 2



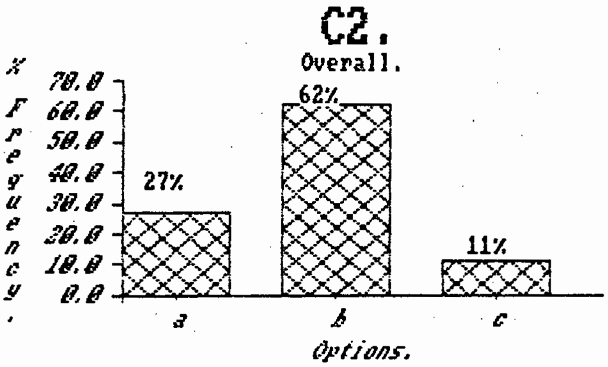
The sketch shows a boy who is standing in the back of an enclosed truck. The truck is moving towards the right at constant speed. There is a hole in the floor of the truck and the boy wants to drop a stone through the hole. The sketch which best shows where he must stand to allow the stone to drop from his hand through the hole is:



(a) (b) (c)

(a) **The overall picture:**

The following graph compares the frequencies with which the pupils in the whole sample select the different options.



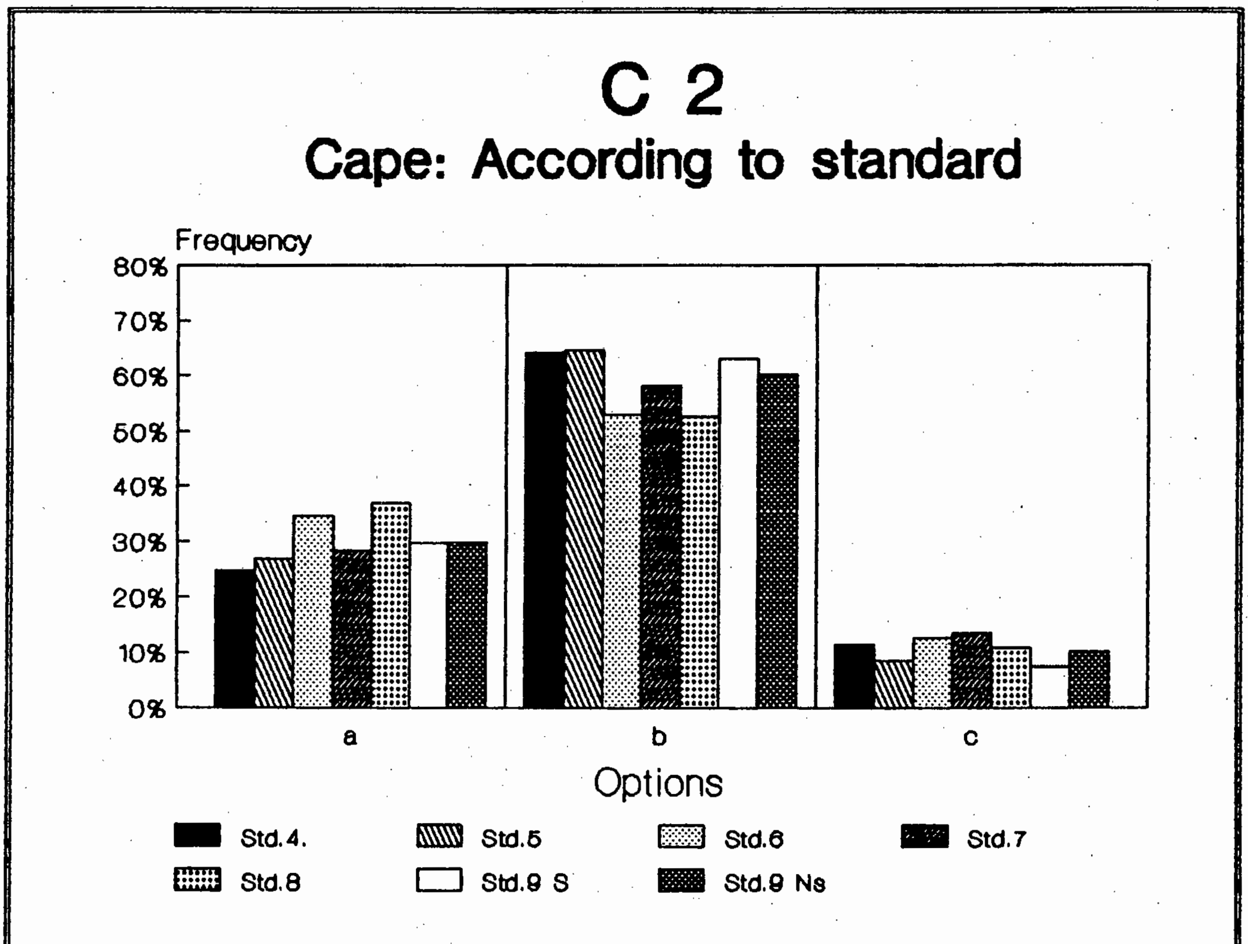
Note:

1. 27% of the pupils in the whole sample select option a, the option which suggests that the boy has to stand in front of the hole.
2. 62% of the pupils select option b, the option which suggests that the boy has to stand over the hole.
3. 11% of the pupils select option c, the option which suggests that the boy has to stand behind the hole.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

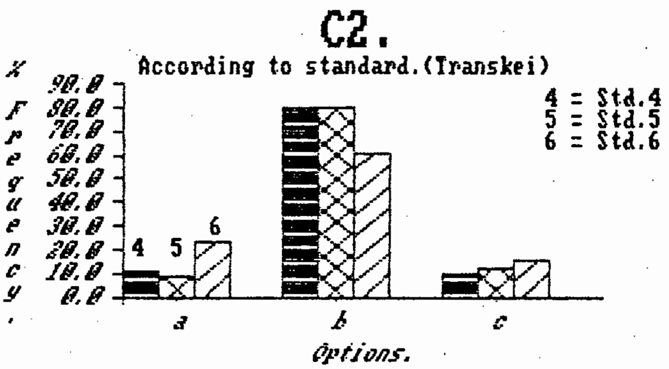
1 Option b is the favourite option of the pupils in all of the standards. It is particularly so with the pupils in standards 4, 5 and 9.

2. Option a is selected by a fair proportion of pupils in all of the standards especially those in standard 6 and 8.

3. Option c is selected by a small but consistent proportion of the pupils in all of the standards.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.



Note:

1. Pupils in standards 4 and 5 overwhelmingly select option b. It is not as popular with pupils in standard 6.
2. Of the pupils of all of the different standards who select option a, those in standard 6 found it the most attractive.
3. Option c is selected by a small but fairly consistent proportion of the pupils in the different standards.

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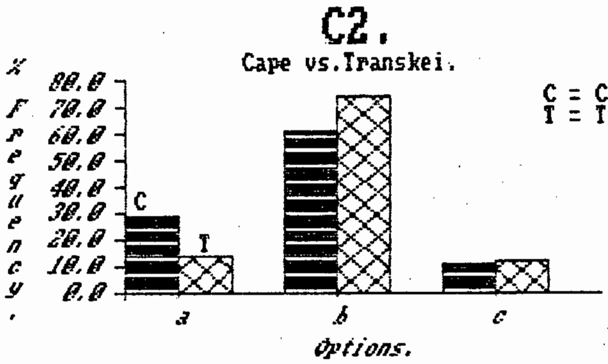
(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which pupils in standards 4, 5 and 6 in schools in the Cape and Transkei select the different options.

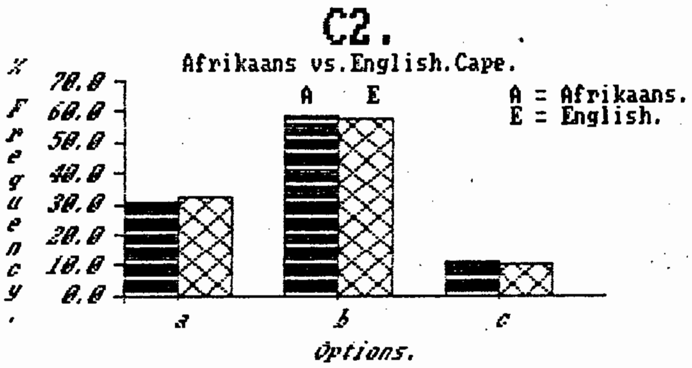


Note:

1. Pupils from the two groups differ in the frequencies with which they select options a and b.
2. 29% of pupils from the Cape and 14% of pupils from Transkei select option a.
3. 61% of pupils from the Cape and 74% of pupils from Transkei select option b.
4. About 11% of the pupils in each of the groups select option c.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



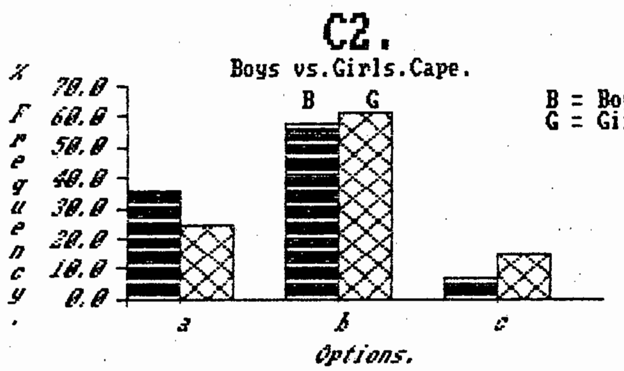
Note:

1. There are astonishingly small differences in the frequencies with which pupils in the two groups select the different options.
2. 31% of the pupils select option a.
3. 58% of the pupils select option b.
4. 11% of the pupils select option c.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

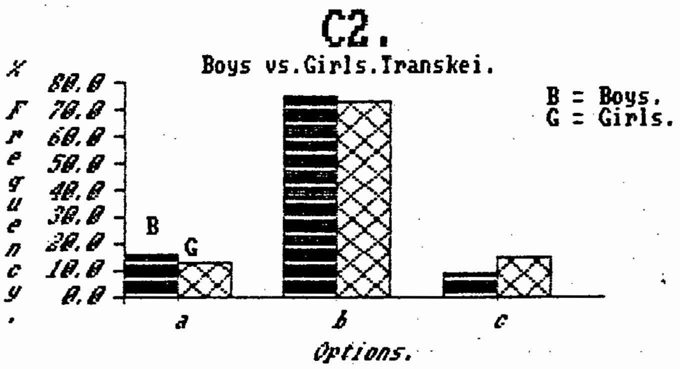


Note:

1. There are differences in the frequencies with which pupils from the two groups select the different options.
2. 36% of the boys and 24% of the girls select option a.
3. 58% of the boys and 61% of the girls select option b.
4. 7% of the boys and 15% of the girls select option c.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

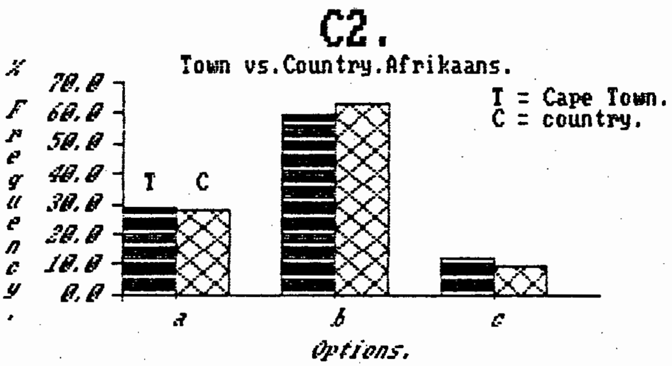


Note:

1. There are no noteworthy differences in the frequencies with which the pupils in these two groups select the different options.

(f) Comparing pupils from Town and country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils at schools in Cape Town and country towns select the different options.



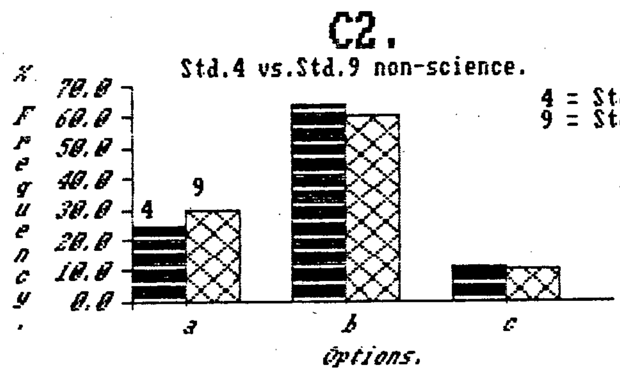
Note:

1. There are no noteworthy differences in the frequencies with which pupils from these two groups select the different options.

(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 pupils who do not do science select the different options.

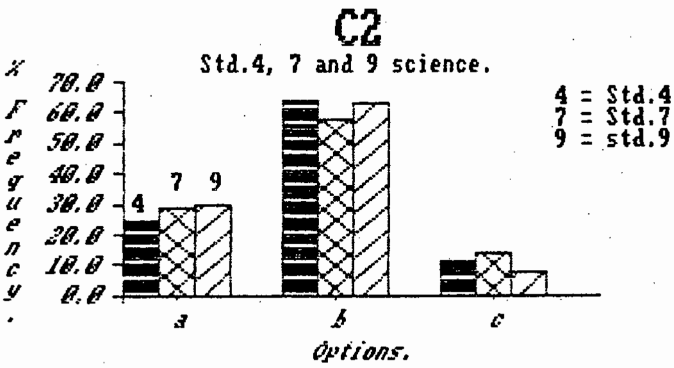


Note:

1. There are small differences in the frequencies with which the pupils in these two groups select options a and b.
2. 25% of standard 4 and 30% of standard 9 pupils select option a.
3. 64% of standard 4 and 60% of standard 9 pupils select option b.

2. <u>Standards 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.



Note:

1. There is a small increase in the frequencies with which the pupils in the different standards select option a from standard 4 through to standard 9.

2. There is very little difference in the frequencies with which the pupils select option b and c.

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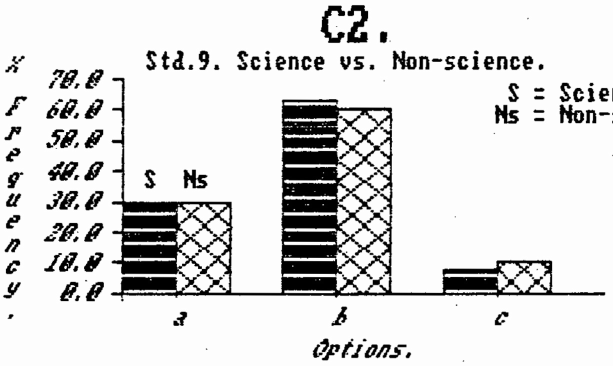
3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science select the different options.

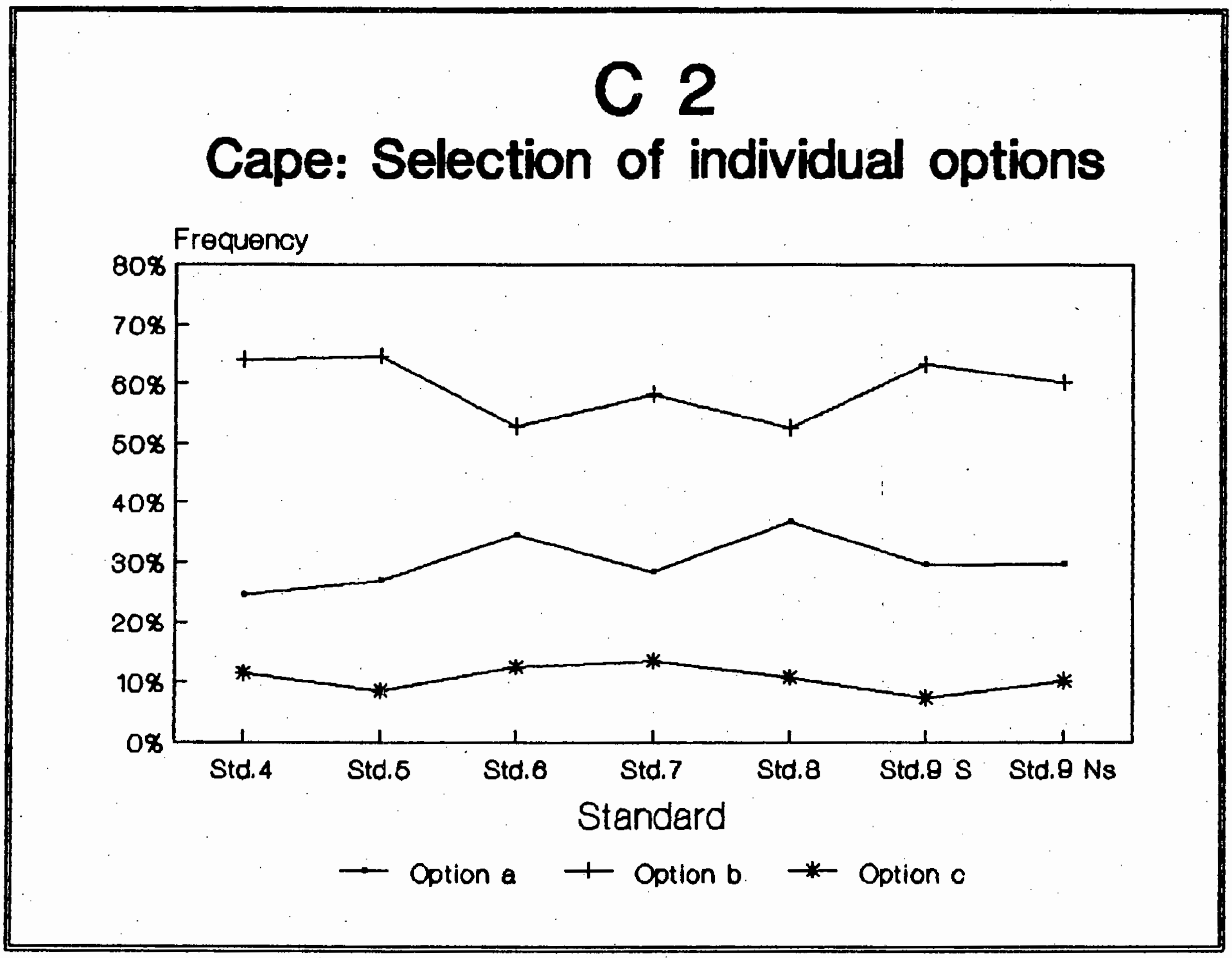


Note:

1. There is no noteworthy difference in the frequencies with which the pupils in these two groups select the different options.

(h) **Selection of individual options:**

The following graph shows how the individual options are selected across the different standards.



Note:

1. There are minima in the frequencies of selection of option b over standards 6 and 8 with corresponding maxima in the frequencies of selection of option a over standard 6 and 8.
2. There is small but consistent support for option c by pupils in all of the standards.

Summary:

1. When we examine the overall picture we find that:

   27% of the pupils in the whole sample believe that the boy should stand in front of the hole;
   62% of the pupils believe that he should stand over the hole;
   11% of the pupils believe that he should stand behind the hole.

2. When we compare the frequencies with which pupils in the different standards in schools in the Cape select the different options we find that:

   the majority of the pupils in each of the different standards believe that the boy should stand over the hole. This belief is especially strong with pupils in standards 4, 5 and 9.
   a fair proportion of pupils in all of the different standards believe that the boy should stand in front of the hole. This idea is especially popular with pupils in standard 6 and 8.
   a small but consistent proportion of the pupils in all the different standards believe that he should stand behind the hole.

   In Transkei we find that:

   pupils in standards 4 and 5 overwhelmingly believe that the boy should stand over the hole. This belief is also the most popular with the standard 6 pupils but they also find the idea that the boy should stand in front of the hole fairly attractive.

3. When we compare pupils in standards 4, 5 and 6 in schools in the Cape and Transkei, we find that:

   29% of the pupils from the Cape and 14% of the pupils from Transkei believe that the boy should stand in front of the hole;

   61% of the pupils from the Cape and 74% of the pupils from Transkei believe that he should stand over the hole.

4. When we compare Afrikaans-and-English-speaking pupils we find that there were no notable differences in the frequencies with which they select the different options;

   31% of the pupils believe that the boy should stand in front of the hole;

   58% believe that he should stand over the hole;

   11% believe that he should stand behind the hole.

5. When we compare boys and girls in schools in the Cape we find that:

   36% of the boys and 24% of the girls believe the boy should stand in front of the hole;

   58% of the boys and 61% of the girls believe that the should stand over the hole;

   7% of the boys and 15% of the girls believe that he should stand behind the hole.

   In Transkei we find no notable differences in the frequencies with which boys and girls select the different options.

6. When we compare the frequencies with which Afrikaans-speaking pupils attending schools in Cape Town and in country towns select the different options we find no appreciable differences between the two groups.

7. When we compare some of the standards we find that

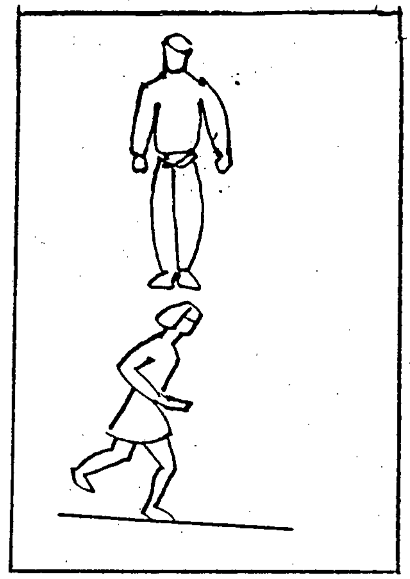
   there is a small increase from standard 4 through to standard 9 in the proportion of pupils who believe that the boy should stand in front of the hole;

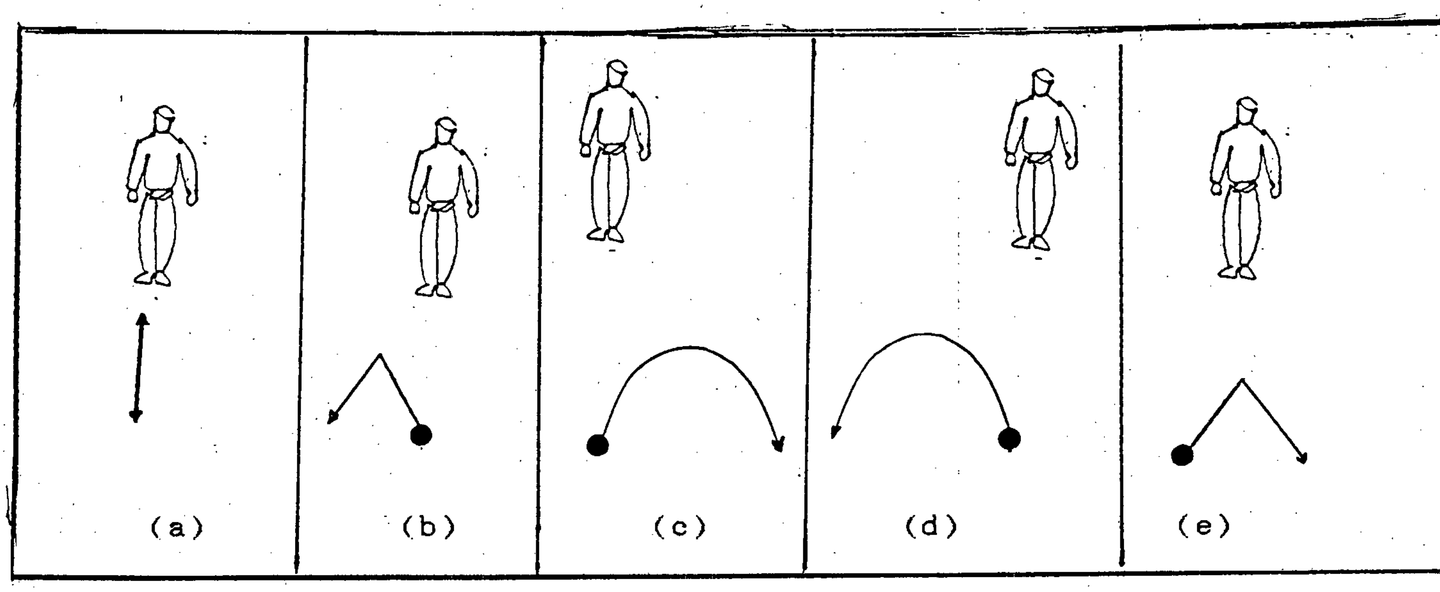
   the belief that the boy should stand over the hole is held by approximately the same proportion of standard 4, 7 and 9 science and non-science pupils.

8 A comparison of the frequencies with which the individual options are selected across all of the standards clearly show the slightly "out of step" behaviour of the standard 6 and 8 pupils.

Question C 4

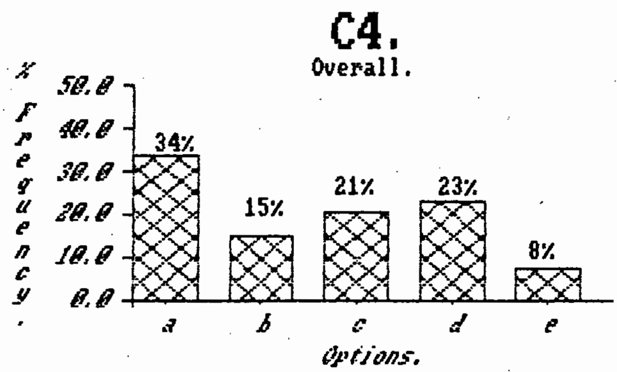
The sketch shows a girl running towards the right past a boy. Just as she passes him, she throws a ball vertically upwards. The sketch which best shows the path which the boy sees the ball travel along, is:





(a) **The overall picture:**

The following graph compares the frequencies with which the pupils in our whole sample select the different options.



Note:

1. 34% of the pupils in the sample select option a, the option which suggests that the ball goes straight up and down.
2. 15% of the pupils select option b, the option which suggests that the ball goes upwards and back at an angle and then down at an angle.
3. 21% of the pupils select option c, the option which suggests that the ball goes up and forward along a parabolic path.
4. 23% of the pupils select option d, the option which suggests that the ball goes upwards and backwards along a parabolic path.
5. 8% of the pupils select option e, the option which suggests that the ball goes upwards and forwards at an angle and then downwards at an angle.
6. 29% of the pupils select options which suggest that the ball

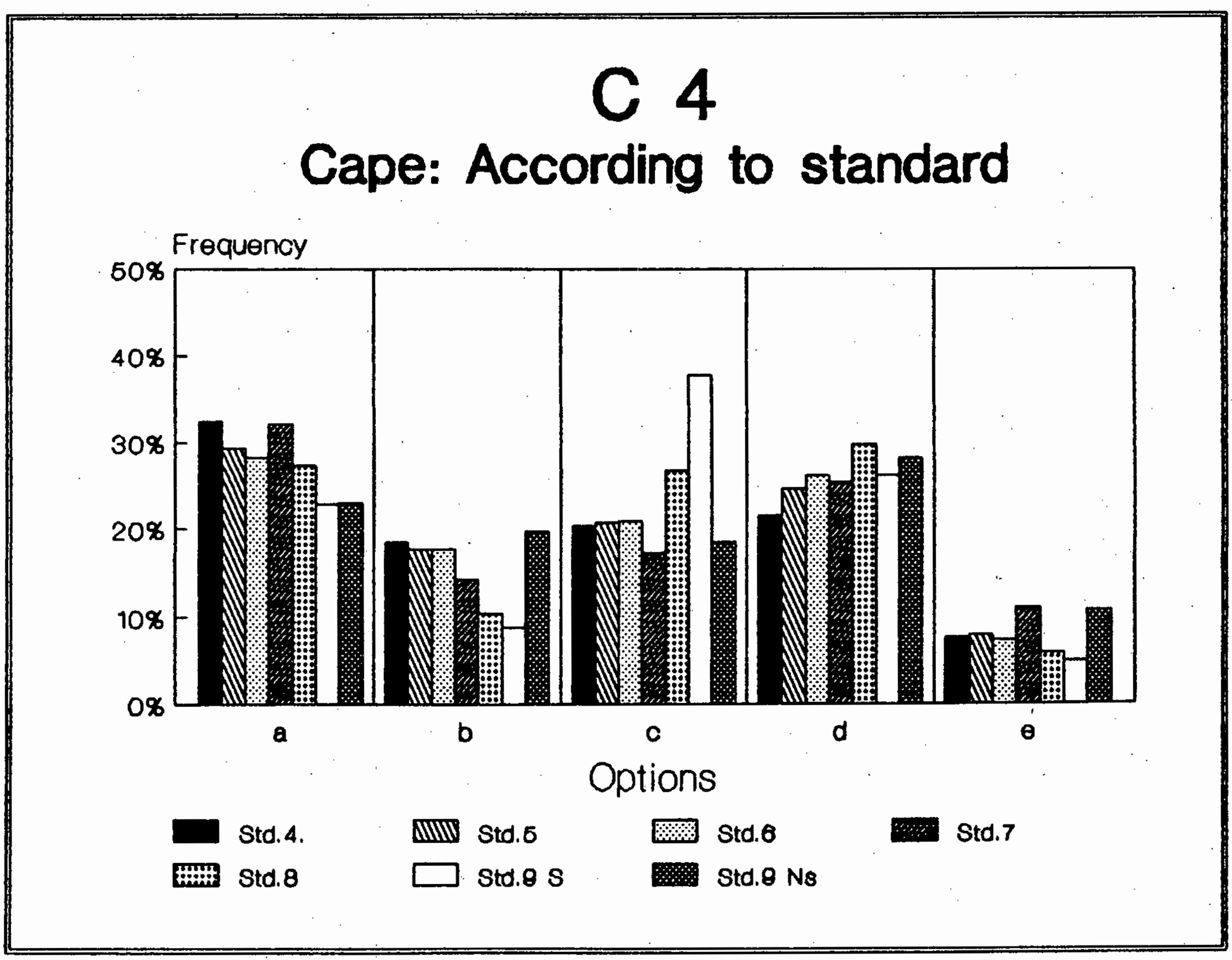
will travel forwards.

7. 38% of the pupils select options which suggest that the ball will travel backwards.

(b) **According to standard:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

1. There is no one option which is overwhelmingly selected by the pupils in any one of the standards.

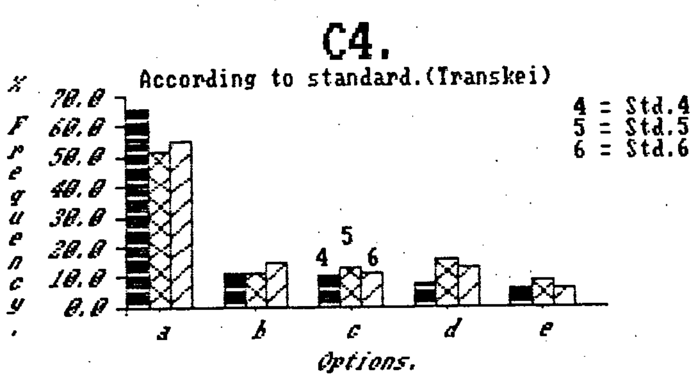
2. Option a is quite popular with pupils in all of the standards,

and especially so with pupils in standards 4, 5, 6, 7 and 8.

3. Option b is relatively popular with pupils in standards 4, 5, 6 and 7 but not with pupils in standards 8 and 9.
4. Option c is the most popular option for pupils in the standard 9 science group and the standard 8 pupils also find it reasonably attractive.
5. When compared to those in standard 4 there is a slight increase in the frequencies with which option d is selected by pupils in the higher standards. This is the most popular option with standard 8 and 9 non-science pupils.
6. Option e is the least popular option but it is consistently selected by pupils in the different standards.

2. In Transkei:

The following graph compares the frequencies with which pupils in schools in Transkei select the different options.



Note:

1. Option a is overwhelmingly selected by pupils in all of the standards. It is the special favourite of the standard 4

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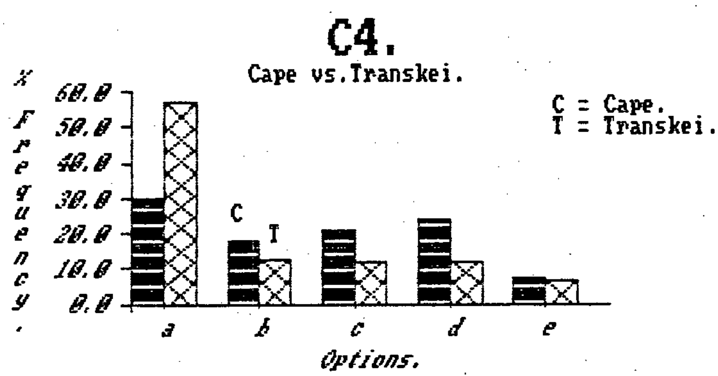
pupils.
2. The other options are selected by approximately the same proportion of pupils in the different standards.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options.

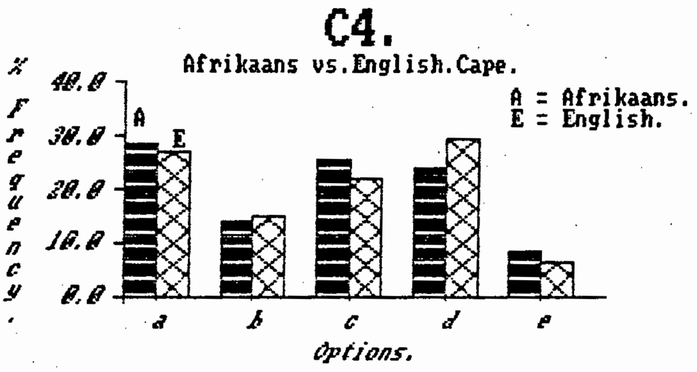


Note:

1. There are large differences in the frequencies with which the pupils in the two groups select options a, b, c and d.
2. 30% of Cape and 57% of Transkei pupils select option a. This is the most popular option with the pupils in both groups.
3. 18% of pupils in the Cape and 13% of pupils in Transkei select option b.
4. 21% of pupils in the Cape and 12% of pupils in Transkei select option c
5. 24% of pupils in the Cape and 12% of pupils in Transkei select option d.
6. 7% of the pupils in both groups select option e.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



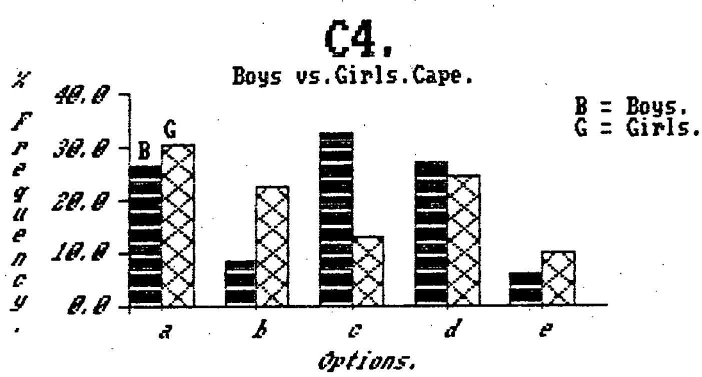
Note:

1. The only noteworthy differences in the way these two groups select the different option lie in the small differences in the frequencies with which they select options c and d.
2. 25% of Afrikaans-and 22% of English-speaking pupils select option c.
3. 24% of Afrikaans-and 29% of English-speaking pupils select option d.
4. 28% of the pupils in both groups select option a.
5. 15% of the pupils in both groups select option b.
6. about 7% of the pupils in both groups select option d.
7. 38% of Afrikaans-and 44% of English-speaking pupils select options which suggest that the ball will move backwards.

(e) **Comparing the sexes:**

1. In the Cape.

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

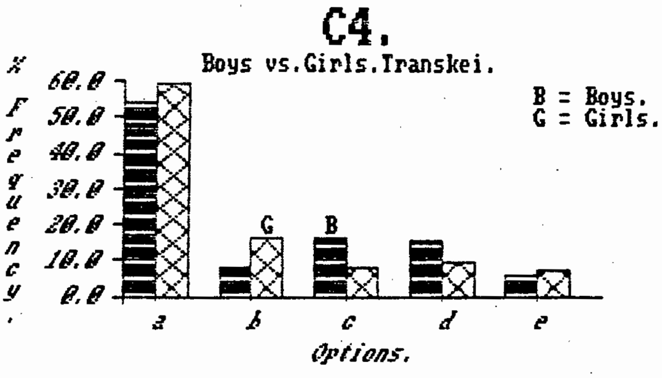


Note:

1. There are small differences in the frequencies with which pupils in the two groups select option a and d but large differences in the frequencies with which they select options b and c.
2. 26% of the boys and 31% of the girls select option a.
3. 9% of the boys and 22% of the girls select option b.
4. 33% of the boys and 13% of the girls select option c.
5. 27% of the boys and 24% of the girls select option d.
6. 6% of the boys and 10% of the girls select option e.
7. 36% of the boys and 46% of the girls select options which suggest that the ball will move backwards.
8. 39% of the boys and 23% of the girls select options which suggest that the ball will move forward.

2. In Transkei:

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.

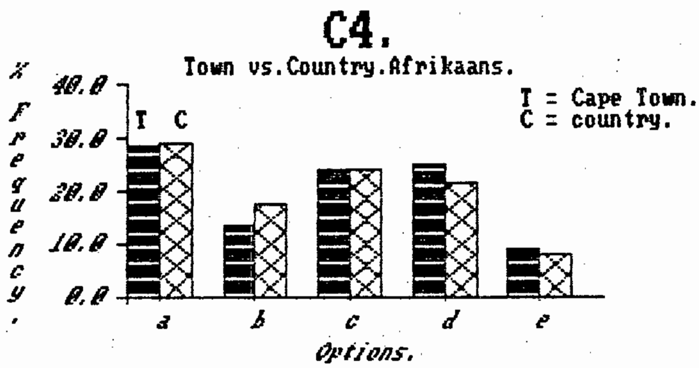


Note:

1. There are only small differences in the frequencies with which pupils in the two groups select options a, b, c and d.
2. 54% of the boys and 60% of the girls select option a.
3. 8% of the boys and 16% of the girls select option b.
4. 16% of the boys and 8% of the girls select option c.
5. 16% of the boys and 9% of the girls select option d.

(g) Comparing pupils from Town and country areas in the Cape:

The following graph compares the frequencies with which Afrikaans-speaking pupils attending schools in Cape Town and country towns select the different options.



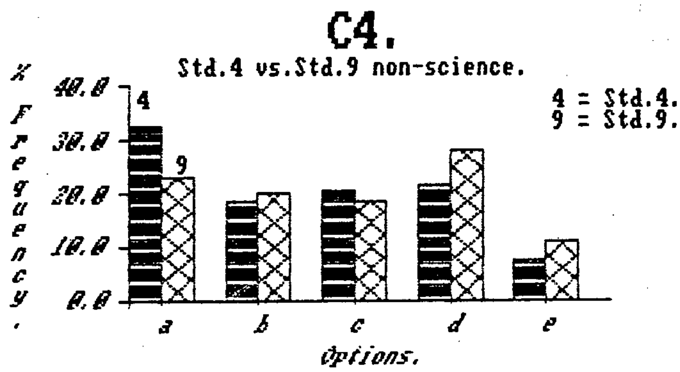
Note:

1. There were no noteworthy differences in the frequencies with which the pupils in the two groups select the different options

(h) **Comparing some standards:**

1. Standard 4 and 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and 9 non-science pupils select the different options.



Note:

1. There are appreciable differences in the frequencies with which pupils in the two groups select options a and d.
2. 32% of standard 4 and 23% of standard 9 pupils select option a.
3. 21% of standard 4 and 28% of standard 9 pupils select option d.
4. 40% of standard 4 and 48% of standard 9 pupils select options which suggest that the ball will move backwards.

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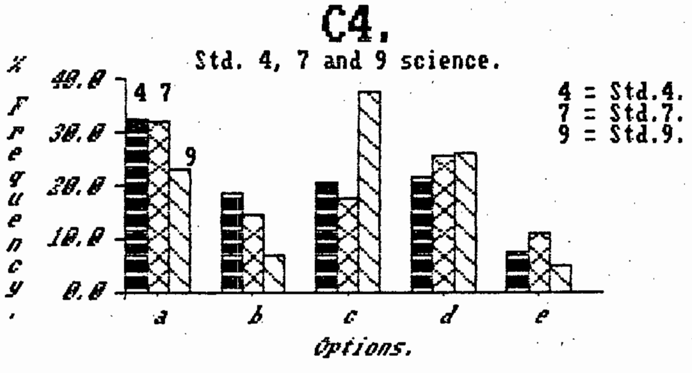
2. <u>Standard 4, 7 and 9 science pupils:</u>

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.

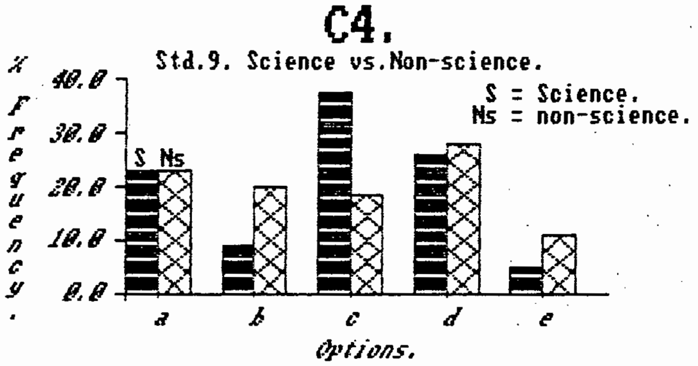


Note:

1. There is a decrease in the frequencies with which option a is selected by the pupils from standard 4 through to standard 9.
2. There is a decrease in the frequencies with which option b is selected from standard 4 through to standard 9.
3. The standard 9 science group select option c with a relatively high frequency.
4. About the same proportion of pupils in each of the standards select option d.

3. Standard 9 science and non-science pupils:

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science select the different options.

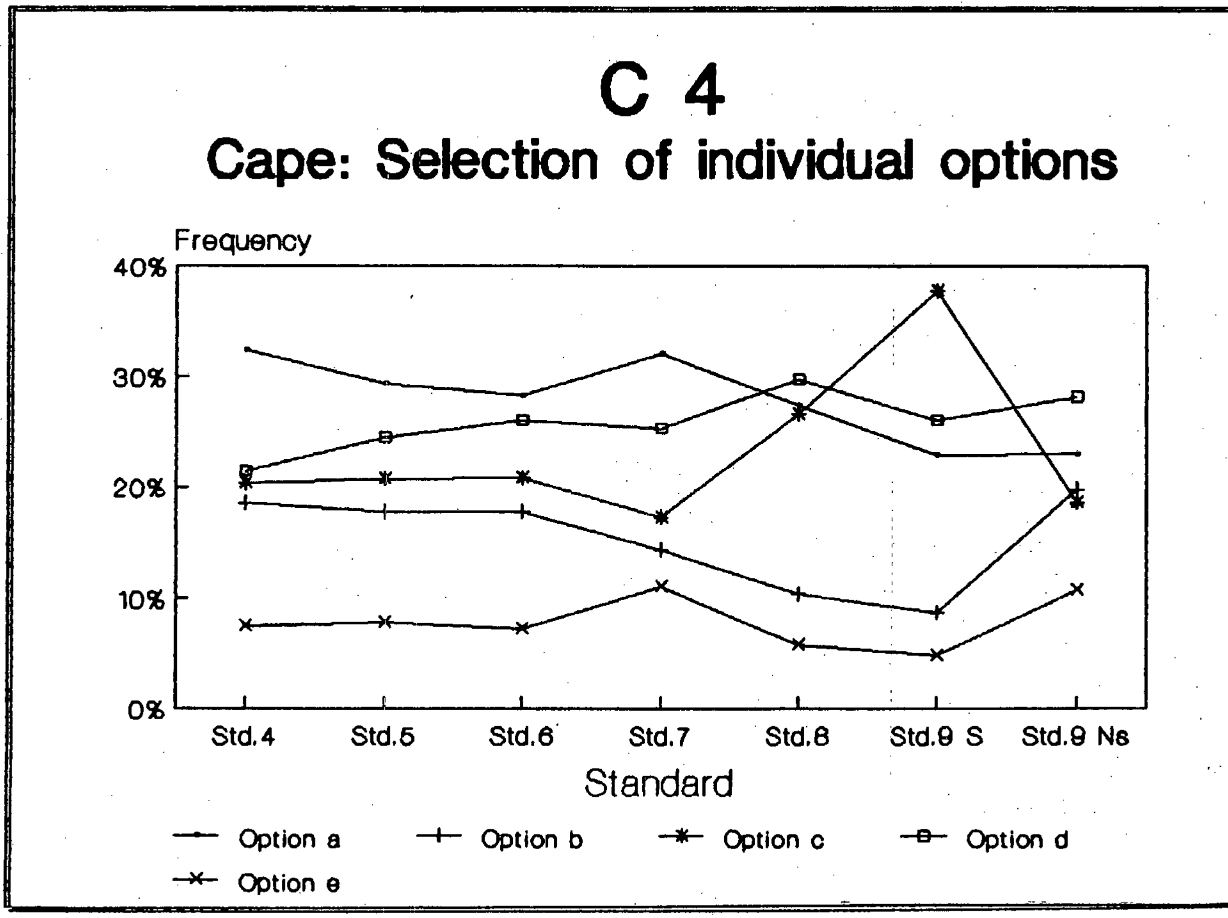


Note:

1. There are clearly large differences in the frequencies with which pupils in the two groups select options b, c and e.
2. 9% of science and 20% of non-science pupils select option b.
3. 38% of science and 19% of non-science pupils select option c.
4. 5% of science and 11% of non-science pupils select option e.
5. 29% of the pupils from both groups select option a.
6. About 26% of the pupils in both groups select option d.

(h) **Selection of individual options:**

The following graph shows the frequencies of selection of the individual options across the different standards



Note:

1 No one option is clearly the most popular option with pupils in all of the groups.

2. There is a decrease in the frequencies with which option b is selected across the standards to a minimum with the standard 9 science group.

3. There is a gradual increase in the frequencies with which option d is selected. It would appear that this is at the expense of option b. It looks as if an awareness that the path

is parabolic is more prevalent among pupils in the higher standards.

4. There is a gradual decrease in the popularity of option a.

Summary:

1. When we examine the overall picture we find that:

   34% of the pupils believe that the ball will travel straight up and down along the same path;
   21% of the pupils believe that the ball will travel up, forward and down along a parabolic path;
   23% of the pupils believe that the ball will travel up, backwards and down along a parabolic path;
   29% of the pupils believe that the ball will travel forward;
   38% of the pupils believe that the ball will travel backwards.

2. When we compare the frequencies with which the pupils in the different standards in schools in the Cape select the different options, we find that:

   pupils in no particular standard believe overwhelmingly in any one of the options portrayed;
   a fairly large proportion of pupils in standard 4, 5, 6, 7 and 8 believe that the ball will travel straight up and down along the same path;
   the majority of pupils in the standard 9 science group believe that the ball will travel upward, forward and down along a parabolic path;

the majority of standard 8 and a large proportion of the standard 9 non-science pupils believe that the ball will travel upwards, backwards and down along a parabolic path.

In Transkei we find that the pupils in each of the standards overwhelmingly believe that the ball will travel straight up and down along the same path. This belief is especially prevalent amongst standard 4 pupils.
The other beliefs are all present in approximately the same rather small proportion.

3. When we compare standards 4, 5 and 6 pupils in schools in the Cape and Transkei we find that:

30% of the pupils in the Cape and 57% of the pupils in Transkei believe that the ball will travel straight up and down along the same path. This is the favoured belief of the majority of pupils in each of the two groups but while it is overwhelmingly popular amongst pupils in schools in Transkei it is not so amongst pupils in schools in the Cape.
21% of the pupils in Cape schools and 12% of the pupils in Transkei schools believe that the ball will travel upward, forward and down along a parabolic path;
24% of pupils in Cape and 12% of pupils in Transkei believe that the ball will travel upward, backward and down along a parabolic path.

4. When we compare Afrikaans-and-English-speaking pupils at schools in the Cape we find that:

28% of the pupils in each of the groups believe that the ball

will travel straight up and down along the same path;
38% of Afrikaans-and 44% of English-speaking pupils believe that the ball will travel backwards;
25% of Afrikaans-and 22% of English-speaking pupils believe that the ball will travel upwards, forwards and down along a parabolic path;
24% of Afrikaans-and 29% of English-speaking pupils believe that the ball will travel upwards, backwards and down along a parabolic path.

5. When we compare boys and girls in schools in the Cape we find that:

26% of the boys and 31% of the girls believe that the ball will travel straight up and down along the same path;
36% of the boys and 46% of the girls believe that the ball will travel backwards;
39% of the boys and 23% of the girls believe that the ball will travel forwards;
33% of the boys and 13% of the girls believe that the ball will travel upwards, forwards and down along a parabolic path;
27% of the boys and 24% of the girls believe that the ball will travel upwards, backwards and down along a parabolic path;
9% of the boys and 22% of the girls believe that the ball will travel backwards,upwards and down in straight lines at an angle to each other.

In Transkei we find that both boys and girls overwhelmingly believe that the ball will travel straight up and down along the same path. The other beliefs are held with a low frequencies by the pupils from the two groups and there are differences between the proportion of boys and girls who share a similar belief.

6. When we compare Afrikaans-speaking pupils attending schools in Cape Town and country towns we find that the proportion of pupils who share similar beliefs in each of the two groups do not differ appreciably.

7. When we compare pupils in some of the standards we find that:

32% of standard 4 and 23% of standard 9 non-science pupils believe that the ball will travel straight up and down along the same path;
40% of standard 4 and 48% of standard 9 non-science pupils believe that the ball will travel backwards with 21% of standard 4 and 28% of standard 9 non-science pupils believing that it will do so along a parabolic path;
the proportion of pupils in the standards 4, 7 and 9 science group who believe that the ball will travel straight up and down along the same path, decreased form standard 4 through to the standard 9 pupils;
in these three groups approximately the same proportion of pupils share the belief that the ball will travel backwards along a parabolic path;
29% of standard 9 science and non-science pupils believe that the ball will travel straight up and down along the same

path;

26% of standard 9 science and non-science pupils believe that the ball will travel backwards along a parabolic path;

38% of standard 9 science pupils and 19% of non-science pupils believe that the ball will travel forwards along a parabolic path;

considerably smaller proportions of standard 9 science pupils than non-science pupils share some of the more "weird" beliefs about the motion of the ball.

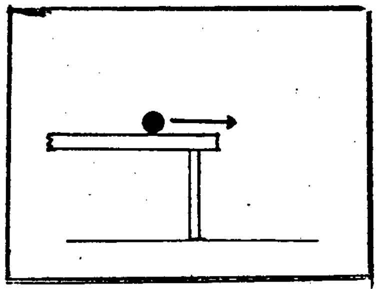
8. An examination of the graph which shows how the individual options are selected by the different standards reveals that:

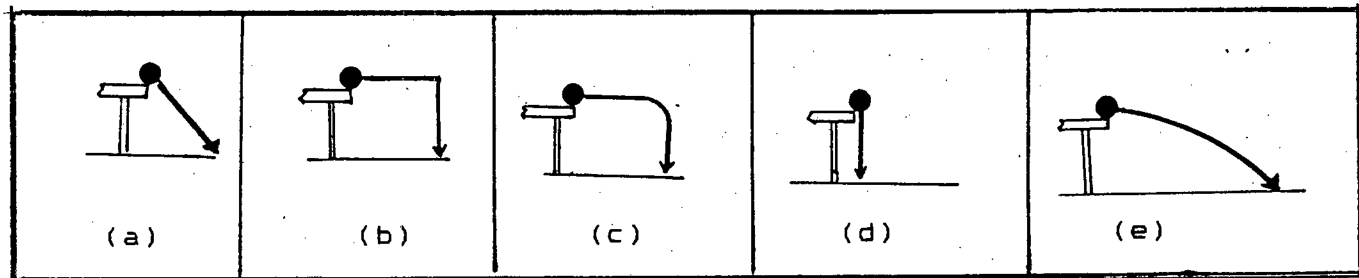
the belief that the ball will travel straight up and down along the same path became less popular with pupils in the higher standards but is none the less widely held;

the belief that the ball will travel backwards along a parabolic path gradually increases across the standards at the expense of the other backward path. This belief is widely held by the pupils in the higher standards.

Question C 6

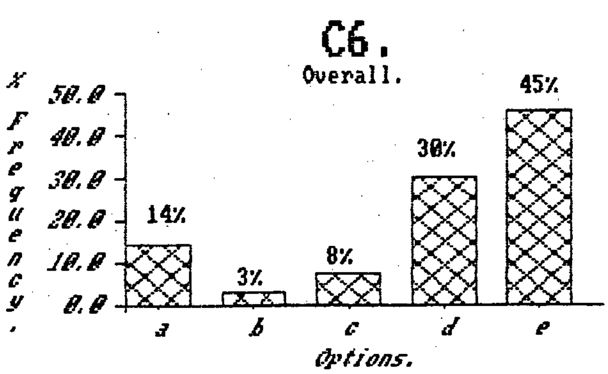
The sketch shows a ball rolling rapidly across a table in the direction as shown. It falls over the edge. The path it will travel along on its way to the ground, is best shown as:





(a) **The overall picture:**

The following graph compares the frequencies with which the pupils in our whole sample select the different options.



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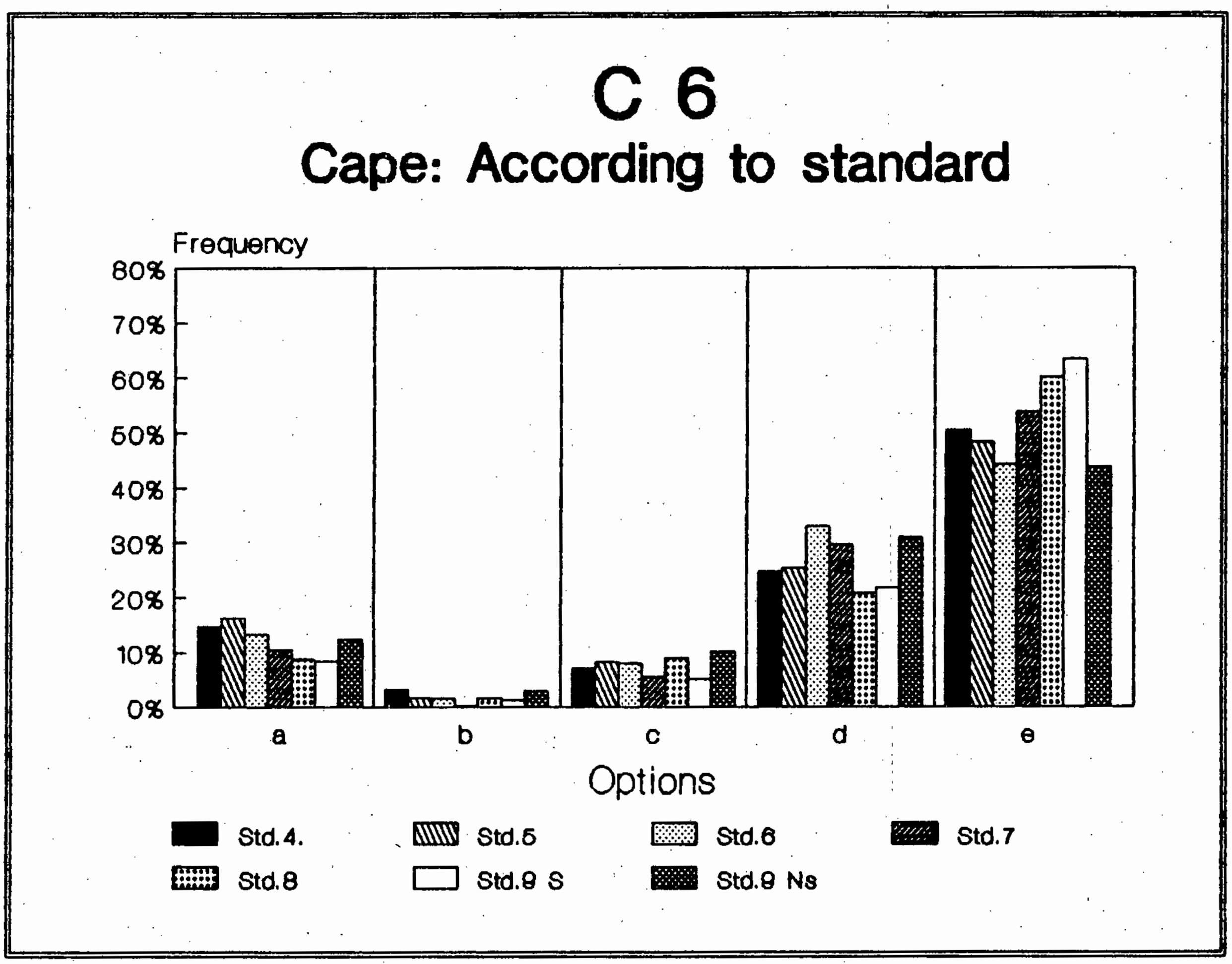
Note:

1. 14% of the pupils in the whole sample select option a, the option which suggests that the ball will fall along a straight line at an angle to the ground.
2. 3% of the pupils select option b, the option which suggests that the ball will move off the table horizontally and parallel to the ground and then at the end of its horizontal flight, fall vertically downwards.
3. 8% of the pupils select option c, the option which suggests that the ball continues along a horizontal path and then curve downwards to eventually fall vertically.
4. 30% of the pupils believe that the ball will fall vertically downwards.
5. 45% of the pupils believe that the ball will fall along a parabolic path.

(b) According to standard:

1. In the Cape:

The following graph compares the frequencies with which Cape pupils in the different standards select the different options.



Note:

1. Option e is the favourite option of the pupils in all of the standards. Its popularity increases with the pupils in the higher standards except for the standard 9 non-science group.

2. Option d is fairly popular with pupils in all of the standards but especially so with the pupils in standards 6, 7 and 9 non-science.

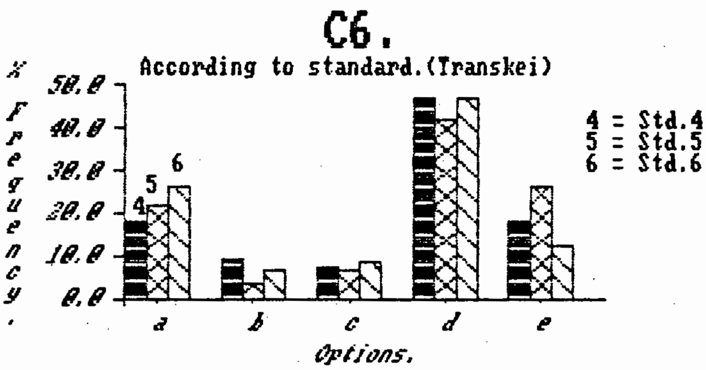
3. Options a and c receive small but consistent support from the

pupils in all of the standards.

4. Option b receives very small but consistent support from the pupils in all of the standards.

2. <u>In Transkei:</u>

The following graph compares the frequencies with which pupils in the different standards in schools in Transkei select the different options.

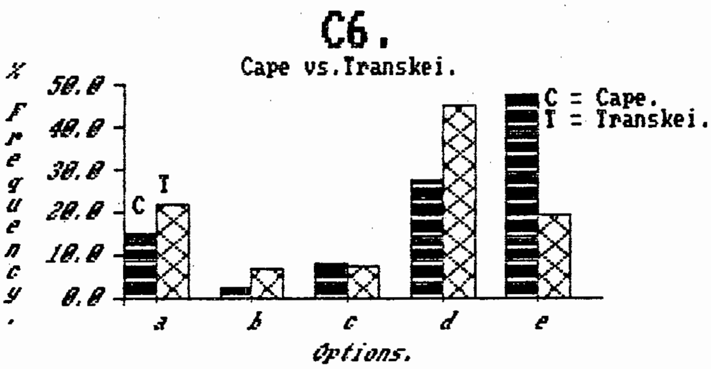


Note:

1. Option d is the favourite with pupils in all of the standards.
2. Options a and e receive fair support from the pupils in all of the standards. The frequencies with which option a is selected increase across the standards. Pupils in standard 5 find option e fairly attractive.
3. Options b and c are selected by a small proportion of pupils in each of the standards.

(c) **Comparing the Cape and Transkei:**

The following graph compares the frequencies with which standards 4, 5 and 6 pupils in schools in the Cape and Transkei select the different options.

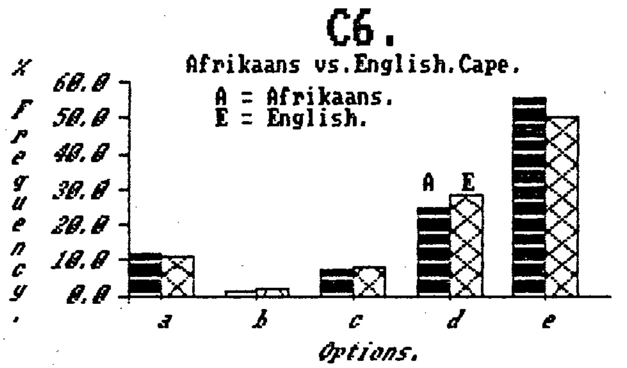


Note:

1. There are fairly large differences in the frequencies with which pupils in the two groups select options a, d and e.
2. 15% of the pupils in the Cape and 22% of the pupils in Transkei select option a.
3. 28% of pupils in the Cape and 45% of pupils in Transkei select option d.
4. 48% of pupils in the Cape and 19% of pupils in Transkei select option e.

(d) **Comparing the language groups in the Cape:**

The following graph compares the frequencies with which Afrikaans-and-English-speaking pupils in schools in the Cape select the different options.



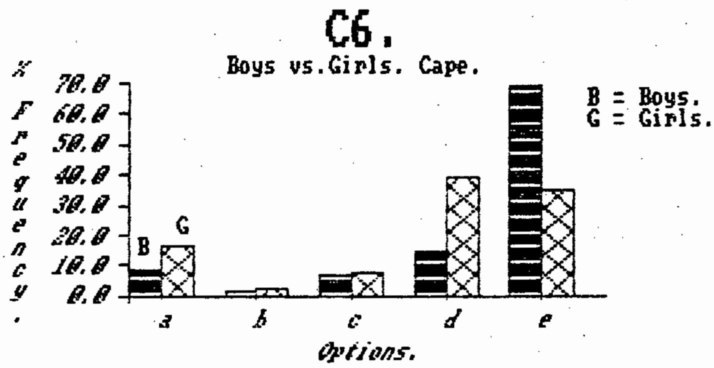
Note:

1. There are only small differences in the frequencies with which pupils in the two groups select options d and e.
2. 25% of Afrikaans-and 29% of English-speaking pupils select option d.
3. 56% of Afrikaans-and 51% of English-speaking pupils select option e.
4. 11% of the pupils in each of the groups select option a.
5. 1% of the pupils in each of the groups select option b.
4. 7% of the pupils in each of the groups select option c.

(e) **Comparing the sexes:**

1. <u>In the Cape:</u>

The following graph compares the frequencies with which boys and girls in schools in the Cape select the different options.

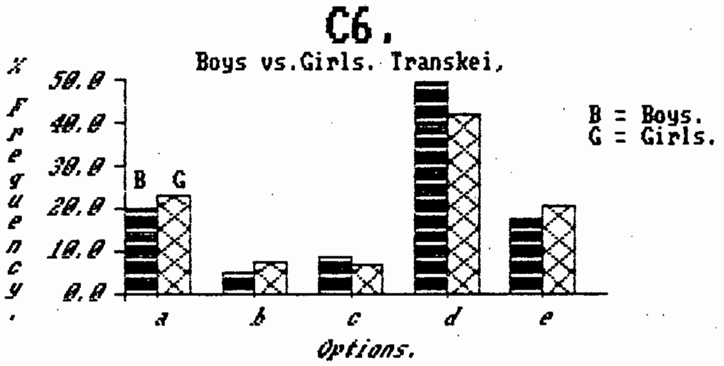


Note:

1. There are large differences in the frequencies with which pupils in the two groups select options a, d and e.
2. 8% of the boys and 16% of the girls select option a.
3. 14% of the boys and 39% of the girls select option d.
4. 69% of the boys and 35% of the girls select option e.

2. In Transkei:

The following graph compares the frequencies with which boys and girls in schools in Transkei select the different options.



Note:

1. There are only small differences in the frequencies with which pupils in the two groups select options a, d and e.
2. 20% of the boys and 23% of the girls select option a.
3. 49% of the boys and 42% of the girls select option d.
4. 18% of the boys and 21% of the girls select option e.

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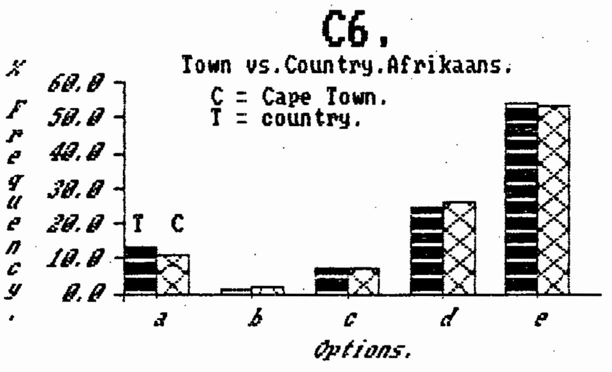
(f) **Comparing pupils from Town and country areas in the Cape:**

The following graph compares the frequencies with which Afrikaans-speaking pupils attending schools in Cape Town and country towns select the different options.



Note:

1. There are no noteworthy differences in the frequencies with which the pupils in the two groups select the different options.

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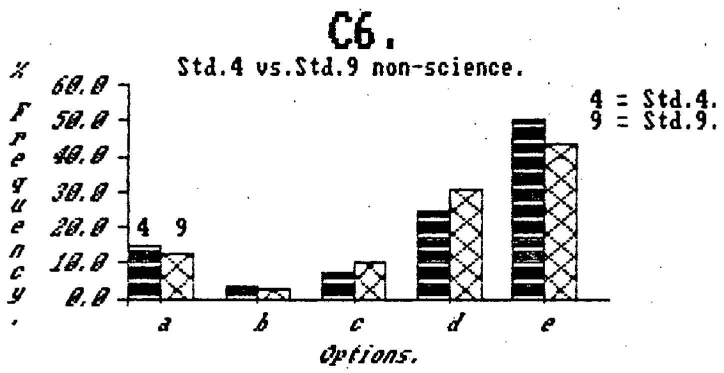
(g) **Comparing some standards:**

1. Standard 4 and standard 9 non-science pupils:

The following graph compares the frequencies with which standard 4 and standard 9 non-science pupils select the different options.

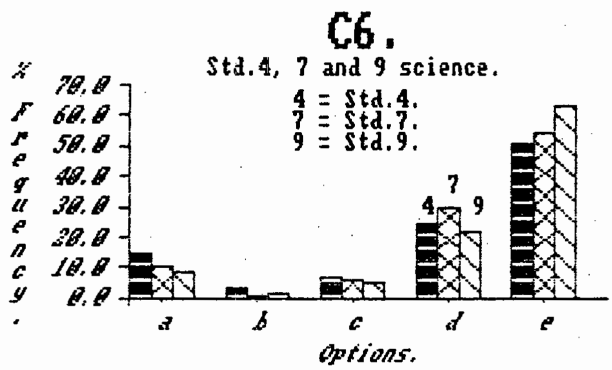


Note:

1. There are only small differences in the frequencies with which pupils in the two groups select options d and e.
2. 25% of the standard 4 and 31% of the standard 9 pupils select option d.
3. 51% of the standard 4 and 44% of the standard 9 pupils select option e.

2. Standards 4, 7 and 9 science pupils:

The following graph compares the frequencies with which standards 4, 7 and 9 science pupils select the different options.

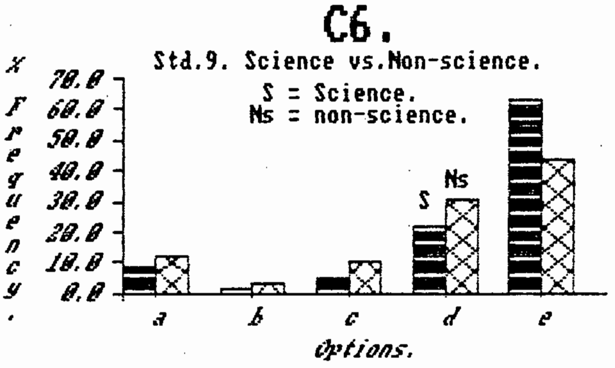


Note:

1. There is a decrease in the frequencies with which option a is selected by the pupils from standard 4 through to standard 9.
2. Option c is selected by a small but consistent proportion of pupils in each of the standards.
3. There is an increase in the frequencies with which pupils in the different standards select option e from standard 4 through to standard 9.
4. Option d is fairly popular with pupils in all three of the standards and particularly with pupils in standard 7.

3. <u>Standard 9 science and non-science pupils:</u>

The following graph compares the frequencies with which standard 9 pupils who do and who do not do science select the different options.

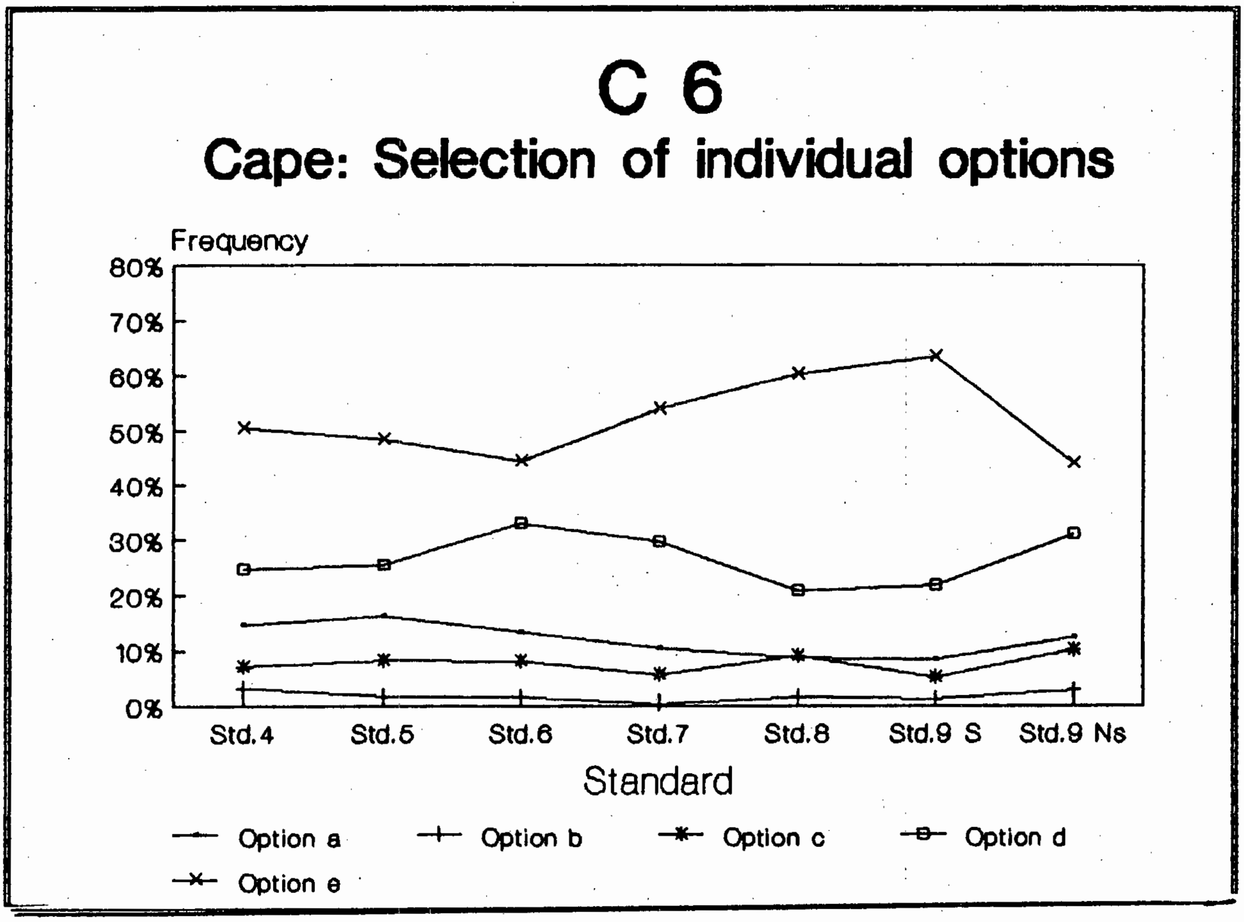


Note:

1. There are differences in the frequencies with which the pupils select options c, d and e.
2. 5% of science and 10% of non-science pupils select option c.
3. 22% of science and 31% of non-science pupils select option d.
4. 63% of science and 54% of non-science pupils select option e.

(h) **Selection of individual options:**

The following graph shows the frequencies with which the individual options are selected across the different standards.



Note:

1. There is a minimum in the curve for the choice of option e over the standard 6 group and a corresponding maximum in the curve for option d by the same standard.
2. There is an increase in the popularity of option e from standard 6 through to the standard 9 science group. There is a decrease in the popularity of this option from standard 4 to standard 6.

4. There is an increase in the frequencies of selection of option d from standard 4 through to standard 6 followed by a decrease in its popularity to a minimum with standard 9 science pupils.

Summary:

1. When we examine the overall picture we find that:

   45% of the pupils believe that the ball will follow a parabolic path;

   30% of the pupils believe that the ball will fall straight down;

   14% of the pupils believe that the ball will follow a path which is inclined at an angle to the horizontal;

   8% of the pupils believe that the ball initially travels in a straight horizontal line and then curves down until it falls vertically;

   3% of the pupils believe that the ball will travel out horizontally and then fall vertically.

2. When we compare the frequencies with which pupils in the different standards in Cape schools select the different options we find that:

   the majority of the pupils in all of the standards believe that the ball will follow a parabolic path;

   a fairly large proportion of pupils in all of the standards and especially in standards 6, 7 and 9 non-science group, believe that the ball will fall straight down;

   the other beliefs illustrated only receive small support from the pupils in the different standards.

In Transkei we find that:

the majority of the pupils in each of the standards believe that the ball will fall straight down;

there is some support for all of the different beliefs illustrated by pupils in all of the standards.

3. When we compare standards 4, 5 and 6 pupils at schools in the Cape and Transkei we find that:

15% of the pupils in the Cape and 22% of the pupils in Transkei believe that the ball will fall at an angle to the ground;

28% of pupils in the Cape and 45% of pupils in Transkei believe that the ball will fall straight down;

48% of pupils in the Cape and 19% of pupils in Transkei believe that the ball will follow a parabolic path.

4. When we compare Afrikaans-and English-speaking pupils we find that:

25% of Afrikaans-and 29% of English-speaking pupils believe that the ball will fall straight down;

56% of Afrikaans-and 51% of English-speaking pupils believe that the ball will follow a parabolic path.

5. When we compare boys and girls at schools in the Cape we find that:

8% of the boys and 16% of the girls believe that the ball will fall at an angle to the ground;

14% of the boys and 39% of the girls believe that the ball will fall straight down;

69% of the boys and 35% of the girls believe that the ball will follow a parabolic path.

In Transkei we find that the belief that the ball will fall straight down to be the predominant one, with 42% of the boys and 49% of the girls sharing this belief.

6. When we compare Afrikaans-speaking pupils at schools in Cape Town and country towns we find no appreciable difference between the two groups.

7. When we compare the pupils from some standards we find that:

25% of standard 4 and 31% of standard 9 non-science pupils believe that the ball will fall straight down;

51% of standard 4 and 44% of standard 9 non-science pupils believe that the ball will follow a parabolic path;

the proportion of pupils who believe that the ball will fall straight down is fairly large in standards 4, 7 and 9 science pupils;

the proportion of pupils who believe that the ball will follow a parabolic path increases from standard 4 through to the standard 9 science pupils;

22% of standard 9 science and 31% of non-science pupils believe that the ball will fall straight down;

63% of the science and 54% of the non-science pupils believe

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that the ball will follow a parabolic path.

8. An examination of the graph which compares the frequencies with which the individual options are selected across the standards clearly show that options d and e follow trends which are related to each other. Changes in the frequencies with which one of these options is selected is reflected in a corresponding increase or decrease in the frequencies of the other.

There is some evidence of the standard 6 group once again being out of step with the other standards.

Chapter 12

General Implications

Introduction:

Before we proceed to interpret the data collected in this study, it is appropriate to review the relationship between the data collected and the type of instrument used, as well as the general problems associated with interpretation of data as reported in the literature.

Driver, (1983) stresses the fact that the kind of information collected depends on the technique used to collect it. She distinguishes between techniques which she refers to as being "conceptually framed" and those which are "contextually framed". Techniques which are conceptually framed are characterised by their reliance on linguistic data and consist of presenting the subject with a word which represents the concept being investigated and then, through techniques such as word association, concept mapping and free association, investigate his knowledge about the concept presented. The knowledge collected in this way is propositional knowledge about the concept and provides very little information about how accessible this knowledge is in practical situations. Techniques which are contextually framed are based on actual events or phenomena. The subject is presented with information of a perceptual kind which may or may not be used when responding to the task. The data collected is usually behavioural. The underlying theories which the subject is using to solve the problems presented to him are inferred from regularities in his responses. Laboratory tasks and computer simulations discussed earlier are very good examples of this kind of technique. The information collected in this way is called "knowledge-in-action" by Driver. In her opinion these techniques comprise a powerful method of collecting information on conceptual frameworks as they are applied to actual situations. However, they are limited in that they provide very little information about the models, analogies and images which subjects use in generating the observed responses.

The method of investigation which we have used in this study lies at the contextual end of the conceptual-contextual continuum and while we are aware of the limitations which are associated with the use of this kind of investigation, it is important to note that we are really interested in the knowledge-in-action of our pupils and not in using the data collected to infer which underlying conceptual frameworks are being used to solve the problems presented. Furthermore, as far as moving bodies are concerned, we are aware of the fact that pupils are rather vague in their notion of the term force, which sometimes appear to be used to mean the momentum or energy possessed by a moving body (Viennot,1985). Driver (1983) also points out that the meanings which are attached to words by younger pupils may differ significantly from those attached to the same words by adults. McDermott (1984) agrees with Driver that in research on conceptual understanding there is a very close relationship between the results obtained and the method used to collect the data. She lists the following points as being important in evaluating and interpreting the results obtained:

1. *The nature of the instrument used to assess understanding:* To what extent was the subject actively involved in the task.? The responses made in writing answers to written questions may not be the same as those produced when observing a demonstration, using a computer or manipulating apparatus in the laboratory.

2. *The degree of interaction between the subject and the investigator:* Was it possible for the investigator to clarify the responses made by the subject.? While in an interview the investigator may be able to verify the meaning of a particular response and follow up on comments which indicate unsuspected difficulties, the subject's responses may be influenced by the presence of the investigator and unwitting cues given by him or her. **Gilbert and Pope** (in Pope and Denicolo,1986) found that the presence of an interviewer influenced the responses given by pupils to Interview-about-Instances cards. During written tests the responses are very much less likely to be influenced by the presence of the investigator.

3. *Depth of probing:* In how much detail did the investigator examine the understanding of the subjects.? The inference drawn from the collected data may differ if only one question is asked about a concept rather than many, or if only one context is used instead of several different ones. Results based solely on the subject's initial responses may be different from those obtained when the subject has had time to

consider alternatives.

4. *Form of data:* What kind of data was collected: was it written responses to questions, transcripts of interviews or classroom observation.? To determine the frequency of different misconceptions in different populations, the administration of written questionnaires to large numbers of subjects is satisfactory, but if the ideas held by a particular subject are of interest, then an individual interview will be the desired method and the data in the form of a transcript.

5. *Physical setting:* In what ways did the environment in which the data was collected influence the results.? While a specially designed experimental setting may allow an investigator to probe an individual subject's understanding of a particular concept, observing the interaction among a group of subjects in the more natural setting of the classroom may provide a broader perspective on the range of the ideas held by the pupils.

6. *Time frame:* At what point in instruction was the test administered.? Over what period of time was the whole study carried out.? The significance of particular results may depend on whether the test was administered before, during or after instruction. The results based on the single administration of a test may be different to those obtained with more extensive testing.

7. *Aims of the investigator:* How did the perspective of the investigator affect the design of the study or the way in

which the data is interpreted.? For those who teach science the aim and motivation of the investigation is the improvement of instruction while for others the emphasis may be on developing models of thought in humans. Similar data may be used by some investigators to identify and describe specific difficulties which pupils have in understanding science concepts while others will use it to infer the conceptual frameworks within which an individual views the physical world.

The results obtained by any study should be evaluated in the light of the above-mentioned characteristics of the method used. Thus McDermott (1985), for example, states explicitly that the results of a research programme should not be isolated from the context in which they were obtained. This is especially important when evaluating the implications of research for teaching, as generalizations based on a single experimental design may be very misleading. She also stresses the fact that it is from the details of the investigation that useful ideas about and insights into improving instruction are often obtained

General implications:

Before we proceed to evaluate the specific implications of our investigation it is appropriate to investigate the implications of other research in the field of misconceptions, alternate conceptions or childrens' science on science teaching in general. In doing this we will bear in mind that as teachers of science some of our aims should be to allow our pupils to:

(i) exchange their existing ideas for those held by scientists (Hewson,1981);

(ii) develop a more scientific perspective (West, 1982);

(iii) gain an additional perspective related, or relatable, to their earlier ideas. (Solomon, 1983);

(iv) allow pupils to use their own inquiries in their pursuit of further knowledge.(Driver,1983,p.74.)

Furthermore, we must also be aware of the fact that although Kelly (1969) has suggested that we are all scientists from a young age, we should bear in mind that pupils are *not* mature adults and as such bring different ways of thinking and different past experiences to the task of making sense out of their environment. It is of utmost importance to be aware of the nature of these differences when attempting to plan and implement suitable learning activities. (Osborne, 1985, p.55; Driver,1983,p.3.)

Osborne identifies the following areas of difference as existing between pupils and adult scientists:

1. Young pupils are limited in the extent to which they can reason in the abstract. Pupils view things from a self-centred or human-centred point of view. They tend to endow inanimate objects with characteristics of humans and other animals. They tend to consider only those entities and constructs that follow directly from everyday experience. Scientists, on the other hand, have constructed conceptions, such as atoms, which cannot be observed and some, such as potential energy, which

have no physical reality. In developing these concepts scientists have adopted a non-human-centred viewpoint.

2. Pupils are interested in "customised" explanations for everyday events. They will accept more than one explanation for a specific event and are not very concerned if some of the explanations are self-contradictory. They do not distinguish between explanations which might be testable and capable of being disproved, and non-scientific explanations. With their interest in simple pragmatic explanations for everyday events pupils are not too concerned if two theories which explain two different events are in conflict. Science on the other hand has become preoccupied with the coherence between theories and consistent explanations of events. While scientists seek for regularities in events, pupils are more interested in the opposite: they wish to discover the irregular, the unpredictable and the surprising.

3. The level of cognitive maturity of pupils, their experiences, use of language, knowledge and appreciation of the experiences and ideas of others completely limit their interests, thinking processes and construction of meaning. Scientists, on the other hand, draw from the collective wisdom of the whole scientific community which originates from a very wide field of events, some real and some contrived. Furthermore, science has available to it many ways of extending the senses, eg. electron microscopes, a precise language, and operational definitions quite unfamiliar to pupils. Pupils, however, when exposed to scientific explanations can only generate meanings from their own views of the world and their own meanings for

the words used in the explanations. Their appreciation of viewpoints based on our scientific history and technological culture can only develop slowly.

4. Unless a pupil comes from a family in which some member has scientific training it is very unlikely that he will come into contact with, and hence interact with people who have a scientific perspective. It is therefore quite unlikely that a scientific way of looking at events and natural phenomena will be learnt outside the science classroom.

Bearing in mind the aims of science teaching listed above, as well as the characteristics of the pupils, Osborne (1985, p.41) identifies the following three teaching conditions which must be met in order to ensure that these aims are achieved:

1. teaching which will help pupils exchange, evolve or extend their existing ideas about a particular topic;
2. teaching which will present new ideas so that they appear intelligible, plausible and useful to the learner;
3. teaching which will order the topics of the curriculum better in order to take into account learners' intuitive and/or developing ideas.

Furthermore, **Schollum and Osborne** (in Osborne, 1985, p. 51) identify the following three components of a successful school science lesson. The activity which pupils take part in must be:

1. related to the world outside the classroom in a way which will allow the pupils to expand their knowledge of that world and

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to make sense of it in a new way;

2. related to prior ideas stored in the memories of the individual pupils;

3. related to what an important person in the life of the individual pupil would find interesting and would value. This person could be a peer, parent or teacher.

A. *Implication for the science teacher:*

In attempting to make sense of their interactions with the natural and technological worlds in which they live, pupils construct meanings for themselves. They are involved in some kind of learning which is associated with science during every day of their lives whether they are at school or not. (Freyberg and Osborne in Osborne,1985,p.89.) Teachers teach science whenever they help pupils to:

* investigate things and explore ideas;
* ask useful and productive questions;
* seek and develop explanations which are sensible and useful to them with respect to the natural and technological worlds that they confront daily;
* broaden their experience of nature and technology;
* become interested in the explanations of others about how and why things behave as they do and in how such explanations may have been obtained. (ibid,p.89)

Science teachers have always had a number of roles which teachers in other disciplines do not share, such as the maintenance of laboratories and equipment, the handling of dangerous chemicals

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etc. However, when additional aims include taking into account the ideas of pupils and the processes by which they construct new ideas, then some of the teacher's existing roles become more important. **Freyberg and Osborne** (ibid,p.91.) consider the important roles to be those of motivator, diagnostician, guide, innovator, experimenter and researcher. We will briefly examine each of these roles in the light of the approach towards learning in science which we have been following.

1. Motivator:

One of the major problems associated with practical work is that pupils find so many "extraneous" stimuli to distract them. The role of the teacher then becomes one of ensuring that they attend to the "right" stimuli. The more interesting the inherent features of an experiment are, the more important it becomes that the pupils' attention is focussed on the "right" things, i.e. they must know what to look for. This can be achieved by:

* explicitly stating the intent of the lesson or activity so that pupils can reconstruct for themselves the problems to be solved, or the learning task to be carried out;
* encouraging pupils to ask themselves and each other questions which will focus attention and initiate generative learning;
* encouraging pupils to take responsibility for and to direct their own learning by deliberately reducing the cookbook aspects of instructional material to a minimum and thereby leaving greater opportunity for the pupils to make as many

decisions as possible about their work, provided that the teacher may query decisions made and the reasons for the decisions;

* choosing situations which the pupils may find interesting because they are unpredictable and contain unexpected outcomes whenever possible - provided of course that these events are not considered to be tricks or magic;
* encouraging pupils to reflect upon their own ideas as well as those of others. (ibid, p.92)

2. Diagnostician:

If pupils' prior views have a major influence on learning, then it is essential that the teacher must be aware of what these are in the case of his or her pupils (Gilbert et al,1982). Stenhouse, (1986) feels that given the constraints of large classes, limited time available and a fixed syllabus to be covered, that it is understandable that pupils' ideas are often ignored. The results of this approach for the cognitive development of pupils, especially with respect to their regard for science and all formal education, is extremely serious. It is important that the teacher generates a classroom climate in which pupils' ideas are valued and listened to so that pupils will feel absolutely free to express their ideas. The role of the teacher as a listener is inherent in his role as a diagnostician. In fulfilling this role data can be collected through the use of questionnaires, classroom discussion, interviews, answers to tests and examination questions and answers to questions based on experimental work as well as from pupils' problem solving attempts.

3. Guide:

The teacher acts as a guide in that he should help his pupils to learn to construct their own paths to knowledge by helping them to develop strategies for the effective processing of information, thereby enabling them to see both where they are going and to have some idea of how to get there. The teacher can:

1. gently point out logical errors in the pupil's thinking, such as inconsistencies or the drawing of unjustified conclusions;
2. challenge the reluctance of some pupils to consider all possibilities or to suspend judgement;
3. show pupils where they have over - or under - generalised, or based their arguments on false assumptions. (ibid,p.93)

All pupils need guidance in linking new experiences to ideas in their long term memory stores in order to generate meaning. It is the task of the teacher to help the pupil to relate what is being taught to appropriate propositions, episodes and images which he has in his memory store, as well as making him think about relevant past experiences. Science education should encourage pupils' efforts to construct meaning (Pines and West,1986). If teaching is a generative process then the teacher should be providing the pupils with:

* many examples and applications of the new idea;
* materials in several different ways and formats;

* encouragement for further elaboration of the new idea by considering it from a number of different points of view by discussing, for example, historical anecdotes, technological applications, mathematical formulations, societal implications etc.

His task as a guide to generative learning demands from the teacher that he continually interacts with the individual pupils as well as groups in his class as they learn. This is clearly a task which is both demanding and challenging.

4. Innovator:

It is important that the pupils see the teacher as a human resource in that he should be a source of ideas on how to do things, about where to find things, about what could have gone wrong and about what to do next. (ibid, p.94). Providing new or alternate ways of doing things is an important part of his responsibility. On another level he has to be innovative in that once he knows the ideas of his pupils he has to find new ways of helping them to perceive the ideas of others as more intelligible, plausible and useful to themselves than the ones which they currently hold. This is both a daunting and exciting task as it is not at all obvious how to best go about modifying existing ideas.

5. Experimenter:

If we recognise that pupils have what appears to them to be sensible and coherent views about their natural world and events in that world and that their ideas may not agree with accepted scientific ideas about the same world and events, but that through the process of generative learning they may slowly move closer to accepted scientific ideas, then it is important that we as teachers consider very seriously what form of assessment learning should take and what the consequences of the feedback of the results of the assessment may have on pupils. There can be no doubt at all that methods of assessment which we currently use simply encourage pupils to rote learn and pay lip service to accepted scientific viewpoints. Whether they believe that what they have learnt in science lessons is important in understanding the real world appears to be unimportant from an assessment point of view. Freyberg and Osborne (ibid, p.95) suggest that we should be more concerned at assessing:

* the coherence of the pupil's own views and his or her reasons for holding those views;
* whether or not pupils understand the accepted scientific viewpoint;
* what attempts they have made to relate the two viewpoints where these differ.

These authors are of the opinion that if teachers take their role of experimenter seriously, then it is inadequate for them simply to assess pupils at the end of a teaching sequence, but rather that they should assess pupils before and after lessons as well as some months after the lessons in order to ascertain whether the pupils have moved from their own ideas towards the scientific

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ideas. Through teacher experimentation we have to develop new assessment techniques and reporting procedures which will allow both teachers and pupils intellectual integrity and will in addition stimulate pupils to reconstruct their ideas so that they will be more scientifically useful and coherent. If the teacher adopts a generative view of learning then he or she should be "centrally concerned" with the impact of his or her teaching on his or her pupils' views of reality. (ibid,p.98).

B. *Implications for lesson frameworks:*

In terms of the generative model of learning in science, the aim of a lesson, or a sequence of lessons, should be to modify the existing intuitive ideas which the pupils have about the subject under discussion. According to **Cosgrove and Osborne** (ibid,p.101), Renner found that the most common practise among teachers is to attempt to pass on to their pupils a mastery of the content of the subject as they, the teachers, see it. Typically the teacher will give the material to be taught to the class as information; the pupils are then expected to verify the information through observation of a demonstration or their own experiment; and finally the information is applied in some way or other, usually by answering questions and solving quantitative or mathematical problems from a textbook. This process can be summarised as "inform, verify, and practise"(Renner,1982). From the generative point of view it omits the vital activities of originating experiences, interpretation and elaboration. Elsewhere (p.47 above) we have discussed the lesson model of **Nussbaum and Novick** which is based on **Posner's** theory of conceptual change and takes into account the pupils' prior ideas. In a lesson following their approach the alternative frameworks of the pupils is first exposed, conceptual conflict is created and finally cognitive accommodation is encouraged. In a very similar model by **Erickson** (ibid,p.103) the method followed involves firstly presenting the pupils with a set of "experiential manoeuvres" which allow the pupils to become familiar with a wide range of phenomena so that they might expose a set of intuitive ideas or beliefs. The activities involved are expected to allow the pupils to clarify their own ideas and to develop confidence so that they might begin to make predictions. The second stage, which is described as containing "anomaly manoeuvres", involves the creation of situations that lead to unexpected outcomes. In this way elements of uncertainty are introduced and the pupils are expected to restructure their views. The third stage of his model involves a set of "restructuring manoeuvres" to assist the pupils in accommodating unexpected outcomes. This may be achieved by, for instance, group discussion and teacher intervention.

Rowell and Dawson, (ibid, p.104) have developed a model which focuses on the confrontation between scientists' science and pupils' science. Their lesson sequence involves the following steps:

* Through careful questioning the teacher establishes the ideas which the pupils bring with them to the situation under discussion. A conscious awareness of these ideas is seen as being of value to both teacher and pupils.
* These ideas are accepted by the teacher as possible

solutions.

* Pupils are asked to retain their ideas and the teacher states that he or she is going to put forward another possibility which the pupils will help to evaluate later on.
* The "new" idea is taught by linking it to a basic idea already held.
* Once the new idea is available to the pupils the old ideas are recalled for comparison with each other and with reality.

Champagne et al, (1983) suggest a lesson plan which they term "ideational confrontation". The steps involved are:

* the teacher describes the physical situation which is to be used as the instructional event. This may be a demonstration, practical work, problem solving or reading of the textbook;
* the pupils analyse the physical situation and state verbally or in written form the relevant concepts, propositions and variables involved;
* a class discussion follows and inevitably this leads to controversies, the result of which is that each pupil becomes aware of his or her analysis of the situation under discussion;
* instruction now begins with the teacher presenting the science concepts, propositions or variables to explain the situation. Pupils are asked to compare their analyses with

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the one given by the teacher. This forces pupils to confront inconsistencies between their prior ideas and those given by the teacher.

The similarities between the different methods described are obvious.

Based on their work in the Learning in Science Project, **Cosgrove and Osborne** have identified a number of preconditions associated with teaching and learning which must be taken into account by teachers if they are to be at all successful in their attempts to modify the ideas of their pupils. These preconditions are:

1. The teacher has to understand scientists' views, pupils' views and his or her own views. In many cases there is a discrepancy between the teacher's view and those of scientists.
2. Pupils must have the opportunity to explore the context of the concept, preferably with everyday situations. This helps pupils to link the experience to ideas of social relevance and to other relevant ideas and may help with motivation.
3. The pupils must have the opportunity to engage in self-clarification of their own views at an early stage of the teaching. The appreciation by the pupil of his or her own ideas as well as how these differ from those of other people is a major factor in the learning situation. The classroom environment must be such that the pupils will not feel at all threatened when they reveal ideas which may be considered as confused or strange.
4. It is the responsibility of the teacher to introduce the scientists' view as an alternative to those put forward by the

pupils.

5. The scientists' view now has to be made intelligible and plausible by experimentation, demonstration or reference to analogy. The teacher has to accept that at least for some pupils the acceptance of the new view will not take place easily. It is perhaps better for the pupils to remain honest about holding on to their views, and the reasons why, than to superficially accept the teacher's view.
6. The pupils must have the opportunity to consolidate and elaborate the newly accepted idea. They must be given a chance to consider the new concept across a whole range of examples and situations. Pupils should be exposed to activities which require them to use the newly learnt ideas to explain specifically observed events so that they may find it more useful than their old ideas.

Pines and West, (1986) suggest that the phases involved in conceptual exchange are:

* awareness of the existence of competing points of view, active effort by the pupil to integrate the new information into his existing framework and discovering that his framework is unsatisfactory.
* disequilibrium which involves the introduction of anomalies which cannot be explained or predicted by the pupil's existing ideas and beliefs.
* reformulation which involves the presentation of the scientific ideas, the resolution of the anomalies and the

acceptance of these ideas by the pupils.

It is clear that the preconditions listed above cover these aspects.

Based upon the generative learning model and taking account of the preconditions specified above as well as the additional aims of clarifying the pupils' existing views, modifying these views towards the current scientific view, and consolidating the scientific view within the background experience and values of the pupils, **Cosgrove and Osborne** propose their "generative learning" model of teaching. The model has three distinctive phases, viz. *focus, challenge and application*, but these three phases are preceded by a preliminary teacher preparation phase.

1. Preliminary phase: This phase involves the teacher in:

   (i) ascertaining the typical ideas the pupils will bring to the topic;

   (ii) understanding the ideas that scientists use to describe and explain the phenomenon;

   (iii) an appreciation of the ideas he or she uses to describe and explain the phenomenon.

? focus phase: The aim here is to provide a context for later work. This could involve activities to focus attention on a particular phenomenon or to get pupils thinking about their own meanings for words or a combination of both. The teacher has to provide motivating experiences, encourage the pupils to think by asking questions and helping them to interpret their answers. The teacher should make the purpose of this phase clear to the pupils if they are to take the responsibility for their own learning, to become familiar with the context, to ask questions of themselves and to clarify their own ideas.

3. The challenge phase: Pupils present their views to their group or to the whole class. The differing views held by the class are sought, displayed and discussed. Where necessary the teacher introduces the scientists' view at the appropriate level of sophistication and language for the pupils. Critical tests of the different views are proposed, by the pupils where possible, and evidence for the scientists' view is sought. It is during this phase of the lesson that the teacher's role is critical in terms of guidance, input and decisions about which tests are possible in the classroom. If this phase is successful then it should end with the pupils raising many questions as they try

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to accommodate the new ideas.

4. The application phase: In most cases this can be a problem-solving time where the solutions require the newly acquired scientific viewpoint. Discussion about the proposed methods of solution should enhance the process of problem solving and increase the status of the new ideas. The teacher has to assume an active role - diagnosing pupils ideas, encouraging pupils to try alternative solutions, challenging pupils to think about the phenomenon in terms of the new viewpoint and encouraging a reflective, thinking approach by the pupils

Quite clearly the implementation of these ideas requires very active teaching by teachers who must appreciate pupils' ideas, the scientific view to be taught, the types of activities which might achieve the required conceptual change as well as the interaction required with the pupils to bring about conceptual change. A daunting task indeed! It is important to realise that the teaching-and-learning processes have to be seen not as the transfer and injection of information but rather as a complex activity in which the pupils themselves play a major role.(Stenhouse,1986.)

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C. *Implications for practical work*:

In virtually every country in the world science is currently being taught through some form of experimental work by pupils and observation of teacher-experiment. This is done in the belief that pupils will thereby develop their skills of investigation and from the results of their investigations will develop sound scientific knowledge.(Tasker and Freyberg in Osborne,1985,p.66; Driver,1983,p.3.)

However, in the light of constructivist theory, do pupils actually see what we expect them to see or do they attend and respond to other stimuli? **Osborne and Tasker** (in Osborne,1985,p.27), observed a number of activity- based lessons, interviewed pupils and teachers about the aim of the experiment and concluded that there are major differences between the teacher's aims and the learning which was actually taking place. This was due to the following differences between teacher and pupils:

* the ideas pupils brought to the lesson and the ideas which the teacher assumed that they would bring;
* the scientific problem the teacher would have liked them to investigate and what they took the problem to be;
* the activity proposed by the teacher and the activity undertaken by the pupils in spite of considerable teacher intervention;
* the conclusions arrived at by the pupils and those proposed by the teacher.

These findings should be seen in the light of **Wittrock's** theory of generative learning (discussed on p.30 above). He believes that pupils will inevitably construct their own purpose for a lesson, form their own intentions about the activities which they will undertake, draw their own conclusions and carry these through into their subsequent thinking. The extent to which these constructions actually tally with those intended by the teacher will depend on a number of factors. What is quite clear is that it cannot be assumed that the teacher's intentions are transferred directly to the pupils. Teachers have to contrive learning situations in such a way that the mental constructions which are made by the pupils - what the lesson is about, what is to be done and what can and is to be learnt from it - correspond to their own aims.(Osborne and Tasker,in Osborne,1985,p.27; Driver,1983,p.9.) By being aware of and taking into account the ideas which pupils bring with them to lessons teachers can reduce the disparity between teacher's aims and pupils' learning. Furthermore, **Driver** (1983,p.11) points out that it is only within the conceptual framework of a scientist that most experiments, apparatus used and techniques applied make sense. To the uninformed, laboratories can be very mysterious and confusing places.

Tasker and Freyberg (in Osborne,1985,p.p.69-76) observed many practical classes involving pupils in the 11 to 14 year old group and nine different teachers. After analysing sixteen of the lessons in depth they identified the following eight areas in practical work in which discrepancies exist between teacher

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intent or expectation and the learner's perceptions or outcomes:

(a) Discrepancies in intent:

1. Scientific context: While the teacher saw lessons as building on previous lessons, the pupils often saw the lessons as isolated events and did not link them as expected.

2. Scientific purpose: The pupils do not perceive the purpose of the activity as intended by the teacher. In spite of a clear statement by the teacher about the aim of the activity, many pupils fail to recognise it as such and establish alternative purpose.

3. Scientific design: Pupils often do not have any idea of what the critical scientific factors are in an experiment. They have little appreciation of key features in the design of the investigation and as a result no real basis for anticipating the nature of its outcomes. The result is that pupils will sometimes accept secondary results as the significant results of an investigation. The purpose of a control experiment is often not made clear to or understood by pupils.

(b) Discrepancies in action:

4. Pupils' actions: The actions of pupils are guided by the purpose which *they* establish for an activity. When they have difficulty in establishing a meaningful purpose, or when they do not appreciate the design features of the investigation, their purpose and actions degenerate into the blind following of instructions. The danger inherent in this behaviour is that in many pupils intellectual involvement, purpose and action is reduced to a mechanical level and worthwhile learning opportunities are lost.

5. Getting results: If the intended sensible scientific purpose of the activity is not clear to the pupils and if they do not appreciate the critical design features of the experiment, then their interpretation of what results should be looked for and what results are important is often different from those expected from them by the teacher. As far as the pupils are concerned the problem becomes one of guessing what the teacher wants from the activity or getting the "right answer". This may lead to the virtually complete abandonment of scientific method.

6. Consideration of findings: When busy with an activity pupils sometimes do not only focus on unexpected outcomes and events of an activity, but may also not consider their actions and findings in a critical way. If they are concerned simply with getting the "right answer" or with guessing what the teacher expects them to find, they have no reason at all to consider their results critically in a scientific sense. This lack of critical consideration of their findings is also a problem when pupils are asked to calculate events which they may be assumed to be familiar with, e.g. times of flight of projectiles or heights of buildings from free fall data. Their answers are often obviously ridiculously large or small and yet are very seldom criticised.

(c) Discrepancies in views of the world:

7. Impact of experience: Pupils' past experience and existing ideas can result in their placing very different interpretations on an activity from those intended by the teacher. Teachers assume that pupils will automatically relate the experiences of the lesson to the ideas and perspectives of scientists when in reality they can only relate these

experiences to their own existing ideas.

8. Relationship to pre-determined outcomes: It is not uncommon for teachers to write on the board at the end of an activity a pre-determined conclusion using typical scientific language. Sometimes the conclusions listed are inappropriate and even incorrect when related to the events observed by the pupils during the activity. Quite clearly this may lead to confusion and doubt amongst pupils about the scientific method and its value.

Many of these points are also raised by Driver (1983).

These authors, as well as Driver (in Driver,1983,p.2.), are of the opinion that these discrepancies arise because curriculum writers and teachers tend to view practical work done by pupils from their own scientific perspective. This has encouraged a range of mistaken assumptions about how pupils will respond to and learn from practical tasks. They suggest that the discrepancies present between teacher and pupil may be reduced if the following three crucial issues are faced and overcome. Teachers must find ways of ensuring that:

1. their intended purpose for the activity becomes the pupils' own purpose;
2. the activity designed to achieve this purpose is understood and accepted in advance by the pupils as a sensible and

straightforward method of accomplishing it;

3. the pupils'conclusions are valued, discussed and related to the teacher's hoped-for conclusion. (Tasker and Freyberg in Osborne,1985,p.77)

Tasker and Freyberg suggest that the above aims may be achieved if the following methods, which have been used successfully by teachers and described by Tasker and Lambert (Osborne,1985,p.77) are used:

1. At the beginning of the lesson the pupils are put into groups to read through the instructions for the activity to be undertaken. They discuss and report on questions and instructions provided by the teacher with the aim of ensuring that their purpose and design features are understood, accepted and appreciated. They are encouraged to ask questions such as: "What are we trying to do?", "Why do we need a control?", etc. The practical classroom as seen by the authors in this case is obviously one in which the teacher and his colleagues must be willing to accept a fair amount of pupil-noise.

2. Instructions for a particular task are written on a card. The card is then cut up, scrambled and placed in an envelope. Groups in the class then have to re-assemble the material in a sensible order while discussing the reasons for their choices. Finally they check with the teacher before carrying out the task. In general this is said to require about 10 minutes. (although presumably only in simple cases.)

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3. Instructional material is re-considered to ensure that as little ambiguity as possible occurs. The use of short sentences, the underlining of key words as well as built-in questions about what the instructions mean, can all help.

4. Pupils are given the opportunity to consider what their findings mean to them, what the findings mean to the other group members and how their group's findings stand alongside those of the other groups. To do this :

   * each pupil records his or her results and considers the experience against his or her own ideas;
   * pupils put their ideas relating to the experience to other members of the group. Discussion generates a group view;
   * the group view is presented to the class by a member of each group with support from any members of the group;
   * the teacher contrasts the group views and directs discussion, raising issues where necessary until a consensus is reached or further activities are decided upon. There is speculation about possible reasons for unanticipated results.

5. Assessment mechanisms are designed so that the things which are considered important are focussed on in the assessment procedure and the pupils realise this. A teacher's assessment list could include:

   (i) Interpretive skills: Ability to plan, carry out and report on an investigation;

   (ii) Cognitive skills: Ability to formulate a sensible conclusion in terms of the evidence, to interpret results and make predictions, to appreciate the views of others and the evidence on which this is based;

(iii) Manipulative skills: Ability to set up apparatus, take readings, follow instructions where necessary;

(iv) Workshop skills: Ability to tidy up after experiments, observe safety procedures;

(v) Social skills: Responsibility to group and class; ability to share and listen to the view of others.

6. Checklists are developed to ensure:

* that activities are planned with close reference to the specific problems associated with teacher-pupil discrepancies. (See example in Appendix B)
* feedback is obtained through self or colleague evaluation. (See example in Appendix B)
* feedback is obtained through the perspectives of the pupils.(See example in Appendix B)

The checklists do not have to be used for every lesson as they are very detailed but should be employed in a variety of ways, e.g. for certain critical lessons, as a guide to problems which often arise, etc.

In the opinion of **Freyberg and Tasker** (in Osborne,1985,p.80) keys to effective teacher-guided activity-based science lessons are that the teacher helps pupils to generate:

* a satisfactory purpose for the lesson;

* a sensible activity or method of obtaining possible solutions;
* reasonable and sensible conclusions from the experiences; and, if appropriate,
* links to, and an understanding of, the acceptable scientific viewpoints on this particular phenomenon.

D. *Implications for language used by textbooks and teachers:*
Teachers interact with pupils in a number of ways but in general language in verbal or written form is used. What has to be appreciated is that the intended meaning of the teacher or textbook author cannot be assumed to be automatically transferred to the minds of the pupils. Each individual pupil constructs his or her own meaning from the variety of stimuli, which of course include the spoken or written words present in the learning environment. The extent to which the meaning constructed by the pupil is similar to that intended by the teacher depends very heavily on the way the pupil copes with the language used by the teacher. As this medium is normally the main one used in interaction with pupils, it is obviously vitally important to be aware of its limitations in learning situations. **Bell and Freyberg** (in Osborne,1985,p.33) list the following ways in which pupils and teachers can react to the language used in the science classroom:

* ignoring teacher talk: If the language used by the teacher includes words unfamiliar to the pupils, comprehension of what is being said cannot occur. Pupils cannot construct meaning from what is being

said. Edwards and Marland (in Osborne,1985,p.33) point out that pupils may start to construct meaning from a word but that this process triggers off associated ideas from memory store which may have no bearing on the line of argument being used by the teacher.

* noises which sound scientific: When the teacher insists that the pupils use the teacher's language it is possible for them to play the game. Barnes (in Osborne,1985,p.33) states that under these circumstances many pupils consider the lesson to be an instruction about words rather than concepts. Teachers who have poor ideas about science concepts themselves may encourage the use of science terms but fail to see that these terms do not apply in that particular situation. The pupils are using words which are meaningless to them.

* ignoring pupil talk : Insistence by the teacher on the use of correct scientific terms can make him oblivious to what the child is saying in his own language. Pupil contributions may be devalued or ignored.

* the unidentified mismatch: When the teacher uses familiar words which have a specialist meaning in science, both pupil and teacher may be unaware or unable to identify that a problem exists and to locate the source of the problem. Words such as work, energy and

power have social as well as scientific meaning and as such may well be interpreted in ways not intended by the teacher or textbook author.(Solomon 1983.)

* the identified mismatch: Pupils are sometimes aware that a mismatch exists between the meaning which they associate with a word and the meaning which the teacher associates with that word, but in spite of this they continue using their meaning which in the situation is actually an incorrect meaning. Recognizing the teacher's or author's intended meaning does not guarantee acceptance and use of it.

* ordinary words.: It is not only the use of technical and scientific words which may lead to difficulties. Common words can also have a range of meanings associated with them.

As a possible solution to language problems, **Bell and Freyberg** (in Osborne,1985,p.37) stress that activities which allow pupils to verbalize their ideas about the science topic which they are investigating are of the utmost importance provided that the teacher follows them up. It is the opinion of these authors that in order for pupils to change their views it is important that their own views are clear to them and to appreciate how their view differs from that of science. These ideas clearly link with those discussed above in which we have stressed the importance of the pupils being allowed to develop clarity about the objectives, methods, results and inferences of experimental work done by them through, amongst other things, verbalising their own ideas. Quite clearly it is of the utmost importance that teachers are aware of this language problem and that pupils should be addressed in language appropriate to their understanding. Furthermore, teachers must listen to and interpret pupils' talk. Stenhouse (1986) stresses that the teacher has to understand the language used by the child and be able to show the child how his or her language has to be modified to approach the language used by the teacher.

E. Implications for teacher-training:

From the above discussion about the implications of generative learning for the teacher, for lesson models, for practical work and for the use of language in the classroom, it is clear that during his or her training the teacher should:

* become aware of his or her own ideas about accepted science concepts by being introduced to techniques which will enable him or her to become aware of his or her own ideas;

* be made very aware of the ideas of scientists about the same science concepts and appreciate how these ideas may differ from those held by him or her, hopefully moving towards accepting the scientists' ideas;

* learn techniques which will enable him or her to identify the ideas held by his or her pupils. This may involve learning how to:

  generate a non-threatening classroom atmosphere

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use written survey materials and to interpret the results of such surveys;

interview individual pupils;

manage group discussions;

listen to and interpret pupil responses. This is a difficult task because, as **Stenhouse** (1986) points out, pupils may not be able to articulate many of their ideas explicitly. These ideas will have to be interpreted from utterances which may be inappropriate and confused.

* learn to use simple but appropriate language to give instructions and to describe and explain ideas;

* learn to write instructions for experimental work in language in which the clarity of terms used and logical progression will ensure that the pupils understand the aim, appreciate the design, are guided to see the important outcomes of the experiment and to draw reasonable inferences;

* learn techniques of producing conceptual conflict by means of:

anecdotes;

analogies

critical experiments.

This could be the most difficult area of learning by the teacher because it is here that he or she will have to appreciate which experiments or events are the best to illustrate a new concept or to disprove ideas held by the pupils. Quite clearly this is an area which will make enormous demands on the teacher's ingenuity

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in and understanding of science.

* learn techniques which will allow him to assist pupils with conflict resolution and accommodation of new ideas;

* learn techniques of assessing the conceptual change in the pupils;

* learn techniques which will enable him or her to teach pupils questioning skills which may assist them in:

  asking critical questions about their own ideas as well as the ideas of others;

  the exploration of their own environment.(Osborne and Wittrock,1985.)

It is clear from the above that a tremendous amount is expected from the science teacher in terms of learning techniques which will enhance conceptual change in the pupils, but it is our opinion that the most important aspect of the training of teachers has to be in *their* own deep understanding of the basic science concepts involved in the curricula which they are expected to teach and, equally importantly, to understand the methods used to test and verify theories and their resulting predictions in science. This is indeed a daunting task.

In the preceding chapters we have presented evidence that pupils at schools in the Cape and Transkei hold alternate views of science which in most cases agree with those held by pupils and students in other countries around the world. In general we have found that the frequency with which these alternate views are held do not differ substantially between cultural, age and language groups. We have presented evidence that some of these ideas continue to be held by students at university and by students at the University of Cape Town following the post graduate Higher Diploma in Education.

In the light of our findings and of the preceding discussion, we are of the opinion that:

* as the current methods used in undergraduate science and in teacher training in science at tertiary institutions are essentially an extention of the methods used in high schools, these courses are inadequate for conceptual learning;

* since most teachers of science at school have studied and qualified through a system which does not stress conceptual understanding, many of them have misconceptions about many basic science concepts. Helm, 1978, showed that teachers of physical science at high schools harbour serious misconceptions. We have administered our questionnaire to two groups of HDE science method students at the University of Cape Town and have found that members of these groups have serious misconceptions about some fundamental concepts in mechanics. In-service training courses should be used to adress this problem.

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F. Implications for the curriculum:

When considering the content of a school curriculum two very important points about learning in general and science in particular should be borne in mind. The first one concerns learning in general and it is that pupils cannot discover all - or even very much - scientific knowledge for themselves nor can they be given scientific knowledge as though they were empty vessels waiting to be filled. New knowledge has to be firmly anchored in existing knowledge. The second important point relates in particular to learning in science and concerns practical work. For pupils to discover anything they need a prior conceptual framework. Discovery methods can investigate the relationships which exist between concepts but they cannot lead to the formation of new concepts. The acquisition of new knowledge depends on the child's existing knowledge and the structure and organization of the new knowledge. The child's existing conceptual framework is all - important in learning in science and especially so in practical work. (Hodson,1985).

In following a constructivist approach to and the generative model of learning, developers of curricula should attempt to answer the following questions:

* What pre-existing ideas do pupils have about the topic to be taught?
* How can we build on these ideas?
* Is the sequence of presentation of the material the correct one in view of the ideas to be taught and their relationship to other ideas as well as the pupils' pre-concepts? (Driver,

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1983,p.59)

* Can the pupils be expected to successfully complete the topics selected in the time available?
* Will the pupils be able to link the events selected to illustrate the relevant concepts to everyday events in their lives and will they be useful to the pupils?
* Has enough time been allocated to ensure adequate consolidation?

Driver (1983,p.80) is of the opinion that to design a curriculum around major conceptual schemes may mean that most pupils finish their formal education in science without understanding the theories which they have been introduced to nor seeing the illustrative materials as being relevant or interesting. She suggests that illustrative phenomena should not be selected because they support a theoretical idea but rather because they are of practical and everyday interest in their own right. There may also be good reasons to reconsider the level at which a theory is introduced to some pupils, e.g. some pupils may consider electricity as a flow of water in a pipe and not go on to the movement of charged particles. It is important to realise that the task is to teach pupils to understand the theories and explanations of others, including scientists, and not to believe them to be immutable truths. (Driver,1983,p.81.) Pupils should not be led to believe that science is intolerant of individual opinion, as a complete understanding of scientific practise demands that pupils be provided with opportunities to think creatively.(Hodson,1985)

One of the consequences of being exposed to conventional scientific ideas is that the pupils should reorganise their ideas accordingly. This requires time and this should be taken cognisance of in the curriculum.(Driver,1983,p.84.,Clough et al,1987.) Teachers and pupils should have time to discuss, argue, organise and accommodate new ideas. It is very possible that for by far the majority of pupils the science curriculum is too extensive. It is perhaps better to teach a few fundamental concepts which cover many events in day-to-day living than to cover highly theoretical and abstract ideas which for the ordinary pupil have little or no existence in reality.

Chapter 13

Specific implications:

In this section we will, where possible, be investigating the specific implications of our results for classroom teaching. In order to do so we have grouped questions which deal with essentially the same concepts.

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1. Force and motion:

The perceived link between motion and a force acting in the direction of the motion is examined directly by questions A 1, A 2, A 4, A 10, and indirectly by A 8 and A 12. Throughout all of the standards, as well as across all of the groups which we compared, the pupils in our sample overwhelmingly select options which link motion with a force in the direction of motion. If these results are seen in conjunction with our findings with first year university students and post-graduate education diploma students reported on page 73 above, then the implications are that:

* the idea that there must be something acting in the direction of motion to sustain motion is a remarkably pervasive and persistent one;
* current methods used to teach Newton's First Law are not at all successful;
* the number of years of exposure to science teaching has very little effect on the ease with which the concept described in

Newton's First Law is accepted;

* the order of presentation of the concepts involved in the study of force and motion both at schools and at tertiary institutions does not lead to an acceptance of the concept that force is only required to change momentum;
* as pupils and students believe that there is something acting in the direction of the motion of a moving body, that perhaps the first concept to be introduced should be momentum (Osborne,1985,p.48);
* teachers may be unwitting sources of the idea that force is required for motion;
* authors of text-books should spend more time explaining and exploring the implications of Newton's First Law.
* this area of the Physical Science syllabus should be investigated in great detail and in great depth at in-service training courses for teachers.

2. Forces in equilibrium :

The identification of the forces acting on a body at rest, as well as their directions and relative magnitudes, are examined by questions A 3, A 7, A 9 and A 11. In questions A 3 and A 7 an object is suspended: in A 3 from a tree and in A 7 from a man's arm. In questions A 9 and A 11 an object is supported by a surface: in A 9 the it is lying on a table and in A 11 on the palm of a man's hand. In A 8 a cart being pushed by a man is shown to be stuck in sand and the relative magnitudes of the frictional force and the force with which the man is pushing has o be compared. In A 6 and A 12 a tug-of-war situation is presented: in A 6 there is no movement but the competitors are of unequal size, while in A 12 there is movement with constant speed in the direction of one of the contestants. Pupils are asked to compare the magnitudes of the forces which the competitors are exerting.

From the results of questions A 3, A 7, A 9 and A 11 the implications are:

* that the responses of the pupils are determined by the situation used to illustrate the problem. Figure 1, which we have previously presented on page 232, and figure 2 clearly show this.

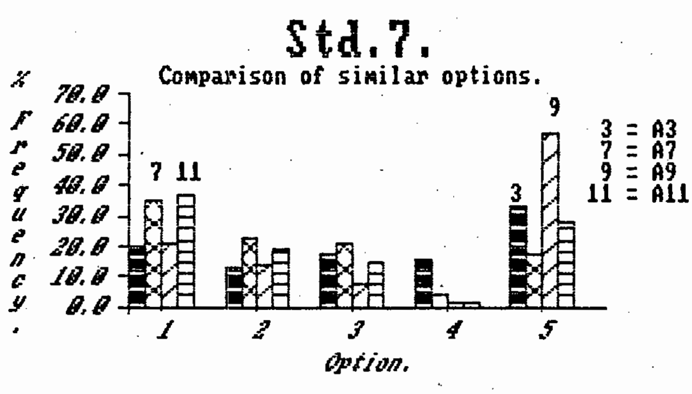

Figure 1

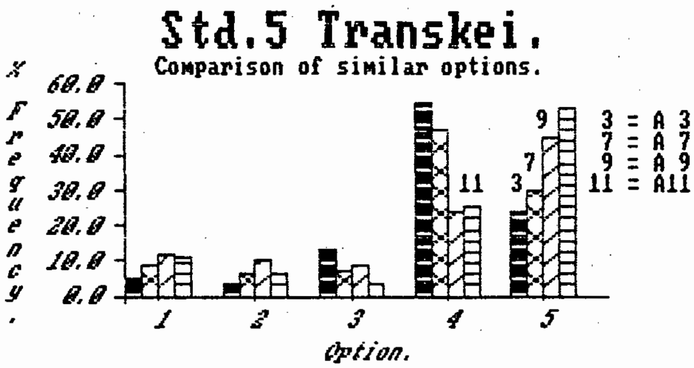

Figure 2

* that as pupils in schools in the Cape tend to select the correct response, i.e. option 1 on the graph, with a higher frequency if a human is seen supporting the object, that in teaching this topic a static condition should be introduced by using a human in the illustration.

* that to illustrate the problem, as is commonly done, with an object lying on a table, is clearly the worst of available methods for pupils in Cape schools. This is clearly shown by the increased frequency of selection of option 5, the option which compares the frequencies with which pupils select a downward-only acting force, in question A 9.

* that in Transkei schools pupils appear to be influenced more by the particular situation than in Cape schools. In the case of suspended bodies an upwards-only acting force is most commonly selected while in the case of bodies supported on a surface, a downwards-only force is commonly selected. The

presence of a human in the problem presented has very little effect on the response elicited from the pupils. As the pupils in Transkei, unlike their counterparts in the Cape, see the two situations presented to them as quite different from each other, it is clearly going to be more difficult to teach the equilibrium condition to these pupils. We therefore suggest that particularly in their case the understanding and acceptance of the presence of the gravitational force in all situations will be a good starting point in teaching the static condition.

* that, as in Transkei schools we find that the frequency with which a single upward-acting force is select decreases up the standards, while the frequency of selection for a single downward-acting force increases, this may be a maturation effect.
* as in Transkei schools boys tend to select a single downward-acting force and girls tend to select a single upward-acting force, the problem will have to be approached quite differently for the two groups. As virtually all schools in Transkei are co-educational, this will present a major teaching problem. Girls have to be made aware of the force of gravity!

* that as the figures 3 and 4 for schools in the Cape, which we have presented previously on pp 235 and 236 above, show, the correct response is selected with increasing frequency as we go across the standards, with a corresponding decrease in the frequency with which the presence of a single downward-acting

force is selected. This implies that either teaching or maturation has an effect. As the equilibrium condition had not been taught to any of the classes at the time of the study, it seems reasonable to assume that the effect produced must be due to maturation.

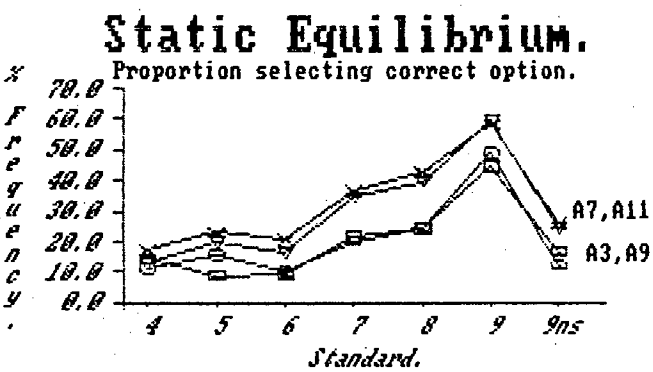

Figure 3

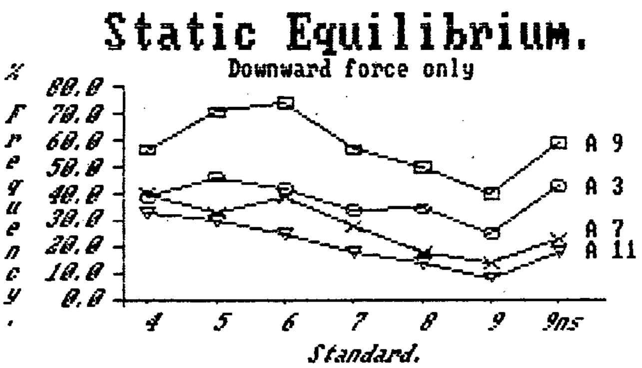

Figure 4

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* as standard 9 pupils who do science select the correct response with a substantially higher percentage frequency than the standard 9 pupils who do not do science, this strongly implies that learning in science has a definite effect in this area.

Figure 5 shows the responses of Cape pupils to two of the options they were presented with in question A 8, the question which asked pupils to compare the relative magnitudes of the applied force and the frictional force acting on a cart which is stuck in sand. Option a suggests that the applied force is larger than the frictional force while option b suggests that the applied force and the frictional force are of equal magnitude.

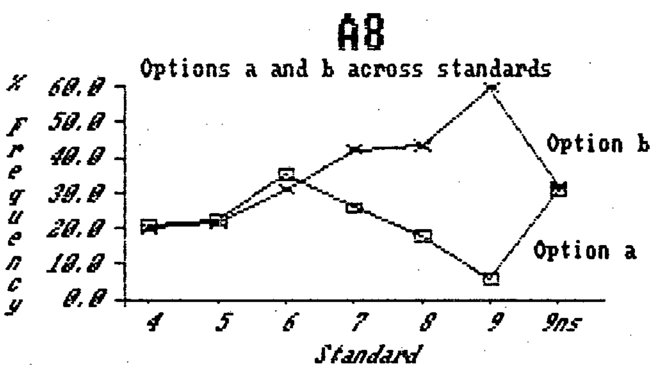

Figure 5

The responses represented in figure 5 suggests that:

* as there is a gradual decrease in the frequency with which pupils from standard 6 through to the standard 9 science group select option a, the option which suggests that the applied

force is larger than the frictional force, and while a substantially higher proportion of standard 9 non-science pupils select this option, this effect is due to learning science at school. This is further borne out by the increase in the frequency with which the correct option, option b, is selected across the standards to a maximum with the standard 9 science pupils. There is some evidence that the same trend is present in the responses of Transkei pupils, but to a less marked extent.

* as about 20% of the pupils in each of the standards in Cape schools select the option which suggests that the frictional force is much larger than the applied force, this idea is widespread and appears to be resistant to change by learning.

* as a substantially higher proportion of pupils in Transkei than in the Cape select this option, this belief is more firmly held in Transkei and may affect the ease with which this equilibrium situation is understood by pupils there.

* as figure 6, which we have presented previously on p. 222 above, shows, the belief that the frictional force is larger than the applied force is held by a larger proportion of pupils in standards 4 and 5 in the Cape, but that although this proportion shrinks to a certain extent, the idea is held by a remarkably similar proportion of pupils in each of the rest of the standards in schools in the Cape. This indicates that this idea is resistant to change through exposure to science teaching and maturation.

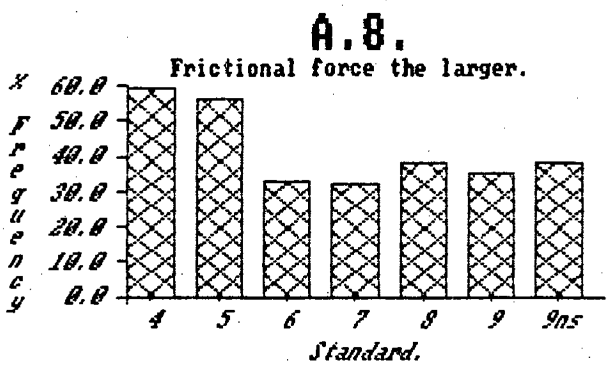

Figure 6

* as the belief that the frictional force is larger than the applied force is more widely held by Afrikaans-speaking pupils than by English-speaking pupils, in Afrikaans medium schools pupils will experience more difficulty in understanding this equilibrium situation and it ought therefore to be given greater attention in teaching.

Our results to question A 6, the tug-of-war situation with unequally sized competitors, have some interesting implications. These are that:

* a large number of pupils do not understand this equilibrium situation.

* the relative sizes of the competitors have a remarkable effect on the selection of the options by the pupils. This implies that when this equilibrium situation is introduced in class or in text-books it is important that the two competitors are

seen to be equal in size.

* girls in the Cape appear to be more affected by the extraneous information that the competitors are of unequal size. The implication here is that girls will experience more of a problem than boys in initially understanding the situation as presented and it is therefore particularly important when teaching in single sex girls-only schools that competitors are seen as equal in size - at least initially.

* the fact that the frequency with which pupils select the correct option, i.e. that the two dogs are pulling equally hard, increases across the standards in schools in the Cape to a maximum with the standard 9 pupils who do science, with an almost parallel decrease in the frequency in selecting the option which suggests that the larger dog pulls the harder, indicates that either learning in science and/or maturation has had an effect. The result may be due to learning in science in standards 8 and 9 or to the fact that these pupils have selected to do science and therefore may be assumed to be better read in science. It is not a maturation effect as the standard 9 pupils who do not do science select these two options with about the same frequency as the standard 7 pupils.

* the fact that our other comparisons do not yield noticeable differences implies that these beliefs are shared evenly by the different groups.

* as far as the pupils in the Transkei are concerned it appears that the three beliefs are very evenly shared by the different standards. This may ofcourse simply imply that the pupils were guessing but if we assume that they are not doing so then this implies a cultural difference. Transkei pupils do not expect that the big dog exerts the greater force to the same extent as their counterparts in the Cape. In the absence of data on pupils in higher standards it is not possible to predict the effect of this result on the teaching of equilibrium to pupils in higher standards.

The results of the answers to our question A 12, the question involving a tug-of-war situation in which one of the competitors is winning, imply that:

* either the pupils misunderstood the question or that the physics of this equilibrium situation is extremely poorly understood. However, the result fits in very well with the results of our investigation into the link between force and motion. A belief that there is an unbalanced force in the direction of motion is clearly implied by the overwhelming selection of the option which suggests that the winner is pulling the harder of the two.

* the belief that the force exerted by the competitor who is pulling in the direction in which the system is moving, increases in popularity in the higher standards. As in the case of the belief of force in the direction of motion, learning in science in school appears to have no influence at

all in the understanding of this situation.

* equilibrium situations involving movement at constant velocity will be difficult to teach as the pupils bring with them a belief that the force in the direction of motion has to be the larger. We believe that a thorough understanding of the relationship between force and motion is a pre-requisite to learning in this case.

* the pupils from Transkei may have been guessing or they really see this situation quite differently from their counterparts in the Cape. If the latter is true, then we believe that this particular situation will be understood more easily by Transkei pupils.

GRAVITY

1. Gravity and Height:

We used questions A 5 and B 5 to investigate the beliefs of our pupils about the relationship between the magnitude of the gravitational force and height above the ground. The implications of our results are that:

* while in general it is true to say that some pupils associate an increase in height with an increase in the gravitational force, i.e. "the higher the heavier", the frequency of the responses elicited from the pupils depend on the situation presented to them. While about 50% of standard 9 science pupils believe that it requires a larger force to hold a car

at the top of an incline as opposed to the force required to hold it at the bottom, only about 30% believe that the gliding bird has a larger force acting on it than the bird seated on the ground. This situation-dependence of the frequency of the elicited response is fairly typical for all of the standards.

* there is a general ignorance of the effect of a relatively small increase in height on the magnitude of the gravitational force in pupils in all of the standards in schools in the Cape. It therefore seems clear that this is an area of confusion for pupils in most standards. The implication is that when Newton's Law of Universal Gravitation is taught, particular attention should be paid to the effect on the value of the gravitational force of the magnitude of the distance between the surface of the earth and that of bodies on or near the surface of the earth, i.e. that compared to the radius of the earth small increases in altitude have negligible effect on the value of the gravitational force.

* girls appear to believe that "higher means heavier" to a slightly larger extent than boys do. This implies that more care should be taken with girls when clarifying the implications of Newton's Law of Universal Gravitation.

* comparison of the frequencies with which standard 4 and standard 9 pupils who do not do science select the options which imply that gravitational force increases with height suggests that the frequency of this belief may increase with increasing age in pupils not studying science at high school.

* there is a noticeable increase in the belief that the gliding bird in question A 5 experiences a smaller force than the bird sitting on the ground when we compare pupils from standards 4, 7 and the 9 science group. This is in all probability due to some learning about Newton's Law of Universal Gravitation and over-estimating the effect of an increase in the distance between bodies. There is also an increase in the frequency with which pupils from these classes select the correct option as well as a decrease in the frequency with which the option which suggests that the bird is weightless is selected. This may be the result of learning in science. The effect of learning in science is further illustrated by a comparison between the frequencies with which standard 9 science pupils and standard 9 pupils who do not do science select the option which suggests that the bird has a smaller force acting on it while it is gliding than while it is sitting on the ground: a substantially higher proportion of science than standard 9 non-science pupils select this option as well as the correct option.

* the idea that higher means heavier is also the predominant one in Transkei.

* there is very little difference between the frequencies with which boys and girls in Transkei schools select the different options on these questions, which implies that this concept can be taught readily in a typical Transkei co-educational classroom.

2. Rising and falling objects:

We used two questions, B 1 and B 3, to investigate the beliefs held by our pupils about the speeds with which objects of unequal mass fall. In question B 1 two balls, one having double the mass of the other, are allowed to fall freely from the same height above the ground. Pupils are asked to compare the speeds with which the balls will strike the ground. In question B 3 two cars are allowed to run freely from the same point down an incline with one car being twice as massive as the other. Figure 6 , which refers to our results to B 1 and which we presented on page 401 above clearly shows that with the exception of standard 6 pupils by far the majority of pupils in the other standards in Cape schools believe that heavier objects fall at a greater speed than lighter ones.

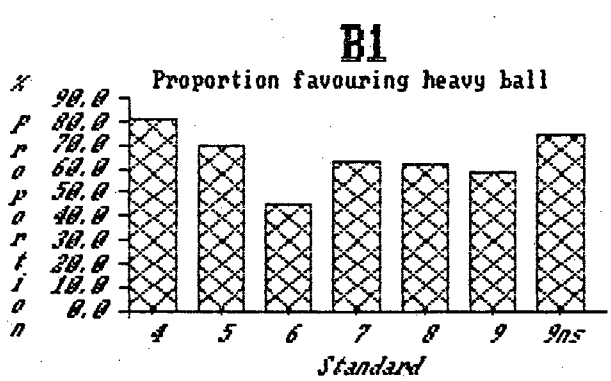

Figure 6

Furthermore, we have once again clearly demonstrated that the frequency with which this belief is held is dependent on the situation presented to pupils. This may be an example of a different mini-theory being used to solve the problem. The following graphs, figures 7 and 8, which we have presented on page 347 above compare the frequencies with which similar options are selected on questions B 1 and B 3.

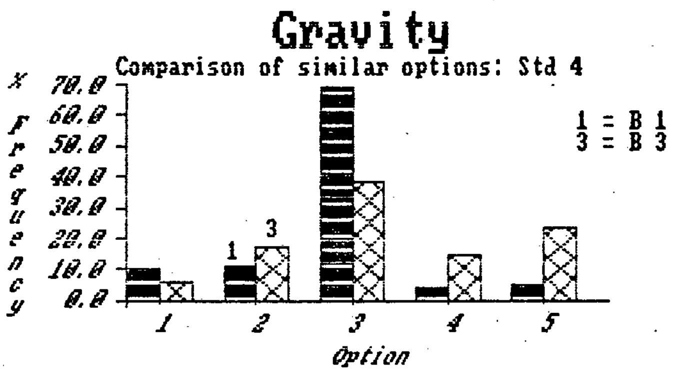

Figure 7

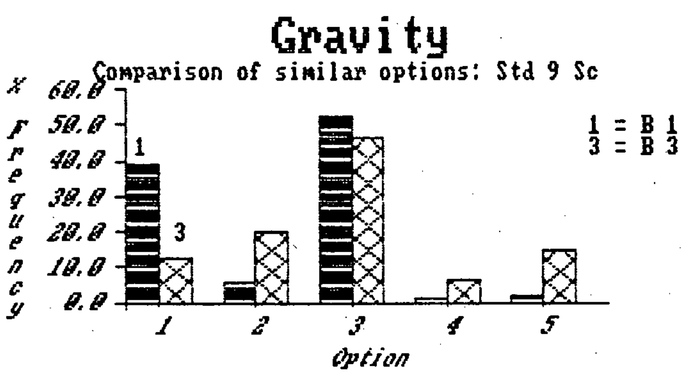

Figure 8

It is clear that the pupils from the two classes we have selected do not see the two situations as similar.

The implications of our results are that:

* the idea that heavier objects fall faster than lighter objects is deeply rooted amongst pupils in schools in the Cape and as such will doubtless be resistant to change. The most popular belief exhibited by pupils in all of the classes and groups which we investigated was that the object with double the mass would travel twice as fast as the less massive one.

* any attempt to demonstrate practically the fact that all objects in free fall experience the same acceleration will need very careful preparation, as any result which could even remotely be interpreted as indicating that the heavier object has the greater speed or falls faster will encourage a belief which is already held by pupils.

* the fact that there is an increase in the frequency with which the correct option is selected by pupils from standard 4 through to standard 9 science pupils, with a large decrease in the case of the standard 9 pupils who do not do science, implies that learning in science around standard 6 has a clear effect on the belief that objects fall equally fast. It is not clear why the standard 6 pupils hold this belief to the large extent that they do: they are the only group of which the majority of the pupils do not believe that heavier objects fall faster than lighter ones.
* the situation-dependence of the responses elicited is further illustrated by the comparison of the responses of girls and

boys. When asked to compare the speeds of freely falling balls, boys do very much better than girls at selecting the correct answer while a substantially larger proportion of girls select the options which suggest that the heavier ball has the greater speed. However, when asked to do the same for cars of unequal mass running down an incline, a substantially higher proportion of boys select options which indicate a belief that the heavier car has the greater speed at the foot ot the incline. We are therefore led to believe that when using the usual illustration of free-falling bodies, girls will experience more difficulty in accepting the idea that both objects will have the same speed after having fallen through the same distance. Furthermore, it is clear that the sexes do not see the two different situations as similar. This could be a very strong argument for the existence of what Claxton refers to as separate mini-theories.

* the data from pupils in Transkei shows that the proportion of pupils who select the correct option increases from standard 4 through to standard 6. This may be due to learning or maturation. However, the majority of pupils believe that heavier objects will have greater speeds than lighter ones when they free-fall for the same distance and as such will experience difficulties in accepting the correct concept. Boys appear to believe this more strongly than do girls. However, when asked to compare the speed of the cars at the foot of the incline, the majority of Transkei pupils indicate their belief that the lighter car will have the greater speed.

Clearly the pupils are not seeing the two situations as similar. While a larger proportion of boys than girls believe that the more massive ball will have the greater speed, about the same proportion of boys and girls believe that the lighter car will have the greater speed. However, the beliefs are shared by the majority of pupils in each of the sexes and as such should not have a substantial effect on teaching in a co-educational classroom.

We used question B2 to investigate the beliefs pupils hold about rising objects. In this question two objects of unequal mass, one being twice as massive as the other, are thrown upward with the same initial speed. The pupils are asked to compare the height reached by the two objects. We find that the belief that the lighter object will reach the greater height to be very firmly rooted in pupils in all of the standards in schools in the Cape. Figure 9, which we have presented on page 420 above, shows this clearly.

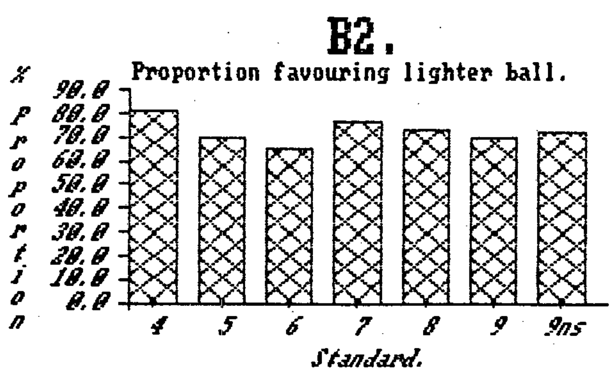

Figure 9

Chapter 13 Specific implications

As our results with falling balls indicate a widely held belief that heavier objects fall faster, this result is expected, as heavier ojects should therefor also slow down more rapidly. The results to questions B 1 and B 2 are in very good agreement with each other and indicate the belief that the acceleration of free-falling objects depends upon their mass. The implications for teaching in general have been spelt out on the previous pages. Once again it is not clear why the standard 6 group do not hold this belief quite as widely as the other groups.

As the results of question B 1 indicate that a substantially larger proportion of girls than boys believe that heavier objects will fall faster than lighter ones, the results of this question indicate that a substantially larger proportion of girls than boys believe that lighter objects will rise higher than heavier ones. This clearly could lead to problems in co-educational classrooms.

Once again in Transkei we find that the majority of pupils believe that the lighter ball will reach the greater height. This is in good agreement with our findings on question B 1. The proportion of boys and girls who hold this belief is so similar implying that the methods used to adress this problem will be the same for boys and girls and as such it should not cause a problem in co-educational classrooms.

Relative Speeds On Overtaking

We used question B 4 to investigate the beliefs our pupils hold about the relative speeds with which two bodies are travelling when the one body is in the act of overtaking the other. From our results it is clear that:

* the majority of pupils in each of the standards in schools in the Cape believe that the body which is in the act of overtaking has the greater speed but that about 26% of the pupils in our sample actually believe that at the moment when the two bodies are opposite each other, they have the same speed. There is an increase with standard in the proportion of pupils who believe that the overtaking body has the larger speed. This indicates both a learning and maturation effect. There is a very sharp increase in the proportion of pupils who hold this belief and a corresponding decrease in the proportion of pupils who believe that the two objects have the same speed, as one goes from the standard 4 and 5 groups to the higher standards. However, the belief that at the moment of overtaking both objects have the same speed is held by about 25% of the pupils in the standard 9 science group. Why there should be an increase in the frequency with which this belief is held by pupils in the standard 9 groups when compared to the pupils in standards 6,7 and 8 is not clear. The fact that about 25% of the pupils in the standard 9 science group believe this after they had completed their studies about motion is a clear indication that this idea is widespread and particularly resistant to change. Careful

selection of examples and discussion is needed to bring about a change in this belief.

* the proportion of standard 9 pupils who do science and who believe that the two objects have the same speed at the moment when they are opposite each other is virtually identical to that of the standard 9 pupils who do not do science and who share this belief. This indicates that this belief is fairly commonly held by pupils in all of our classes and by pupils entering universities. Lecturing staff in tertiary institutions should be made aware of this.

* a slightly larger proportion of girls than boys hold the belief that the two bodies are travelling at the same speed when they are opposite each other and this may imply that girls should be given more time to explore this situation.

* in Transkei the idea that the speeds are the same at the moment of overtaking is also fairly widely held and the pupils should be given time and examples to explore the situation. There appears to be no appreciable difference between boys and girls in this case. This implies that this concept can be dealt with readily in co-educational classrooms as the beliefs of the boys and girls are very similar.

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Circular Motion

We used questions C 3, C 5 and C 7 to investigate the beliefs of our pupils about the path along which an object which is travelling in a circle will travel after being released. From our results it is clear that while the idea that the path along which the released body will travel is a curve is widely held, the frequency with which this response is elicited depends upon the situation presented as well as the age and standard of the pupils. In the following graphs we have compared the frequency with which similar options are selected by standard 4 pupils and standard 9 science pupils. On the graphs the different paths are represented as follows:

Option 1: radial path.
Option 2: in a straight line at an angle to the radius
Option 3: tangential path.
Option 4: curved path

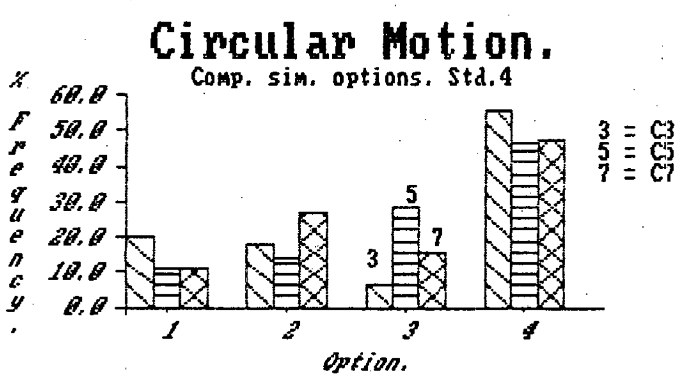

Figure 10

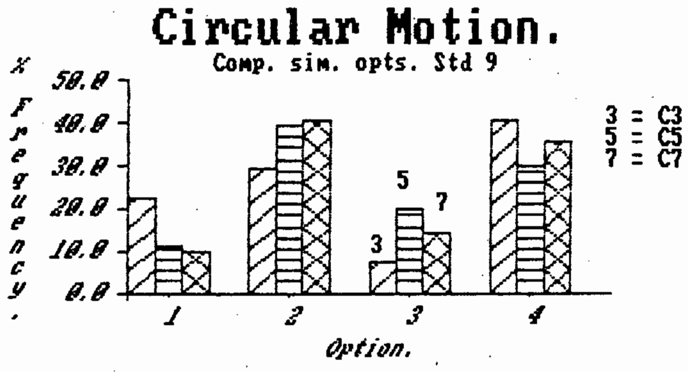

Figure 11

It is clear from figures 10 and 11 that while the belief that the released body will travel along a curve is widely held by pupils in both of these groups, the belief that it will travel along a straight line at an angle to the radius is also held by a substantial proportion of standard 9 science pupils. Our results imply that:

* for the researcher, it is important to realise that the situation used to investigate the beliefs held by subjects will effect the frequency with which different paths are selected.

* a remarkably consistent but small proportion of pupils in each of the standards believes that the path will be tangential. It will quite clearly be quite difficult to convince the remaining majority of the pupils that this is the correct path, and we would suggest careful observation of objects being swung around and released will assist with

learning in this case.

* a belief in the persistence of curvilinear motion in the absence of a force is widely held amongst pupils both in schools in the Cape and Transkei.

* in all three cases presented there was a gradual decrease in the frequency with which the curved path is selected by the pupils in the different standards, reaching a minimum with the standard 9 science pupils. As the pupils in standard 9 who do not do science select this option with a frequency which is very similar to that of the standard 7 group, this is clearly the effect of learning in science.

* in all three cases presented there is a gradual increase in the frequency with which a straight line path which is at an angle to the radius is selected by the pupils in the different standards, reaching a maximum with the standard 9 pupils who do science. This is probably due to learning in science.

* a substantially greater proportion of girls than boys hold the belief that the released object will travel on a curve, while a larger proportion of boys belief that the object will travel along a straight line at an angle to the radius. In a co-educational school this means that girls may be more resistant than boys to accepting a tangential path and may have to spend more time on this topic than the boys in the class. This could be a problem for the teacher.

* the trends in Transkei schools are similar to those in Cape schools except that the beliefs of boys and girls do not

differ appreciably. This implies that this topic can be readily tackled in a co-educational classroom in Transkei.

Projectile Motion

We used questions C 1, C 2, C 4 and C 6 to investigate the beliefs held by our pupils about the paths along which objects with an initial forward motion will fall if they are released and allowed to fall freely to the ground. From our results it is very clear that the majority of our pupils do not believe that the path will be a parabola in the direction of the initial motion. It is also clear that the path selected depends upon the standard which the pupils are in as well as upon the situation presented to the pupils. The following graphs which we presented on pp 534 and 526 show this very clearly

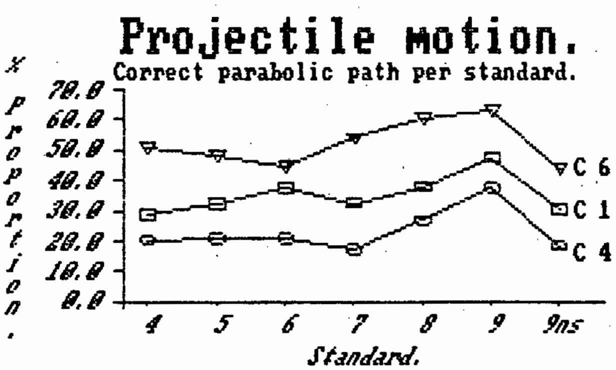

Figure 12

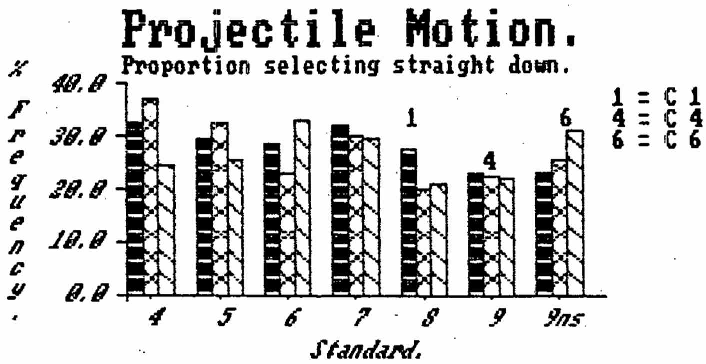

Figure 13

From figures 12 and 13 it is clear that the perceptualy more complex situation presented in C 4 elicits fewer "correct" responses from our pupils.

It is also clear that with the exception of C 6 the proportion of pupils who believe that the object will fall straight down in general decreases from standard 4 through to the standard 9 non-science group. The standard 7 pupils appear to select this option with a frequency which is slightly too high to fit in this general trend. This trend is probably the result of a combination of maturation and of learning.

Furthermore, it is clear from our results that in the free-moving situations presented, the proportion of pupils who select the path which indicates a belief that the object will actually fall backwards is fairly constant. This can be interpreted as meaning that they believe that the motive force has been removed and therefore the body will stop moving forwards, in which case one will actually expect the body to fall straight down.

Alternatively it may be due to very strong perceptual clues present in these everyday situations.

In all of the situations presented we find that there is a gradual increase in the proportion of pupils who select the correct forward parabolic path from standard 4 through to the standard 9 science group, followed by a decrease to the standard 9 non-science group. This is probably due to learning, although one can also argue that pupils who do science in standards 8 and 9 elect to do so and that these pupils probably observe their environment more closely due to some form of "science orientation".

The consequence of these beliefs for teaching, we believe, is that the immediate acceptance by pupils of parabolic paths of motion will be difficult. We believe that practical demonstrations which minimize perceptual clues to be of utmost importance when introducing this topic.

Furthermore, we find that boys and girls differ greatly in their beliefs about the paths along which objects will fall. Figures 14 and 15 which we have presented on pp 527 and 531 above show this clearly.

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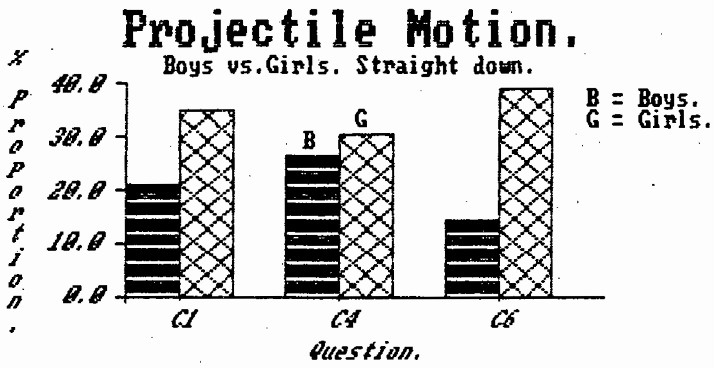

Figure 14

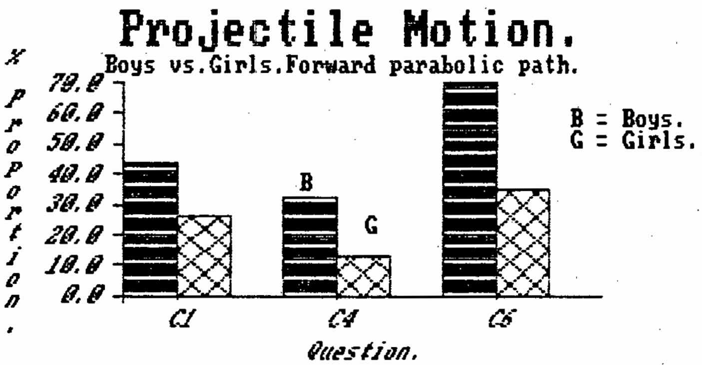

Figure 15

It is clear from figures 14 and 15 that in co-educational settings teaching this concept will be problematic and will require skillful handling by the teacher. We suggest once again that practical observation is going to be of the utmost importance.

We also find that all the other comparisons which we drew in

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schools in the Cape yield results which are very similar. This means that all of our pupils in all of the schools which we tested respond remarkably similarly to these situations.

In Transkei we find that the predominant belief is that the object will fall straight down. There is very little difference in the proportion of boys and girls who select this option. Clearly practical demonstration is going to be important here but the problem of different responses of boys and girls present in Cape schools will be absent in Transkei schools. This is a welcome finding as virtually all schools in this area are co-educational.

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APPENDIX A: QUESTIONNAIRES

INLIGTING EN ANTWOORDBLAD/ INFORMATION AND ANSWER SHEET.

STANDARD:
STANDERD: → | 4 | 5 | 6 | 7 | 8 | 9 |

SEX :
GESLAG : →

BOY	GIRL
SEUN	DOGTER

HUISTAAL :
HOME LANGUAGE : → | AFRIKAANS | ENGLISH | |

AGE :
OUDERDOM : → [ ]

	YES	NO
IS PHYSICAL SCIENCE OR GENERAL SCIENCE ONE OF YOUR SUBJECTS AT PRESENT ?		
IS ALGEMENE WETENSKAP OF SKEINAT EEN VAN U HUIDIGE VAKKE ?	JA	NEE

AFDELING A / SECTION A

1. a b c d e
2. a b c d e
3. a b c d e
4. a b c d e
5. a b c d
6. a b c
7. a b c d e
8. a b c d
9. a b c d e
10. a b c d e
11. a b c d e
12. a b c

AFDELING B / SECTION B

1. a b c d e
2. a b c d e
3. a b c d e
4. a b c
5. a b c

Please turn over/
Blaai om asseblief.

SECTION C / AFDELING C

1. a b c d e
2. a b c
3. a b c d
4. a b c d e
5. a b c d
6. a b c d e
7. a b c d

SECTION D / AFDELING D

1. a b c d e
2. a b c d e
3. a b c
4. a b c
5. a b c d e

%%%

Baie dankie vir u hulp / Thank you very much for your help.

INFORMATION

In this test paper I am going to ask you to give your opinion about four different kinds of things.

In Section A you must compare the relative sizes of forces and the direction in which the forces are acting. (By relative I mean that you must compare the size of the two forces with each other to see which one is the bigger).

In Section B you must compare the relative sizes of the same quantity in two different objects e.g. their speed.

In Section C you must select the path an object will travel along after something has been done to it, or after it has done something.

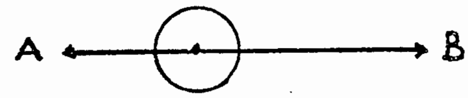
In Section D you are asked to compare the temperatures of boiling liquids as well as one or two other things.

To answer the questions, all you have to do is to put a tick in the correct block on the answer sheet provided. *Please fill in all the details on the answer sheet as this is important to me.*

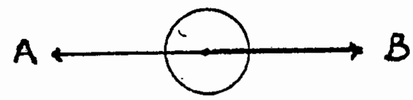
SECTION A : INFORMATION

In this section the size of a force is shown by the length of an arrow. The arrowhead shows the direction in which the force is acting. For example, two forces, A and B acting on a body may be shown as :

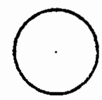
(i) In this case force A acts in a direction opposite to force B and is smaller than B.



(ii) Here forces A and B are equal in size but act in opposite directions.

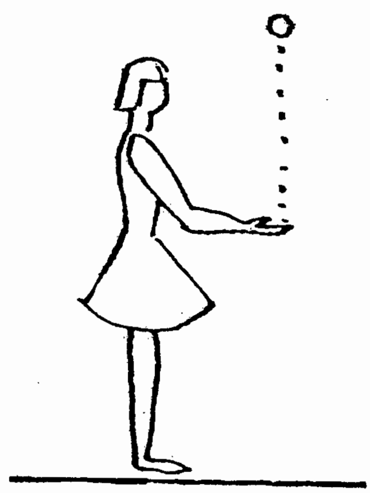


(iii) Here there are no forces acting on C.



SECTION A : QUESTIONS

1. The sketch shows a girl throwing a ball vertically upwards. The sketch which best shows the forces acting on the ball immediately after it has left the girl's hand, is :



(a)

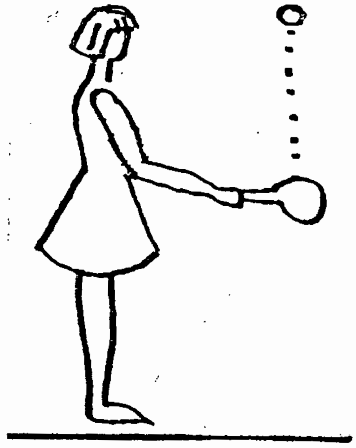
(b)

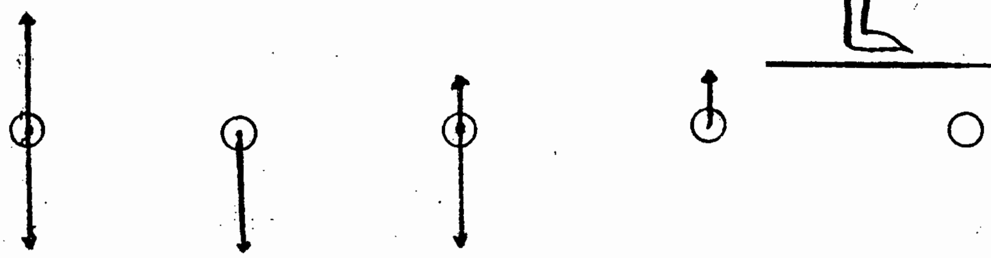
(c)

(d)

(e)

2. The sketch shows a girl who has used a bat to hit a ball vertically upwards. The sketch which best shows the forces acting on the ball when it has reached its highest point and just before it starts to fall back to the ground, is :

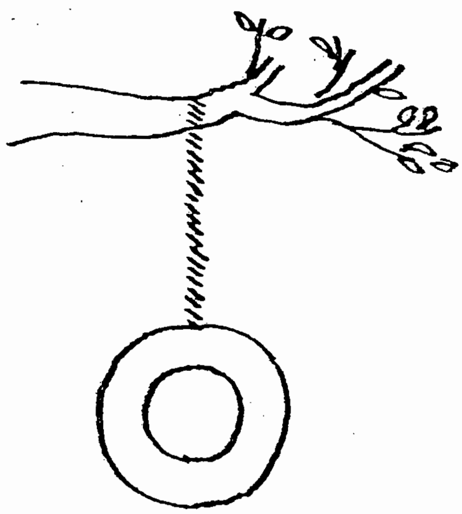


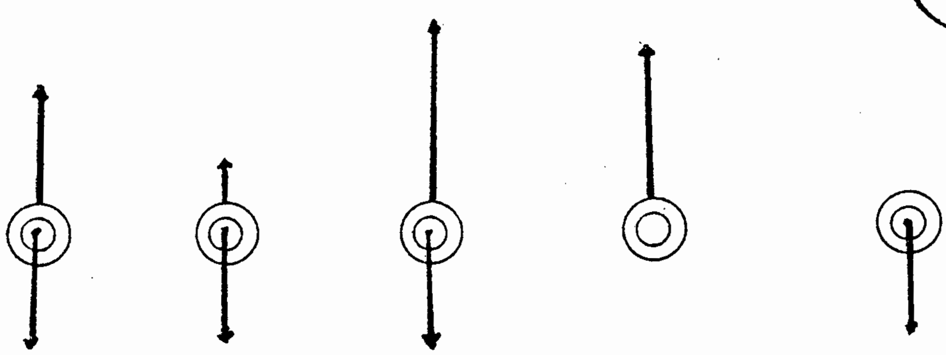


(a) (b) (c) (d) (e)

3.

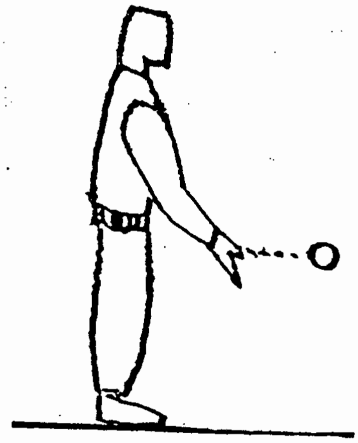
The sketch shows a tyre which is hanging from a rope which has been tied to the branch of a tree. The sketch which best shows and compares the sizes of the forces acting on the tyre, is :

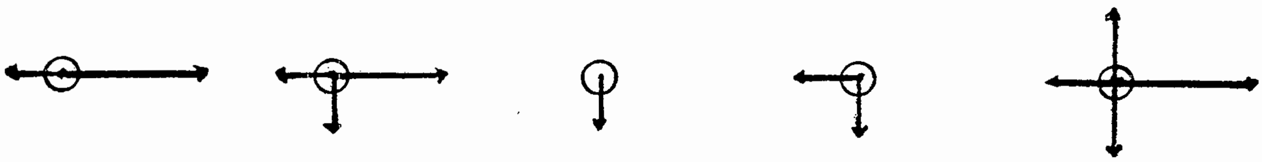




(a) (b) (c) (d) (e)

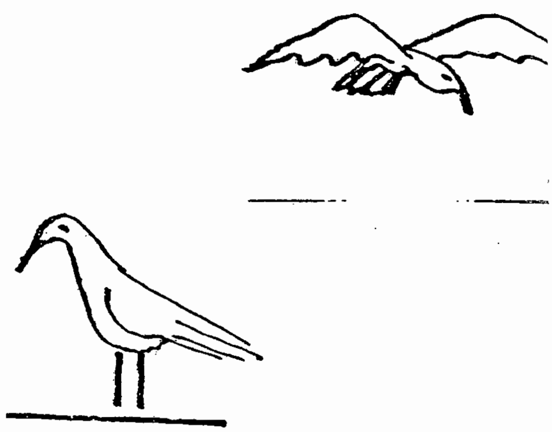
4. The sketch shows a boy who has thrown a ball horizontally away from him. The sketch which best shows the forces (including friction or resistance) acting on the ball immediately after it has left the boy's hand, is :

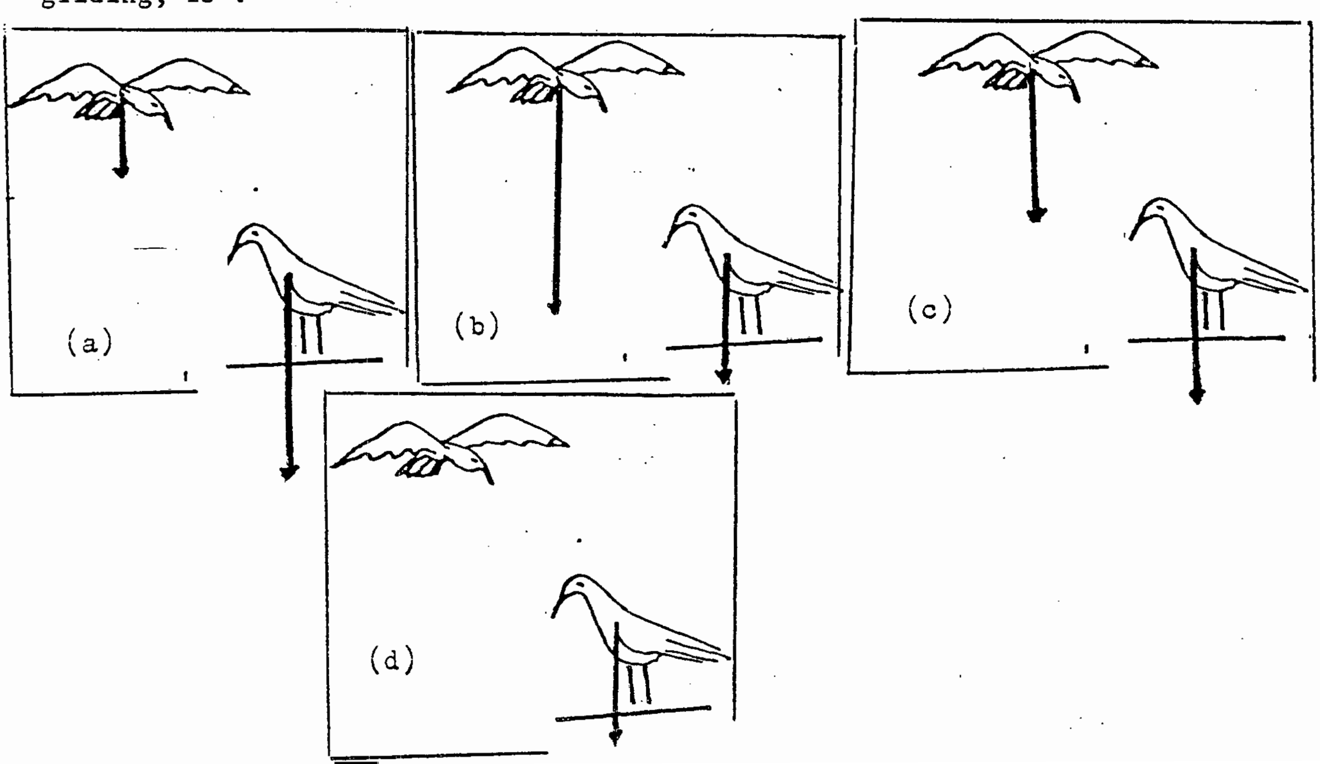




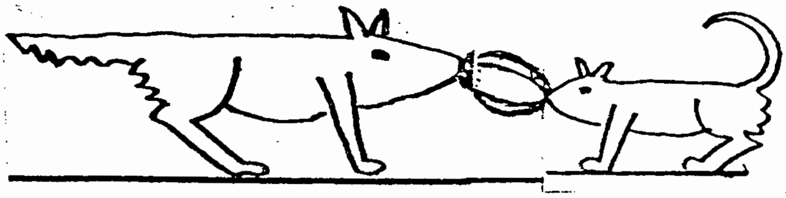
(a) (b) (c) (d) (e)

5. The sketches show the <u>same</u> bird sitting on the ground and gliding along 100 metres high in the air. The pair of sketches which best compares the size of the force with which the earth attracts the bird when it is sitting on the ground and again while it is gliding, is :

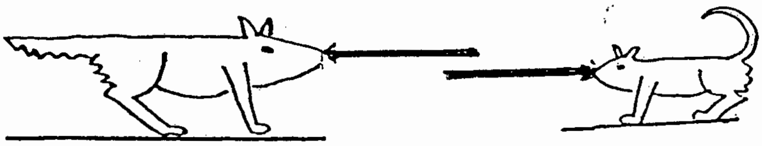


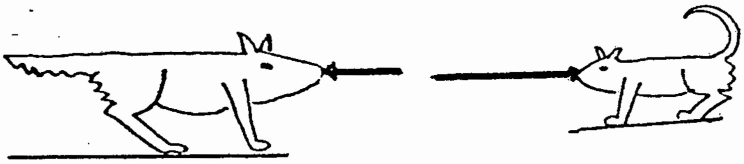


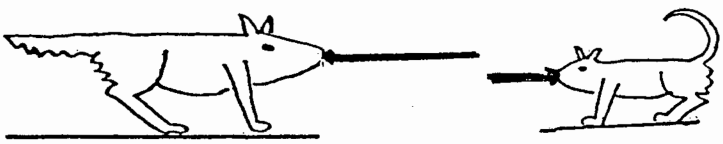
6.



The sketch shows two dogs pulling against each other at opposite ends of a sack. They are not moving. The sketch which best shows how hard each dog is pulling, is :

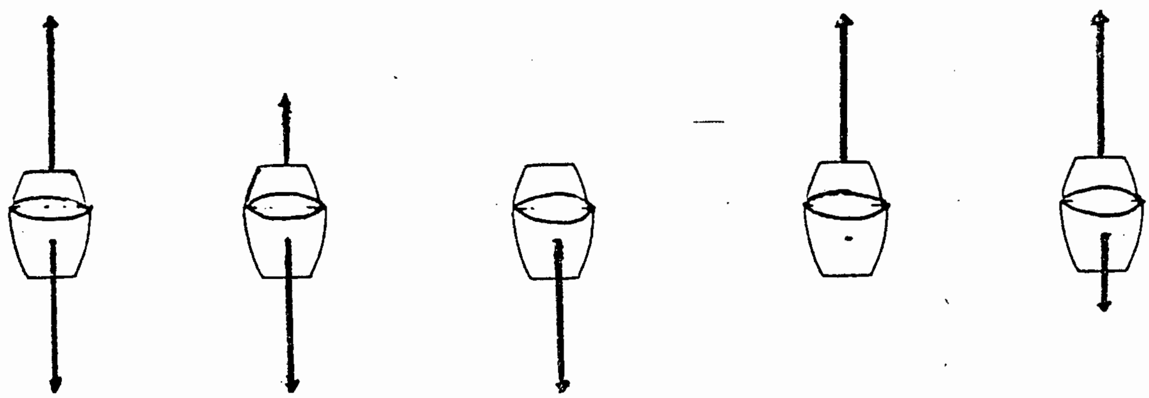
(a) 

(b) 

(c) 

7.

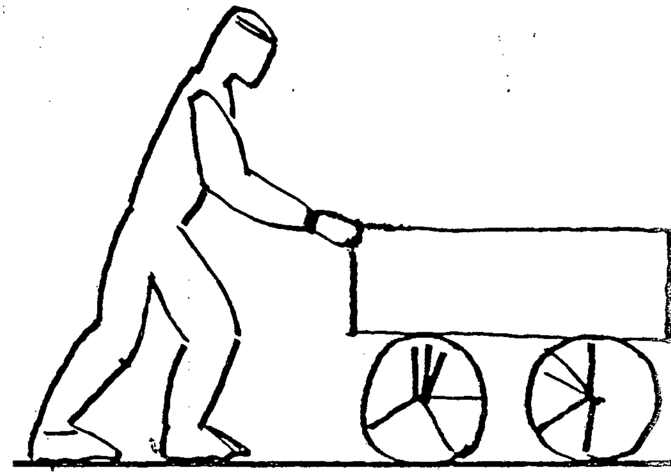
The sketch shows a man holding a bucket of water in his hand. The sketch which best shows and compares the forces acting on the bucket of water is :

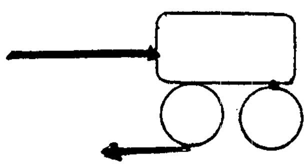


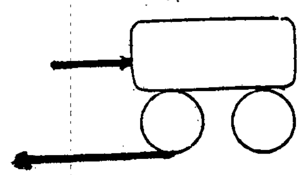
(a) (b) (c) (d) (e)

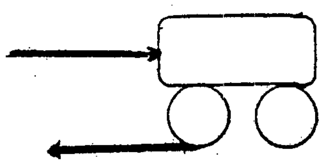
8.

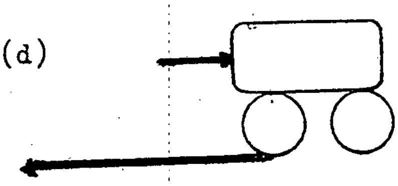
The sketch shows a boy who is pushing a cart. The cart is not moving because it is stuck in sand. The sketch which best shows the relative sizes of the force with which the boy is pushing compared to the frictional force or the force of resistance, is :



(a) 

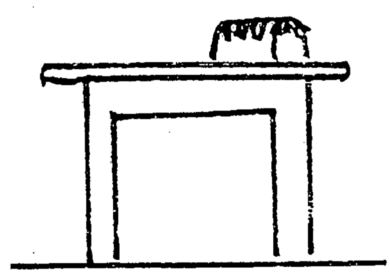
(c) 

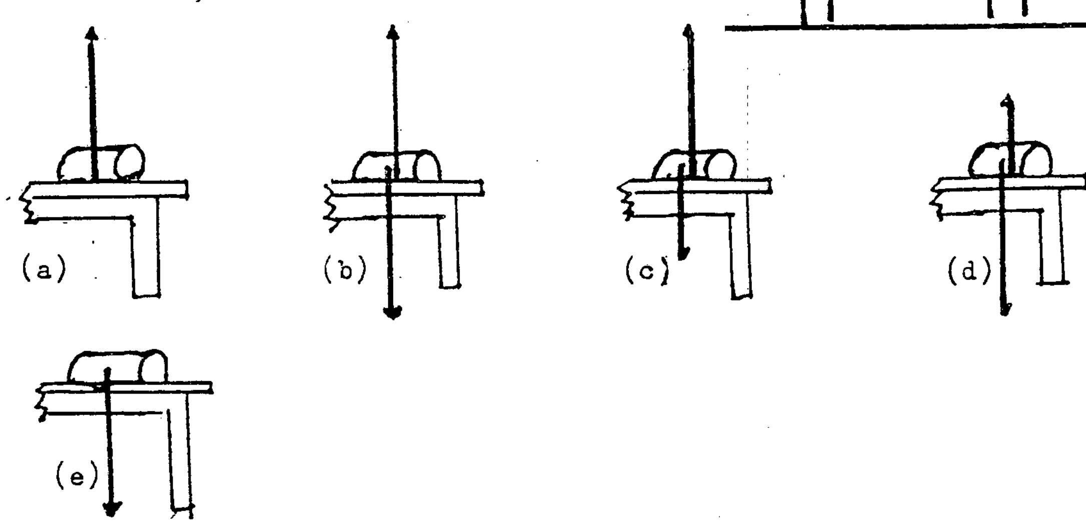
(b) 

(d) 

9.

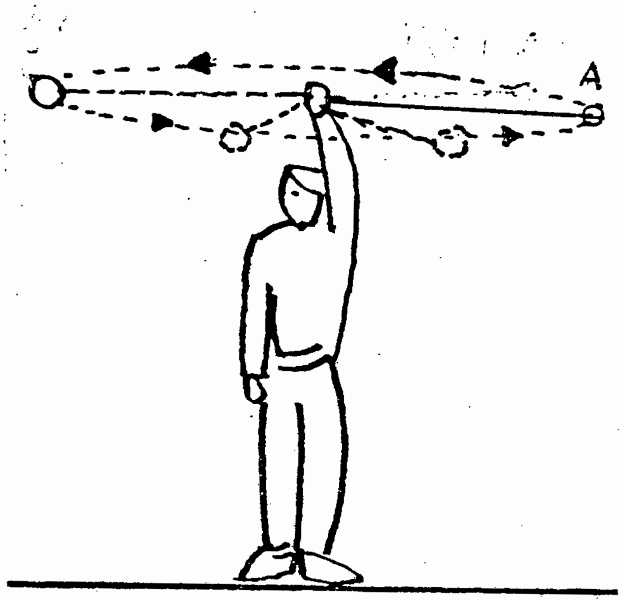
The sketch shows a loaf of bread lying on a table. The sketch which best shows and compares the sizes of the forces acting on the bread, is :

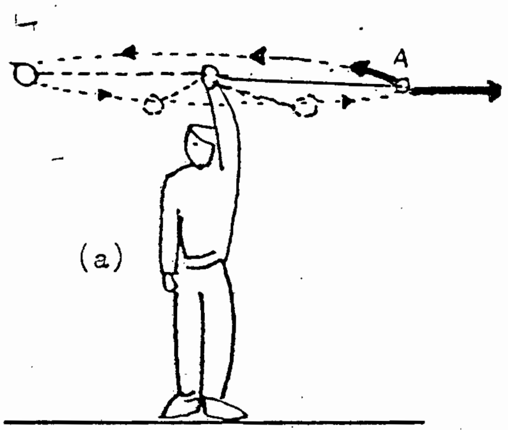




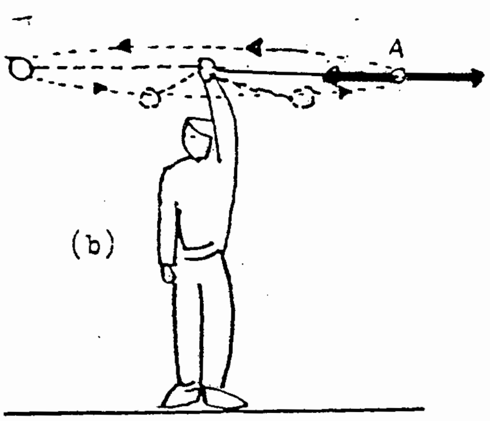
10.

The sketch shows a boy who is swinging a ball, which is attached to a string, horizontally around his head. The force or forces acting on the ball at A because of its motion (not gravity and friction):

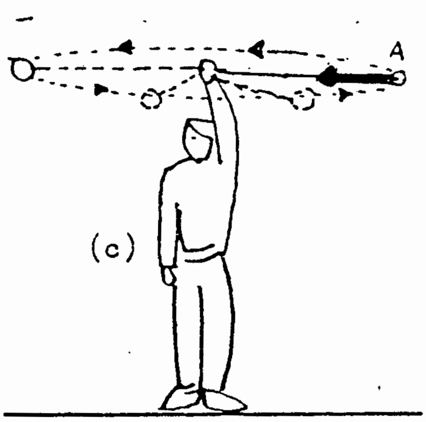




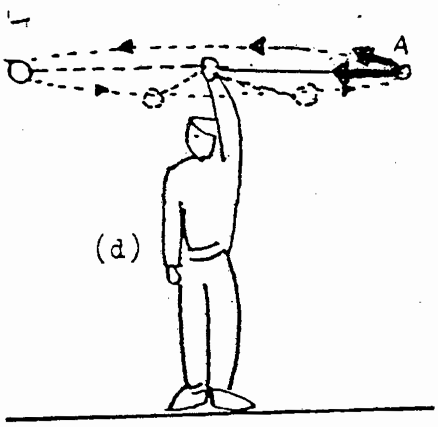
(a)



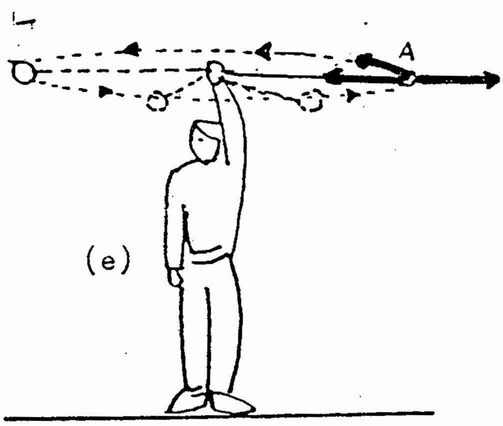
(b)



(c)

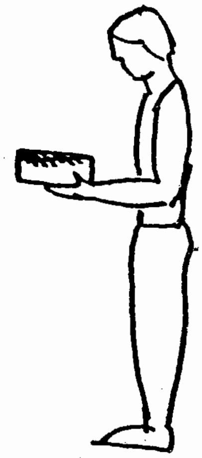


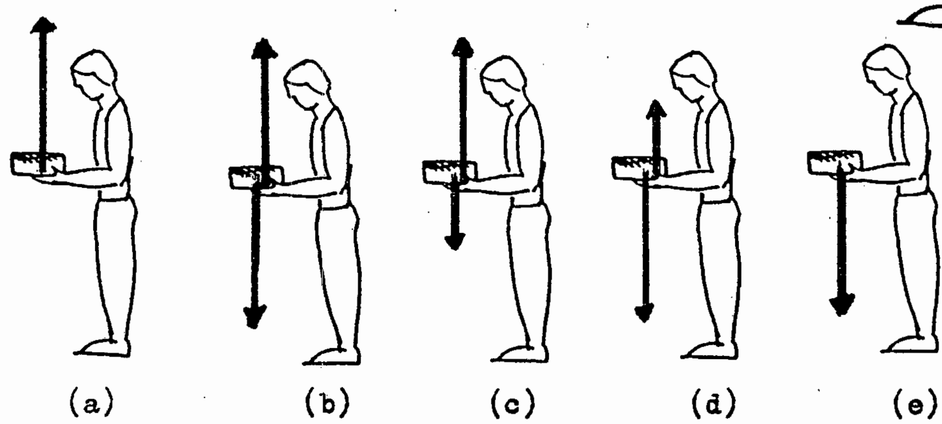
(d)



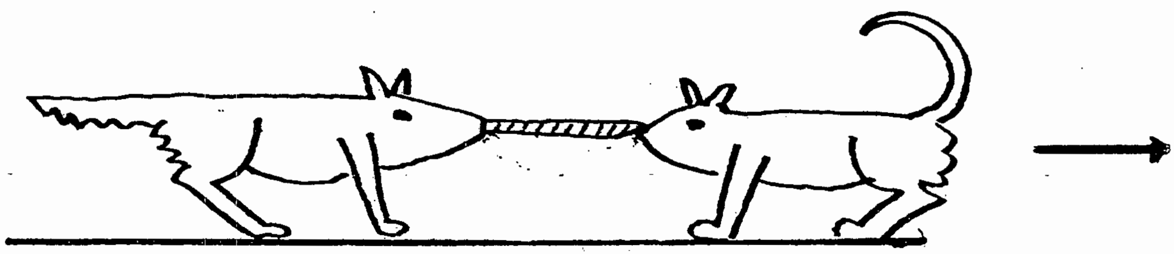
(e)

11. The sketch shows a man holding a brick in his hand. The sketch which best shows the forces acting on the brick is :

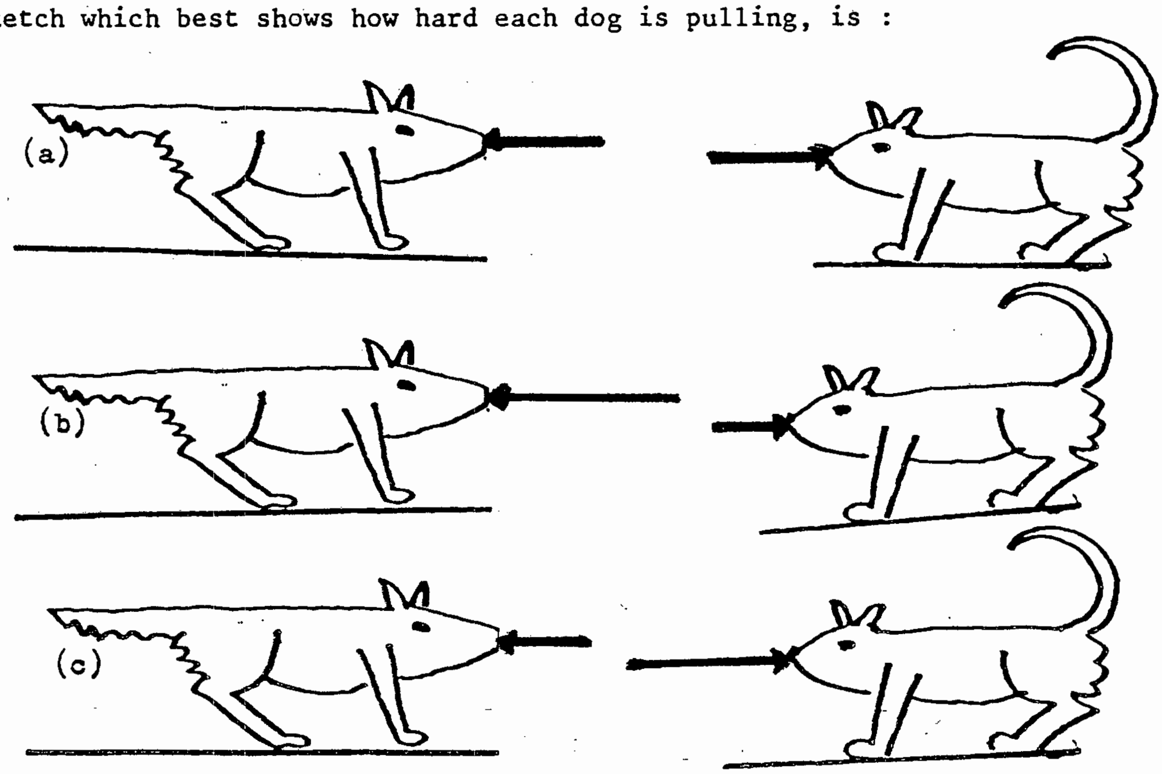




12.

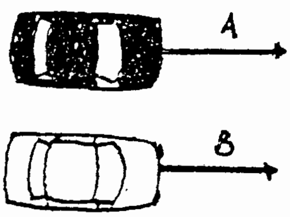


The sketch shows two dogs pulling against each other at opposite ends of a rope. They are moving slowly towards the right. The sketch which best shows how hard each dog is pulling, is :

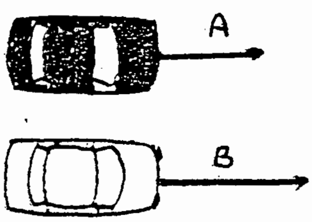


SECTION B : INFORMATION

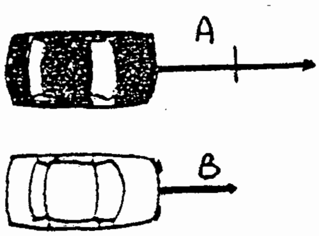
In this section you must compare the relative sizes of the same quantity e.g. speed, distance travelled, etc. in two different objects. Here arrows are again used but now the *length* of the line indicates the *relative size* of the quantity which we are comparing. For instance, if we are comparing the *speed* at which two cars are moving, then the following sketches would indicate that :

(i) 

A and B have the same speed.

(ii) 

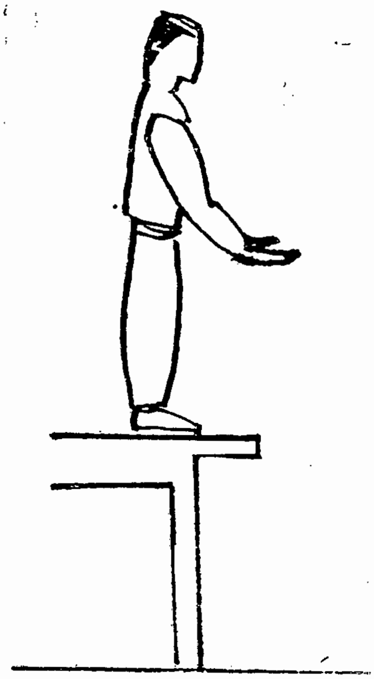
B is moving faster than A

(iii) 

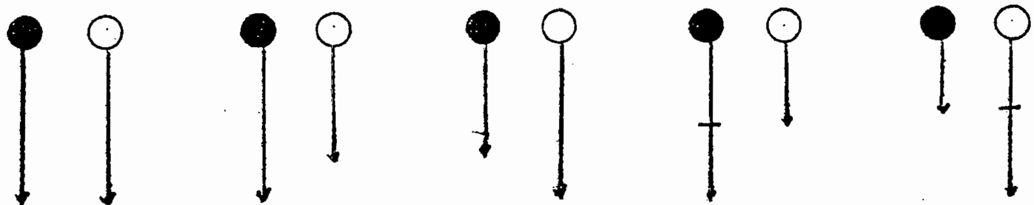
A is moving twice as fast as B.

SECTION B : QUESTIONS

1.

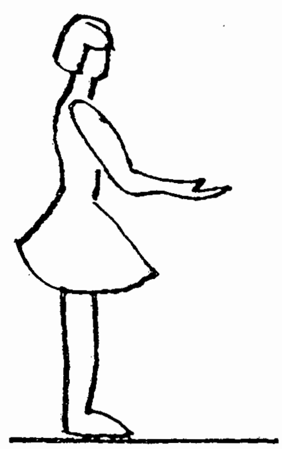


The sketch shows a boy who is standing on the top of a table. He has two marbles in his hand. The black marble is twice as heavy as the white one. He drops them at the same time and they fall towards the ground. The sketch which best shows the relative <u>speeds</u> with which the marbles hit the gound, is :

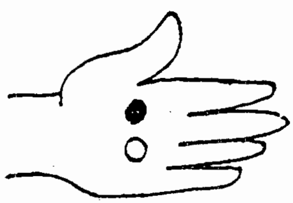


(a) (b) (c) (d) (e)

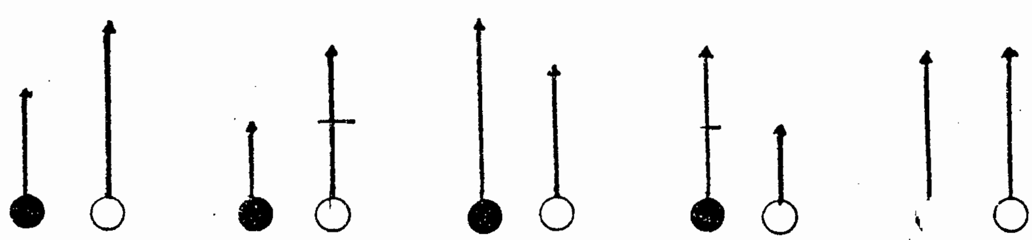
2.



The sketch shows a girl who has two marbles in her hand. The black marble is twice as heavy as the white one. She now throws them vertically upwards.



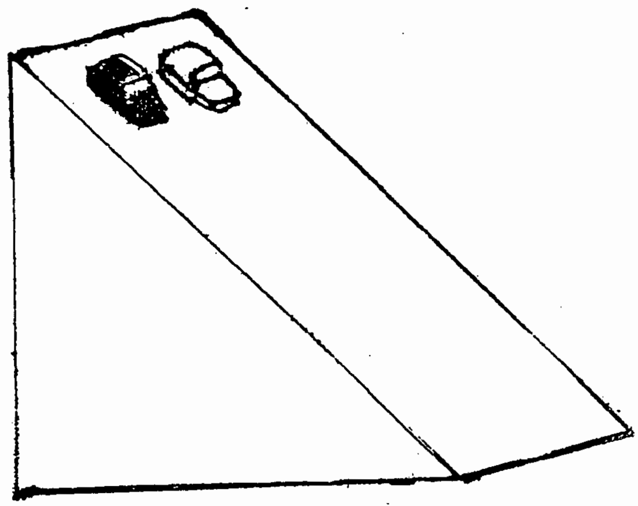
The marbles leave her hand with the same speed. The sketch which best shows the <u>heights</u> reached by the marbles, is :

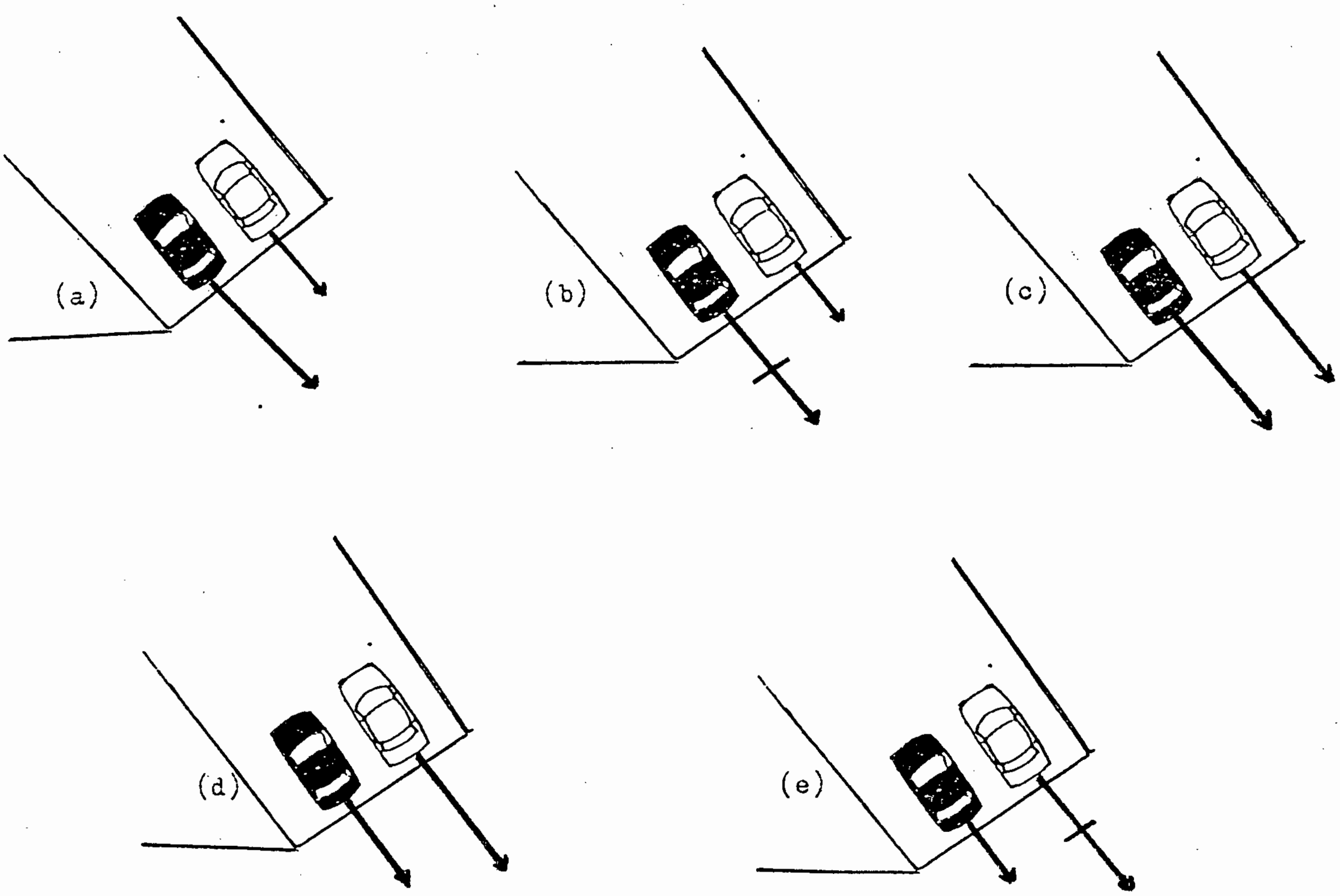


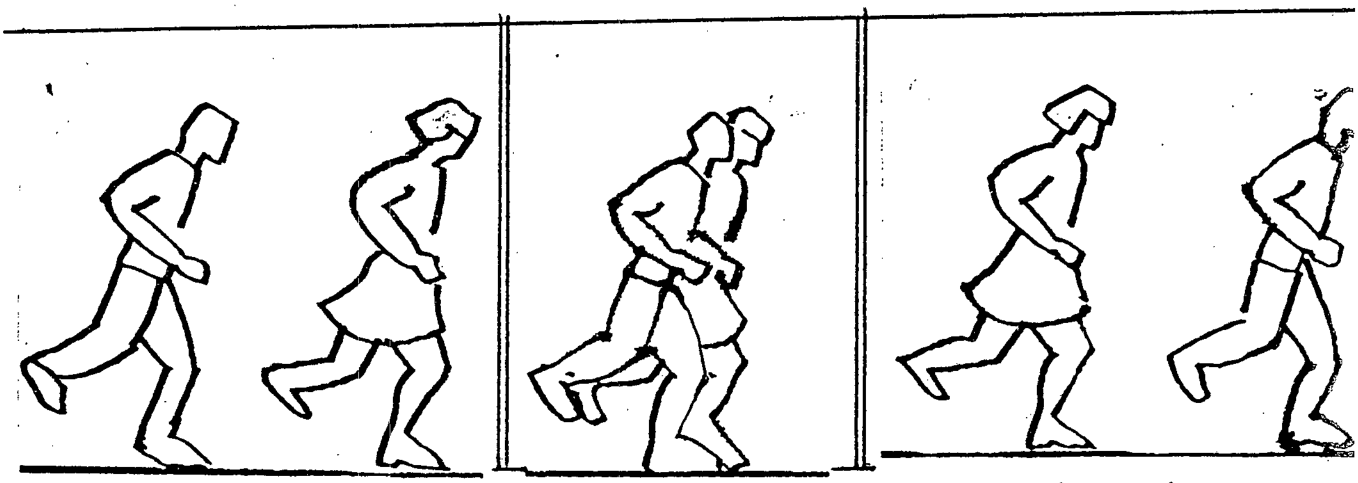
(a) (b) (c) (d) (e)

3.

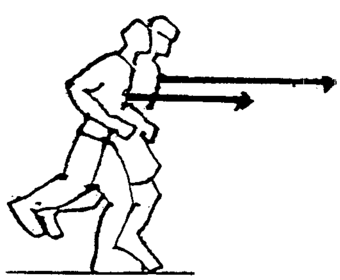
The sketch shows two little cars placed on an incline or ramp by a boy who is racing them against each other. The black car is twice as heavy as the white one. He lets them go from the same point on the incline and at the same time. The sketch which best shows the relative speeds with which the cars reach the bottom of the incline, is :



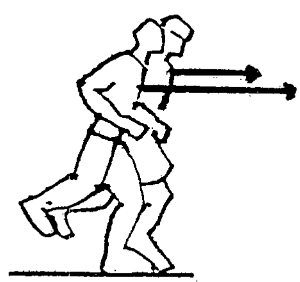


4. 

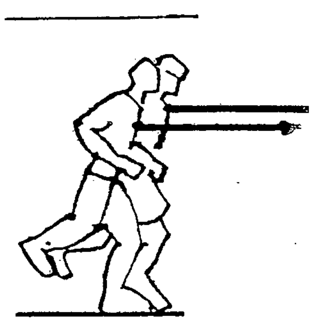
The sketches show a boy running after, catching up with and passing a girl in a race. The sketch which best compares their speeds at the moment the boy is next to the girl, is :



(a)



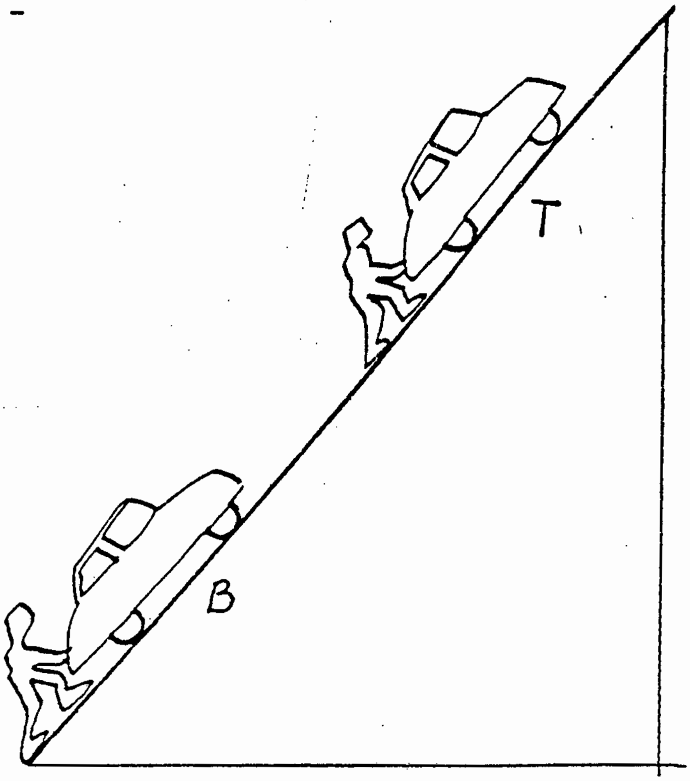
(b)

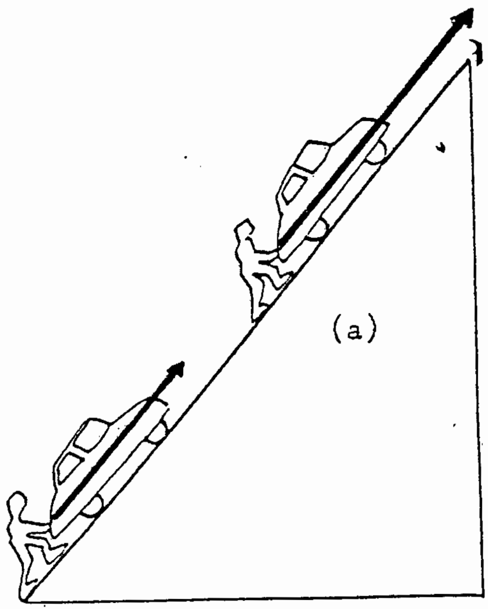


(c)

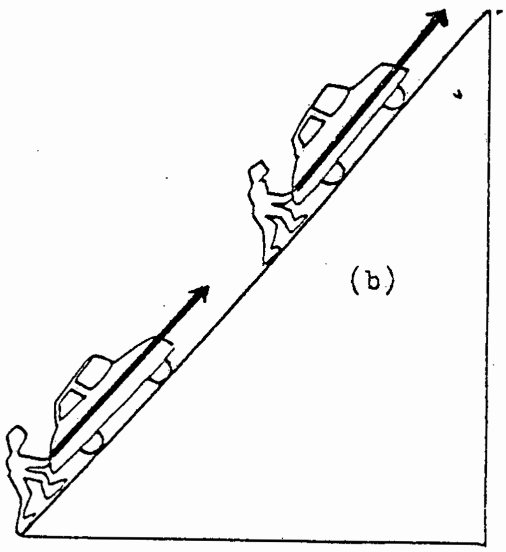
5.

The sketch shows two identical cars being held on a hill by two men. The cars are not moving. The car at T is higher up the hill than the car at B. The sketch which best compares the sizes of the forces which each of the men has to produce to hold his car, is :

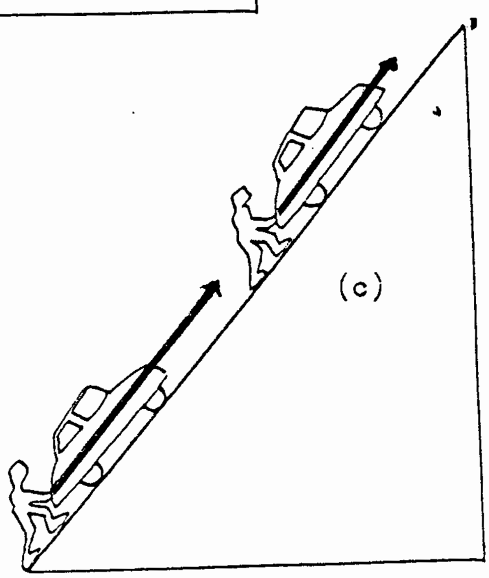




(a)

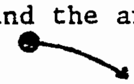


(b)



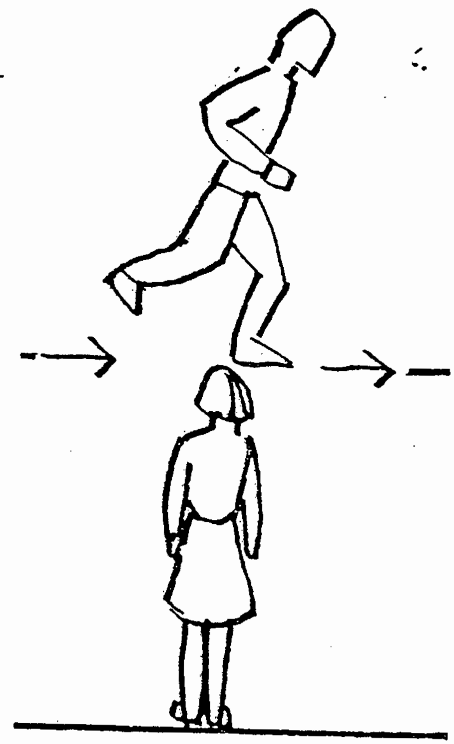
(c)

SECTION C. ; INFORMATION

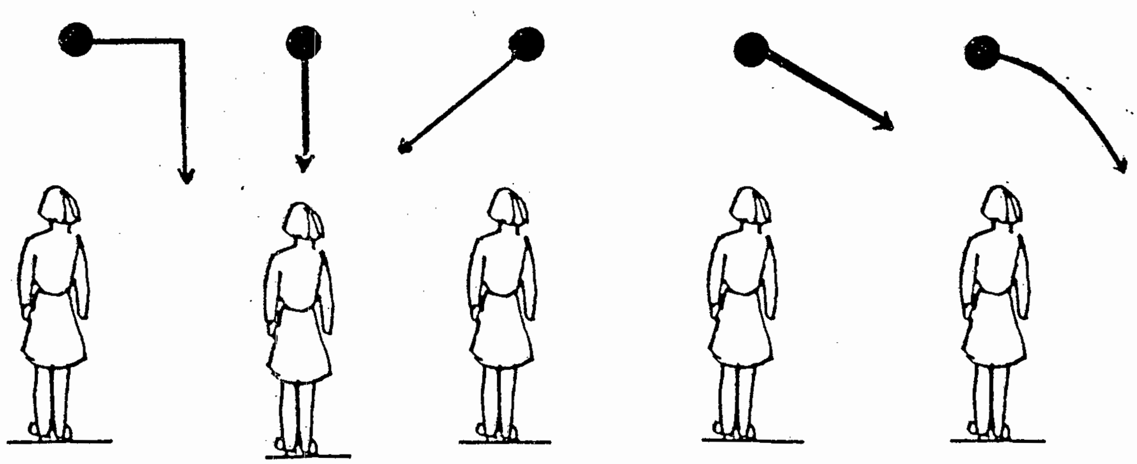
In this section you are asked to select the path along which an object will travel compared to the ground, or as seen by a stationary observer (a boy or girl who is standing still). The shape of the line shows the shape of the path and the arrowhead shows the direction in which the object is travelling, e.g.  This sketch indicates that a ball is travelling in a curve towards the right.

SECTION C : QUESTIONS

1.

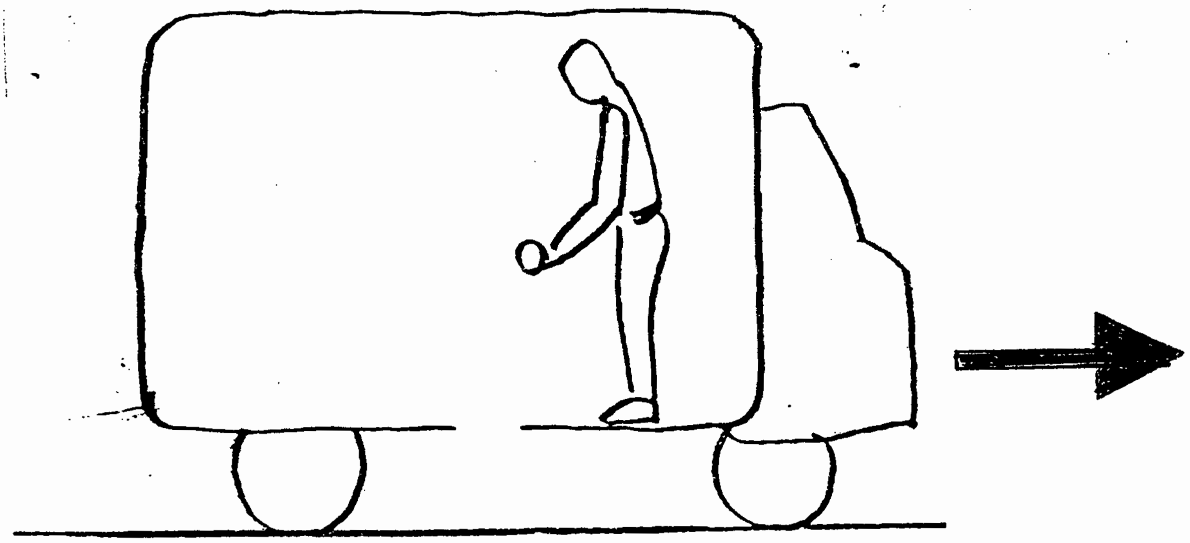


The sketch shows a boy who is running along to the right and a girl is is watching him. Just as he passes her, he drops a ball from his hand. The girl sees the ball fall to the ground. The sketch which best shows the path the girl sees the ball fall along, is :

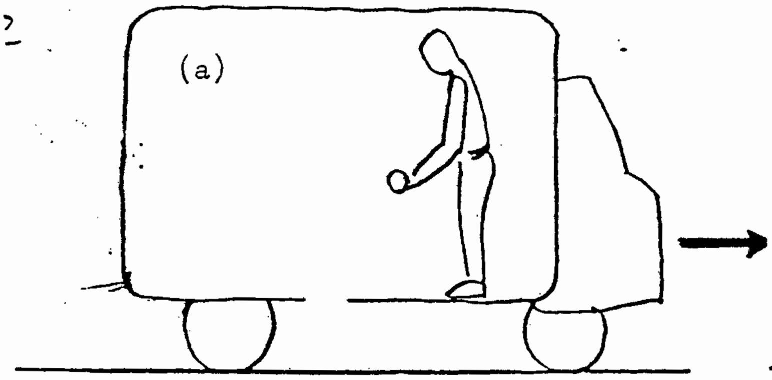


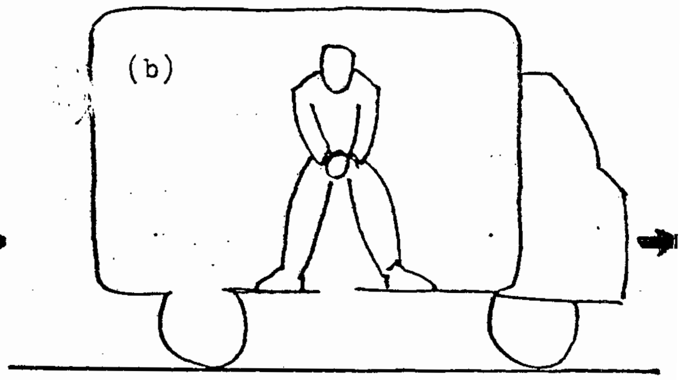
(a) (b) (c) (d) (e)

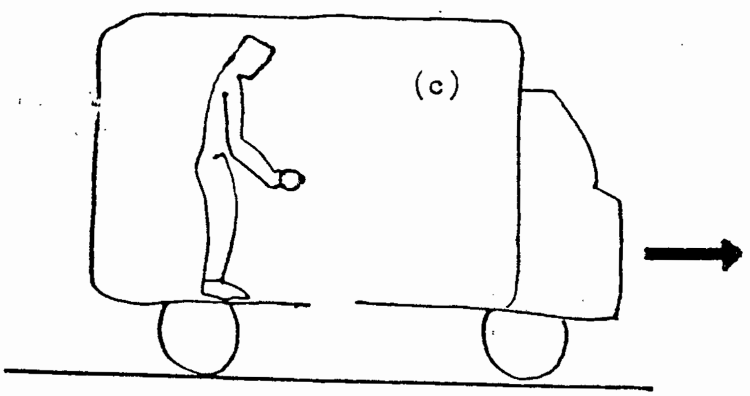
2.



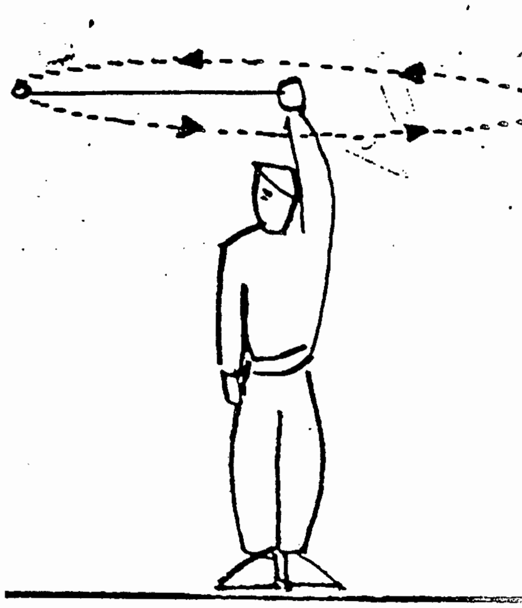
The sketch shows a boy who is standing in the back of an enclosed truck. The truck is moving towards the right at constant speed. There is a hole in the floor of the truck and the boy wants to drop a stone through the hole. The sketch which best shows where he must stand to allow the stone to drop from his hand through the hole, is :



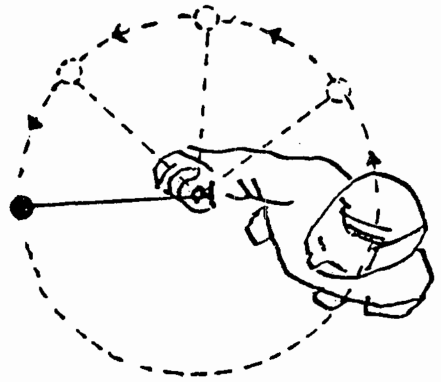




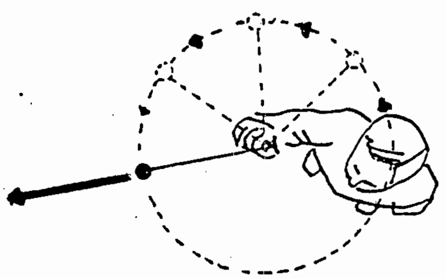
3. The sketch shows a boy who is swinging a ball, which is attached to a string, horizontally around his head.



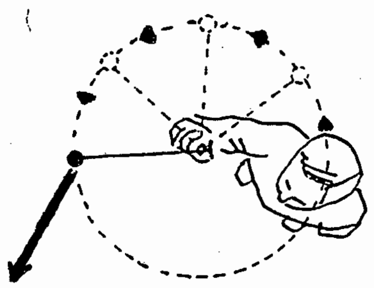
Seen from above it would like this:



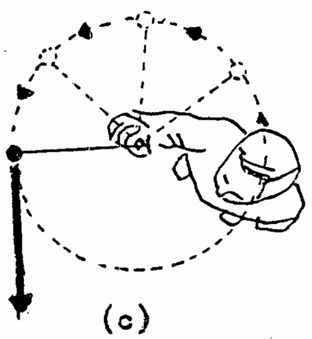
He lets the string go when the ball is at A. The path the ball will travel along after he has released it, is :



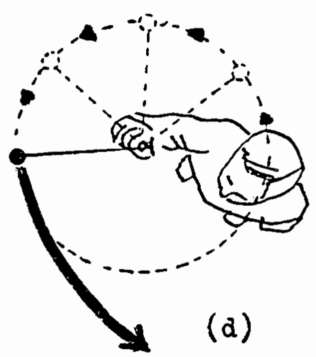
(a)



(b)

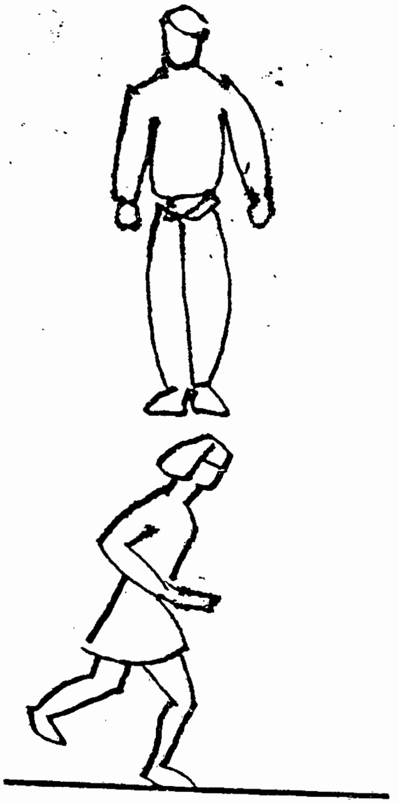


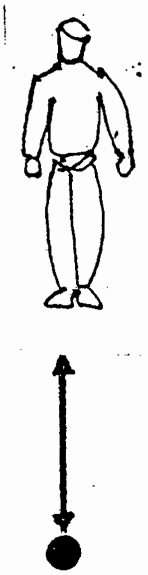
(c)



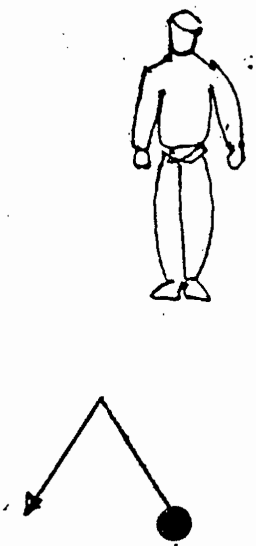
(d)

4. The sketch shows a girl running towards the right past a boy. Just as she passes him, she throws a ball vertically upwards. The sketch best shows the path which the *boy* sees the ball travel along, is:

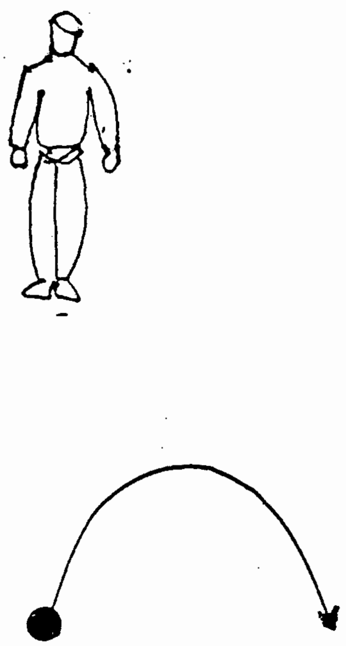




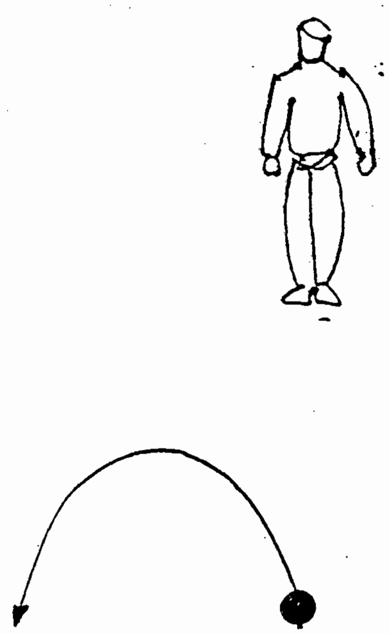
(a)



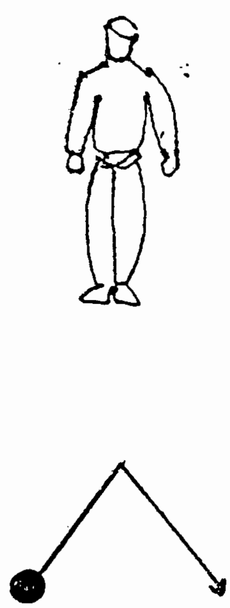
(b)



(c)

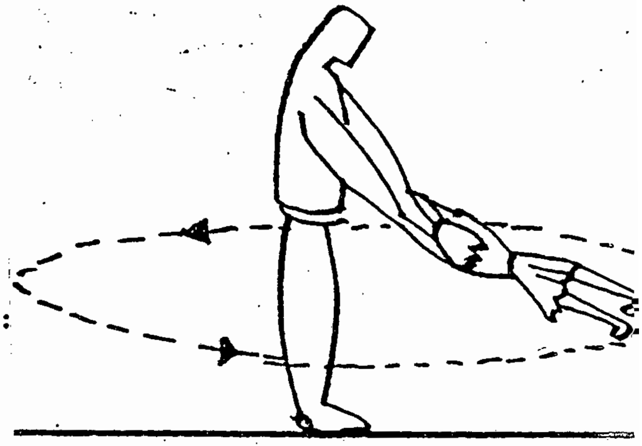


(d)

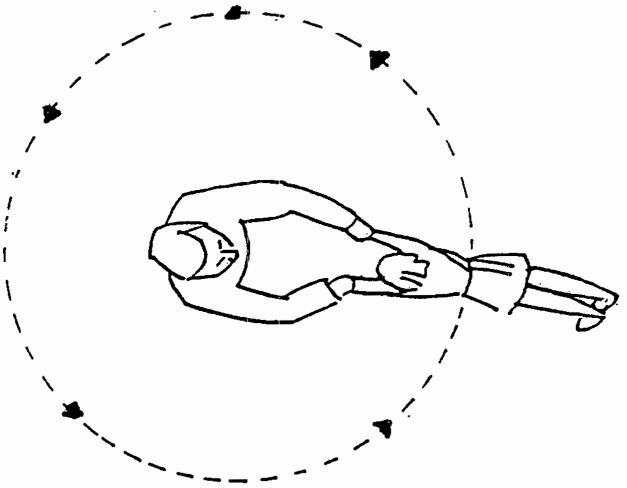


(e)

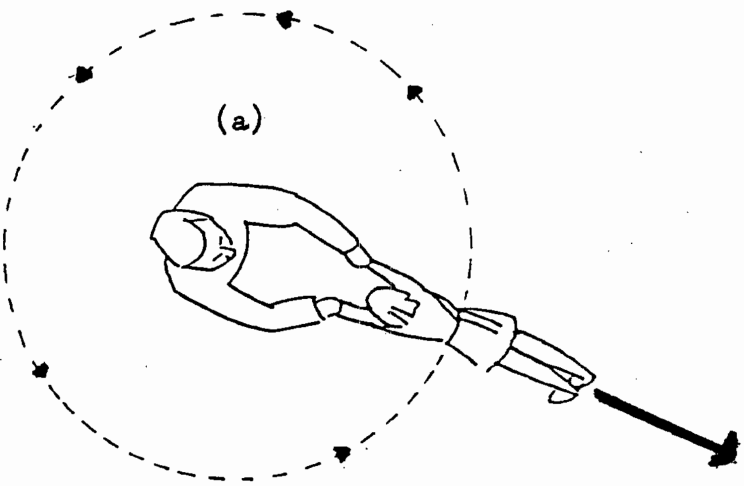
5. The sketch shows a girl who is being playfully swung in a circle by her father.

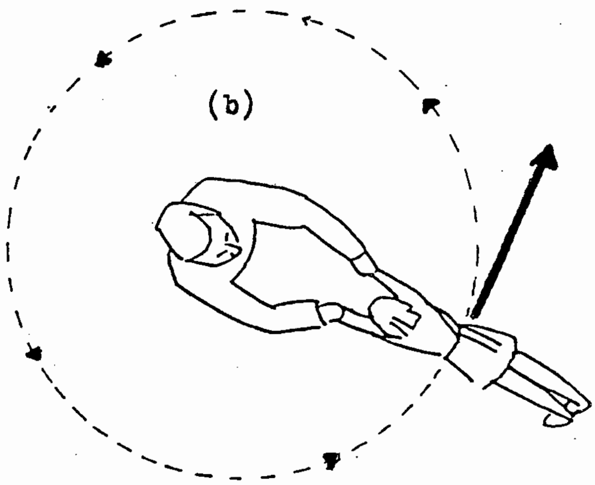


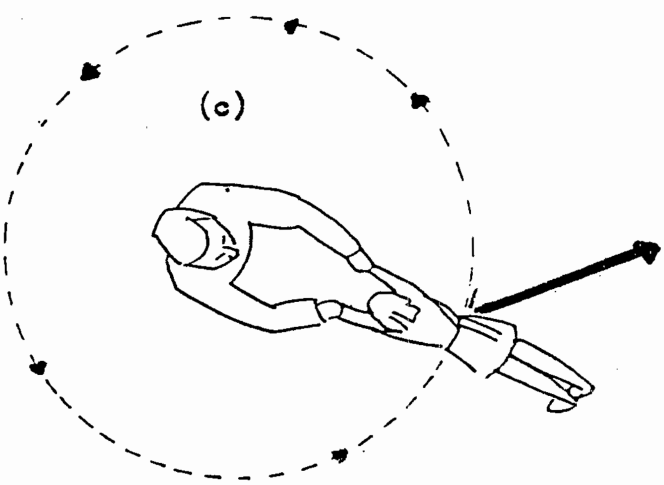
Seen from above it would look like this :

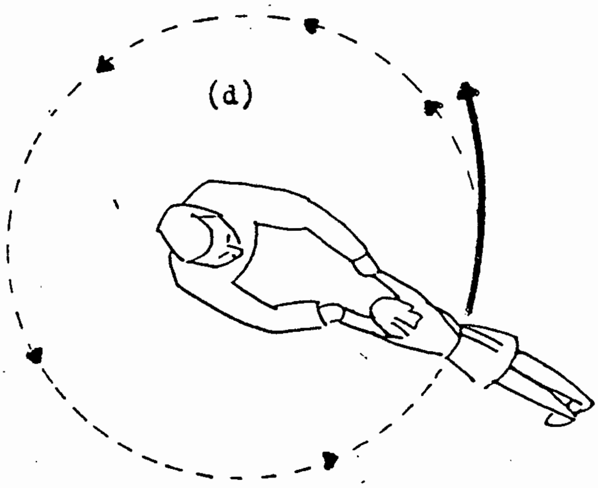


The father releases the girl when she is at A. The path she will travel along after being released, is best shown as :

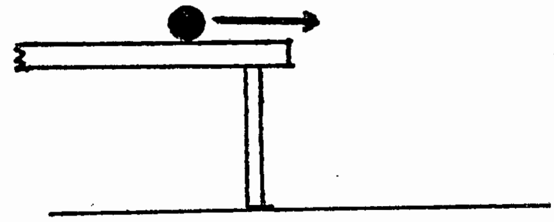


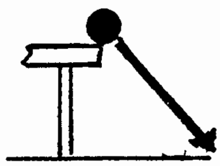




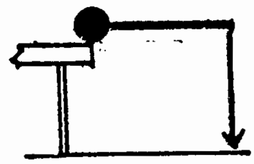


6. The sketch shows a ball rolling rapidly ~~around~~ across a table in the direction as shown. It falls over the edge. The path it will travel along on its way to the ground, is best shown as :

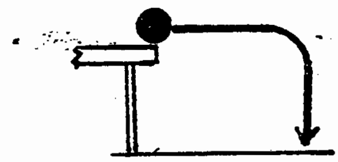




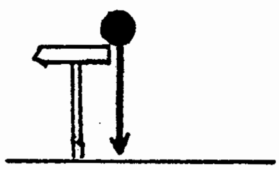
(a)



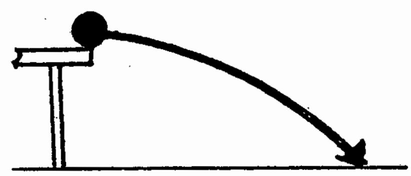
(b)



(c)

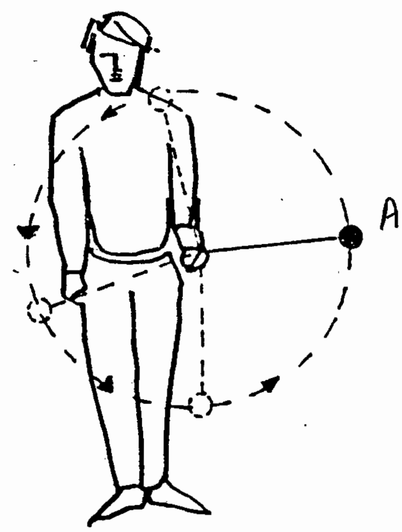


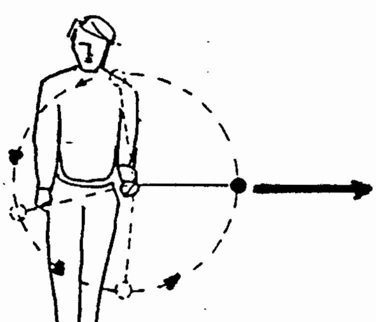
(d)



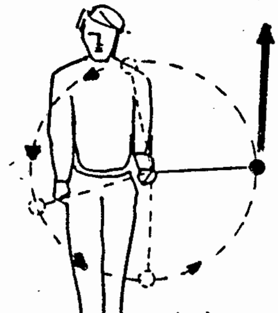
(e)

7. The sketch shows a man who is swinging a ball, which is attached to a string, vertically in front of him. He lets the string go when the ball is at A. The path the ball will travel along after he has released it, is :

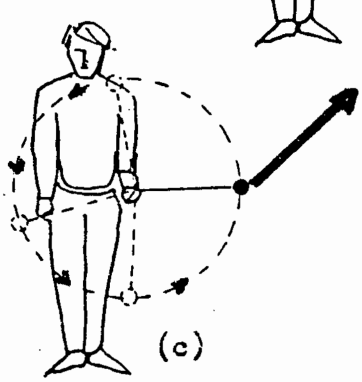




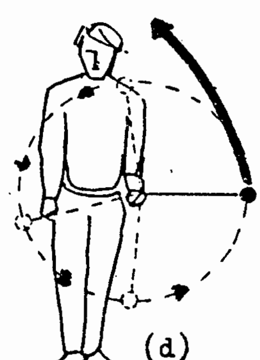
(a)



(b)



(c)

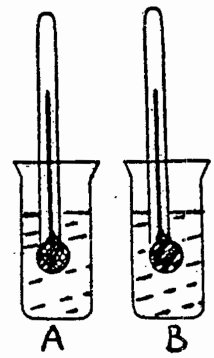


(d)

SECTION D : INFORMATION

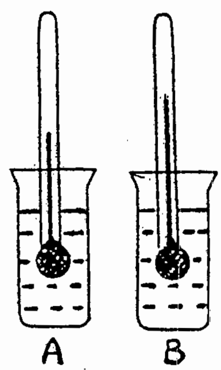
In this section you are asked to compare two temperatures. This you will do by comparing the length of the mercury column in two identical thermometers, e.g.

(i)



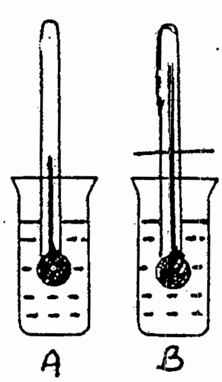
A and B are at the same temperature. They are equally "hot".

(ii)



B is at a higher temperature than A. B is "hotter" than A.

(iii)

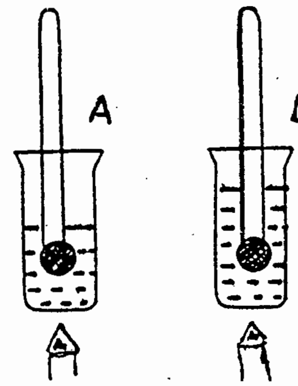


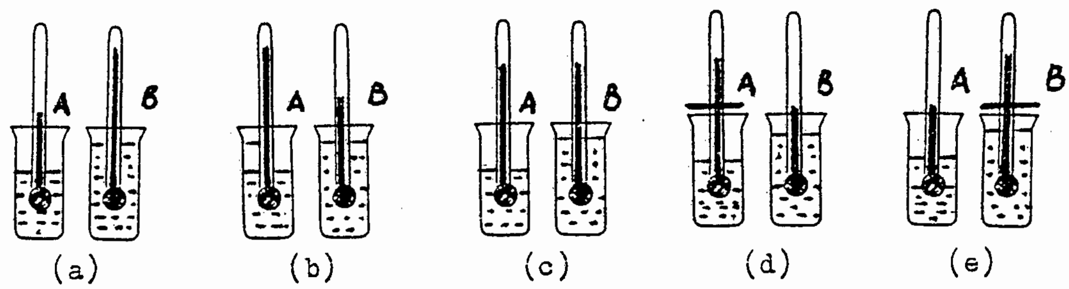
The reading on the thermometer in B is twice as high as that on the thermometer in A.

SECTION D : QUESTIONS

1.

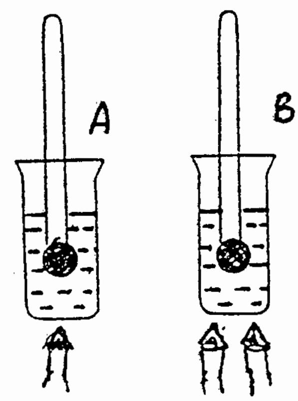
The sketch shows two beakers which contain the same liquid and identical thermometers. Beaker B contains twice as much liquid as Beaker A. The liquids in both beakers are heated by identical flames and both liquids are boiling. The sketch which best compares the readings on the thermometers, is :

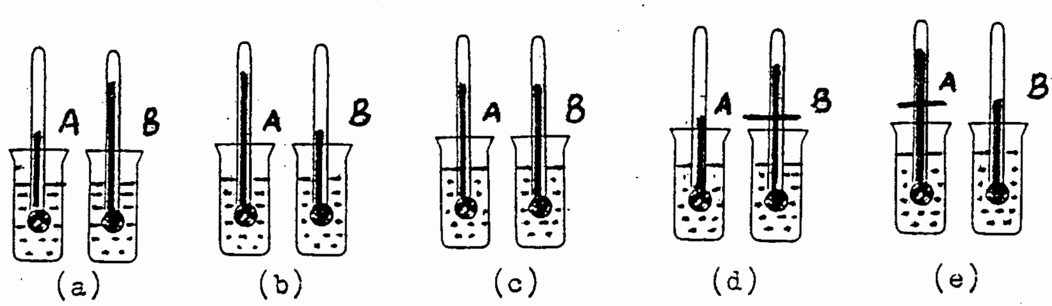




2.

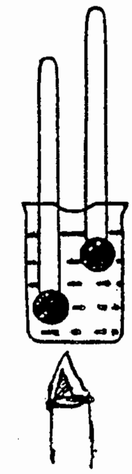
The sketch shows the two beakers containing the same volume of the same liquid as well as identical thermometers. The liquids are being heated with identical flames. Beaker A has one flame only. Both liquids are boiling. The sketch which best compares the readings on the thermometers, is :



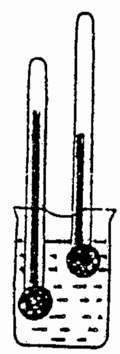


3.

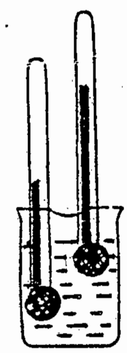
The sketch shows water boiling over a flame. Two identical thermometers are placed in the boiling water as shown. The sketch which best compares the readings on the thermometers, is :



(a)



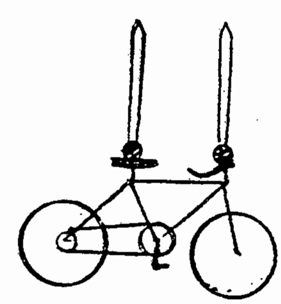
(b)

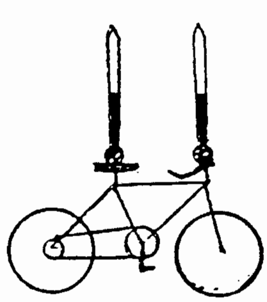


(c)

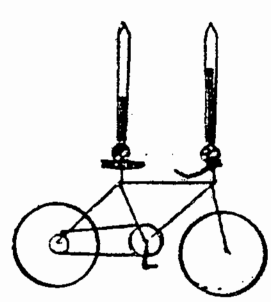
4.

On a cold winter's morning a boy uses a thermometer to compare the temperature of the plastic saddle with the temperature of the metal handlebars of his bicycle. The sketch which best compares the readings on the thermometers, is :

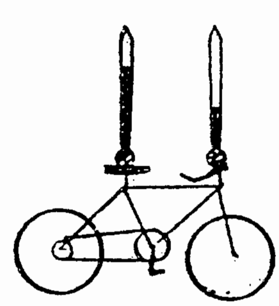




(a)

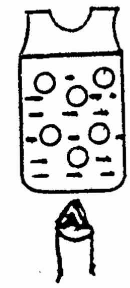


(b)



(c)

5.



The sketch shows water which has been boiling in a beaker for some time. Bubbles of gas are coming to the surface. The bubbles consist of :

(a) Air
(b) Hydrogen and oxygen gases
(c) Water vapour
(d) Air mixed with hydrogen and oxygen gases
(e) Nitrogen and oxygen gas mixed.

I N L I G T I N G

In hierdie vraelys gaan ek u vra om u mening to gee oor 4 verskillende onderwerpe.

In Afdeling A moet u die relatiewe grootte van kragte en die rigting waarin die kragte uitgeoefen word met mekaar .. vergelyk. (Met relatief bedoel ek dat u die grootte van die kragte mekaar moet vergelyk om te kyk watter een die grootste is).

In Afdeling B moet us die relatiewe grootte van dieselfde grootheid in twee verskillended voorwerpe vergelyk, bv. hul spoed.

In Afdeling C moet us die baan waarlangs 'n voorwerp sal beweeg nadat iets daar aan gedoen is, uitkies.

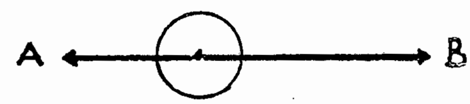
In Afdeling D word u gevra om die temperatuur van kokende vloeistowwe te vergelyk asook een of twee ander dingetjies.

Om die vrae te beantwoord moet u net 'n kruisie in die toepaslike blokkie op u antwoordblad maak. Vul asseblief al die vrae op die antwoord blad in. Dit is belangrik vir my.

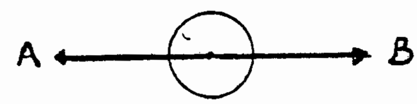
AFDELING A : INLIGTING

In hierdie afdeling word die grootte van 'n krag deur die lengte van 'n pyl aangedui. Die punt van die pyl dui die rigting waarin die krag uitgeoefen word aan, byv.: twee kragte A en B word op voorwerp C uitgeoefen. Dit mag soos volg voorgestel word :

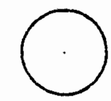
(i) In hierdie geval is krag A kleiner as krag B en word die kragte in teenoorgestelde rigtings uitgeoefen.



(ii) Hier is kragte A en B ewe groot maar hulle word in teenoorgestelde rigtings uitgeoefen.

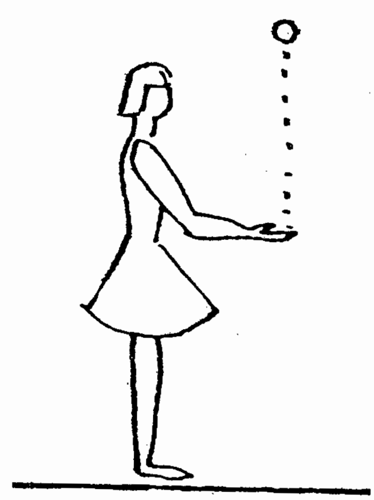


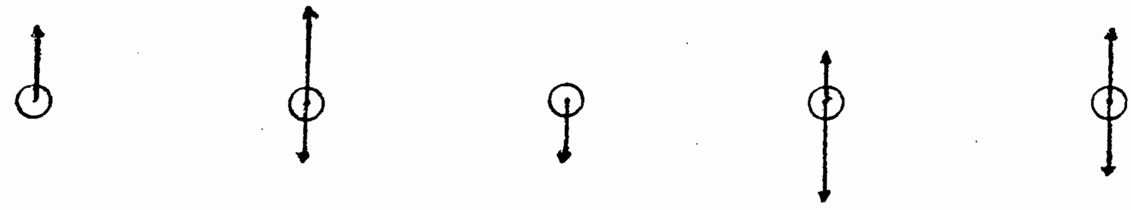
(iii) Hier word daar geen kragte op C uitgeoefen nie.



AFDELING A : VRAE

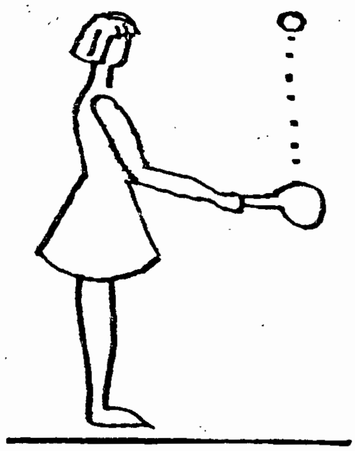
1. In die skets gooi 'n dogter 'n bal vertikaal opwaarts. Die skets wat die kragte wat op die bal uitgeoefen word *onmiddellik* nadat dit die dogter se hand verlaat het, die beste aandui, is :

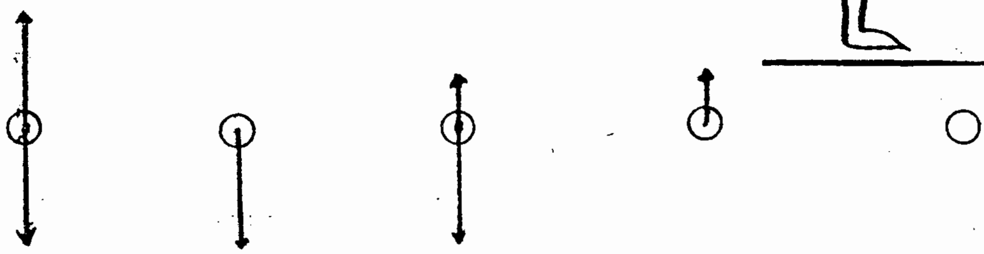




(a) (b) (c) (d) (e)

2. In die skets gebruik die dogter 'n raket om 'n bal vertikaal opwaarts te slaan. Die skets wat die kragte wat op die bal uitgeoefen word wanneer die bal sy hoogste punt bereik het en net voordat dit begin terugval grond toe, die beste aandui, is :

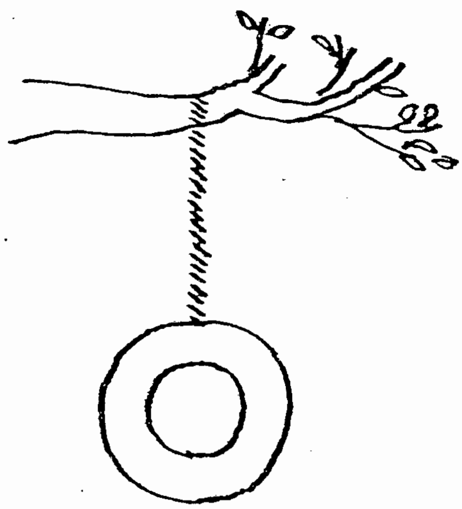


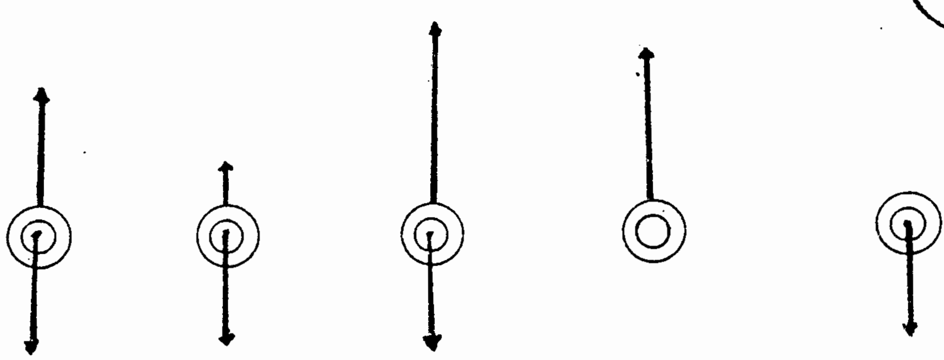


(a) (b) (c) (d) (e)

3.

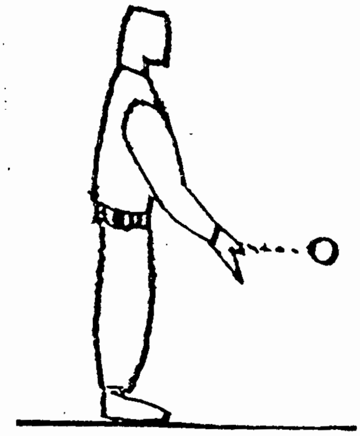
Die skets toon 'n buiteband wat aan 'n tou hang wat aan 'n tak vasgemaak is. Die skets wat die kragte wat op die buiteband uitgeoefen word aandui en hulle grootte die beste vergelyk, is :

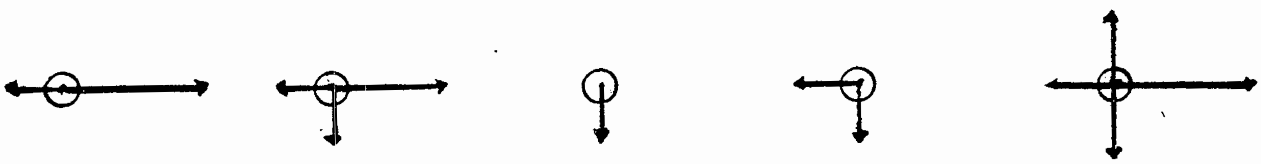




(a) (b) (c) (d) (e)

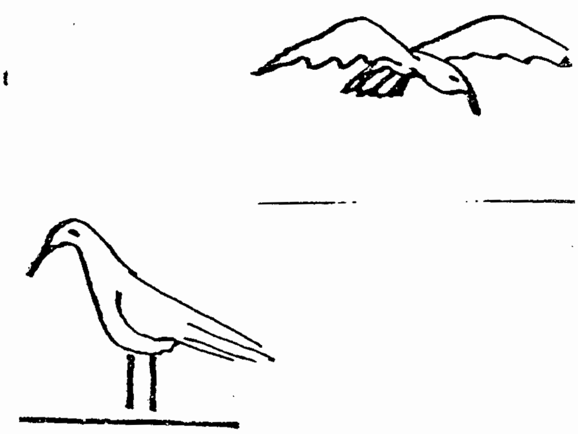
4. In die skets gooi 'n seun 'n bal horisontaal weg van hom af. Die skets wat die kragte (dit sluit wrywing of weerstand in) wat op die bal uitgeoefen word onmiddellik nadat dit die seun se hand verlaat het, die beste aandui, is :

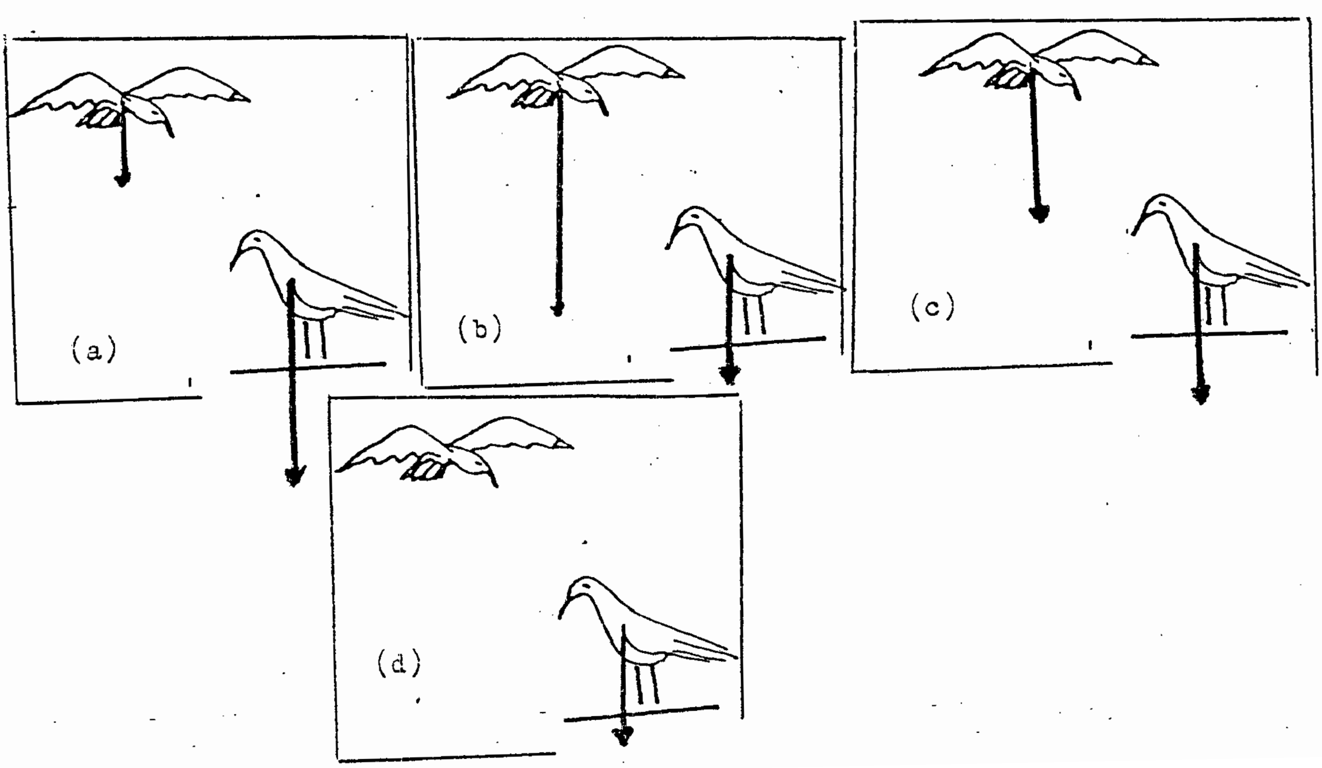




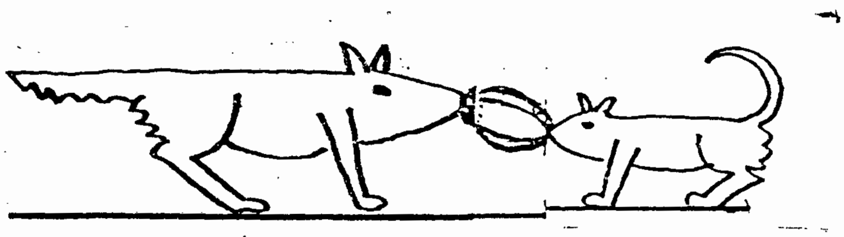
(a) (b) (c) (d) (e)

5. Die skets dui 'n voël aan wat op die grond sit en dieselfde voël wat 100 meter hoog in die lug sweef. Die paar sketse wat die grootte van die aantrekkingskrag wat die aarde op die voël uitoefen terwyl dit op die grond sit en weer wanneer dit sweef, die beste vergelyk, is :

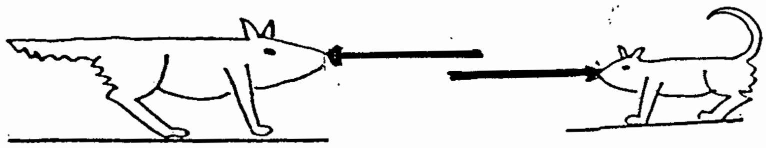


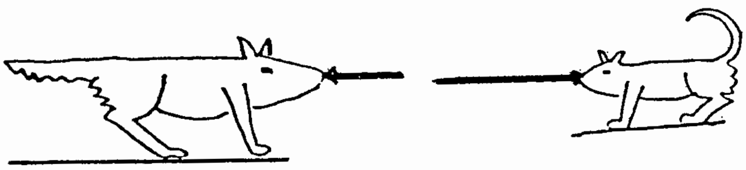


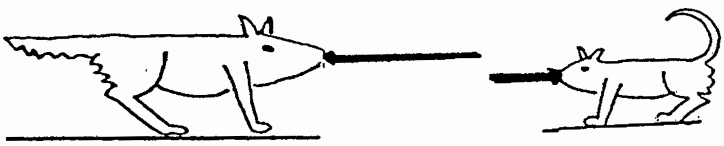
6.



In die skets trek twee honde teen mekaar aan die teenoorgestelde kante van 'n sak. Die honde beweeg nie. Die skets wat die best aandui hoe hard elk een van die honde trek, is :

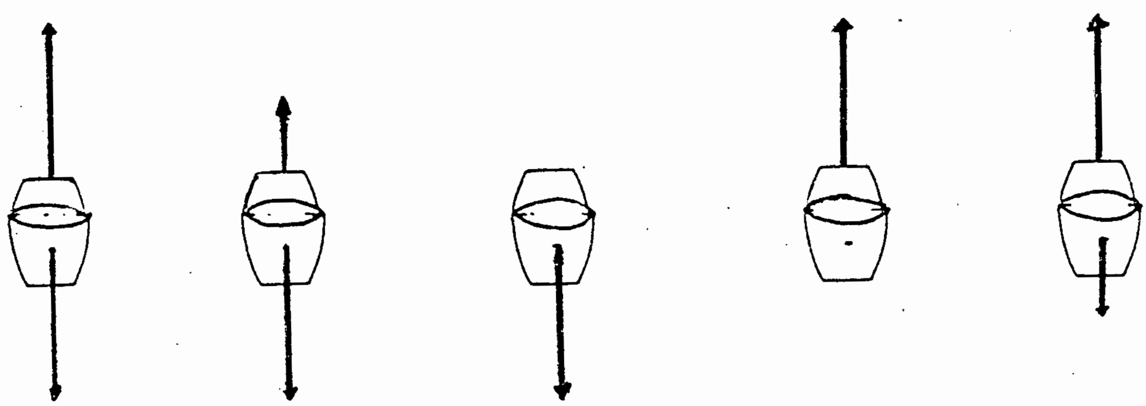
(a) 

(b) 

(c) 

7.

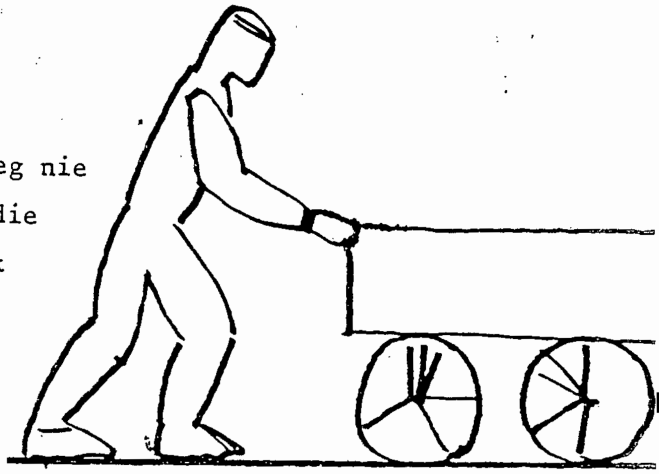
In die skets hou 'n man 'n emmer water in sy hand. Die skets wat die kragte wat op die emmer uitgeoefen word en hulle onderskeie groottes die beste aandui, is :



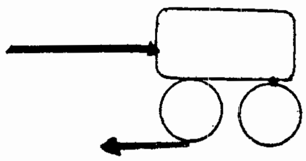
(a) (b) (c) (d) (e)

8.

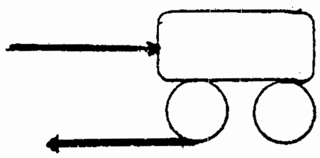
In die skets stoot 'n seun 'n wa. Die wa beweeg nie omdat dit in the sand vassit. Die skets wat die krag waarmee die seun stoot die beste vergelyk met die wrywing of weerstand, is :



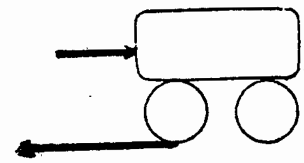
(a)



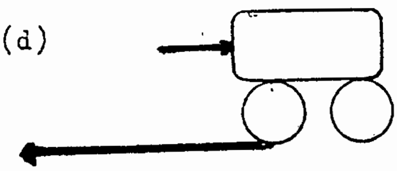
(b)



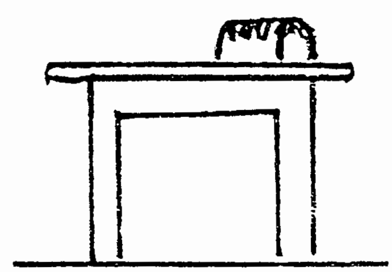
(c)

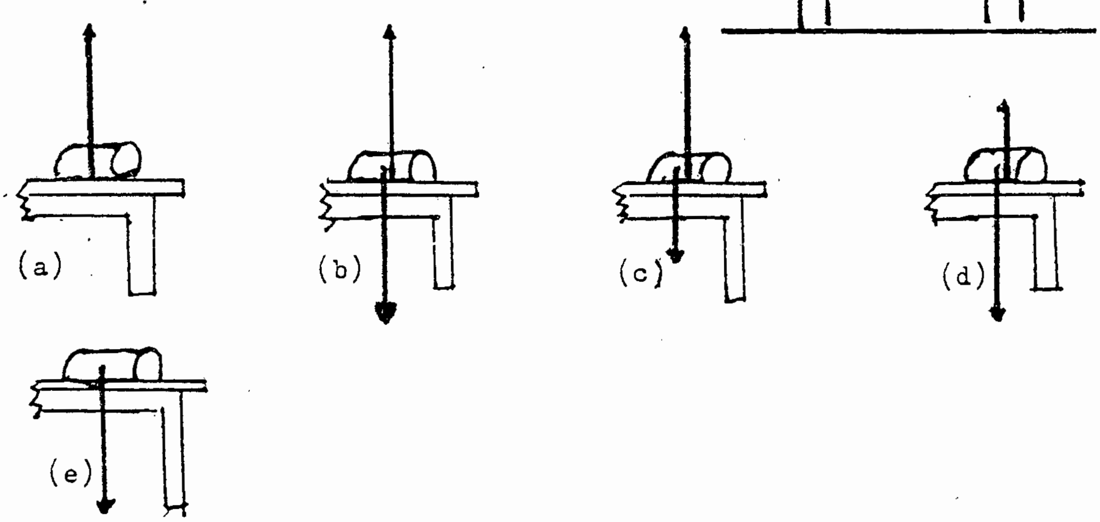


(d)



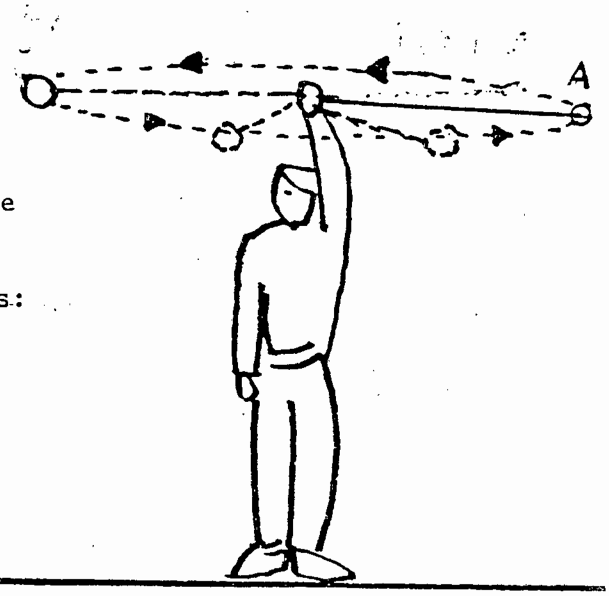
9. In die skets lê 'n brood op 'n tafel. Die skets wat die kragte wat op die brood uitgeoefen word en ook hul groottes die beste aandui, is :

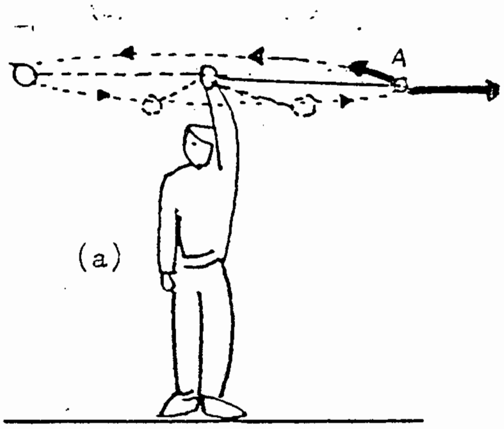




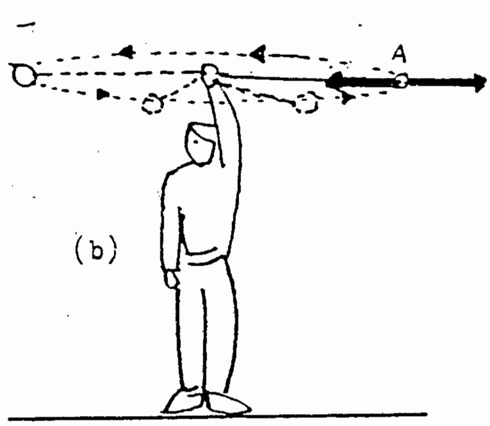
(a) (b) (c) (d) (e)

0. In die skets swaai 'n seun 'n bal wat aan 'n tou vasgemaak is in 'n horisontale sirkel om sy kop in die rigting soos aangedui. Die krag of kragte wat op die bal uitgeoefen word by A as gevolg van sy beweging (nie swaartekrag of wrywing nie), is:

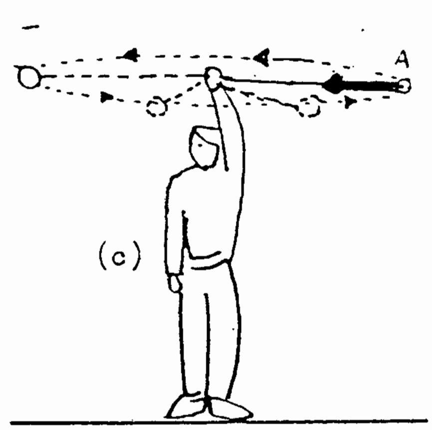




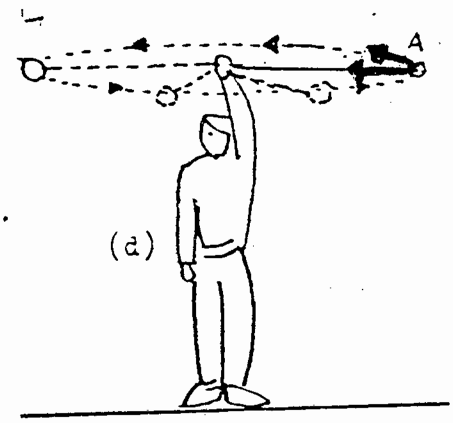
(a)



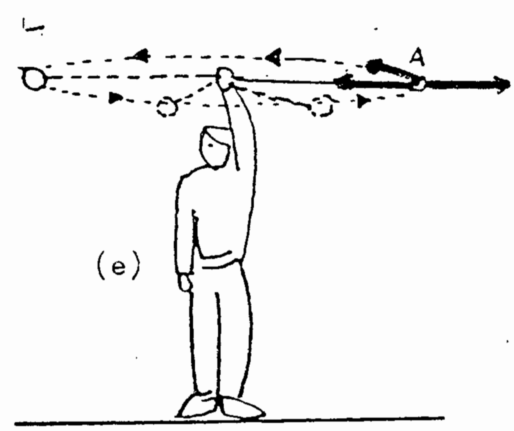
(b)



(c)

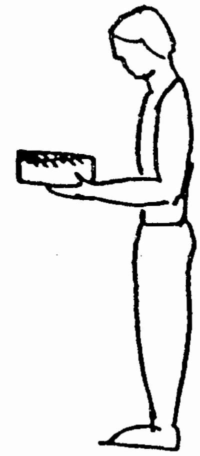


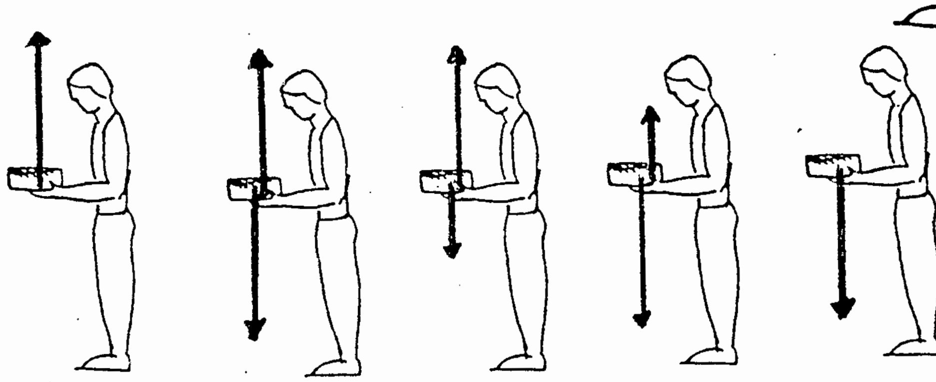
(d)



(e)

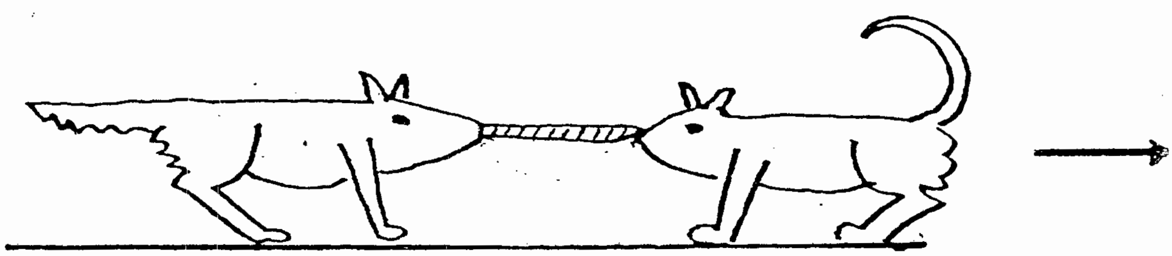
11. In die skets hou 'n man 'n baksteen in sy hand. Die skets wat die kragte wat op die baksteen uitgeoefen word en ook hul groottes die beste aandui, is :



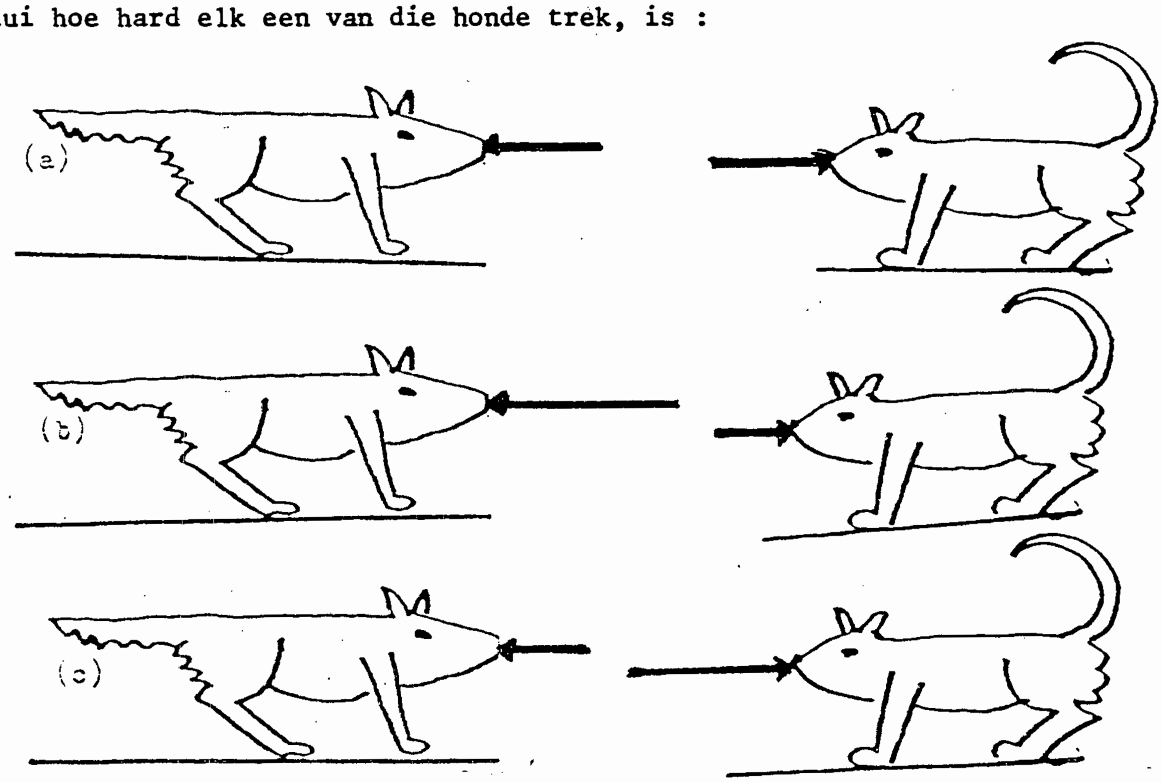


(a) (b) (c) (d) (e)

12.



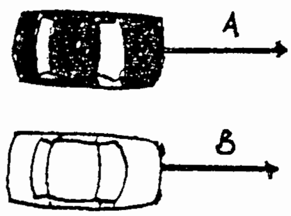
In die skets trek twee honde teen mekaar aan die teenoorgestelde kante van 'n tou. Die honde beweeg stadig na regs. Die skets wat die beste aandui hoe hard elk een van die honde trek, is :



AFDELING B. : INLIGTING

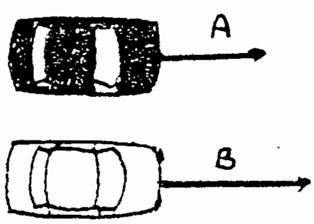
In hierdie afdeling moet u die relatiewe grootte van dieselfde grootheid bv. spoed, afstand afgelê ens. vir twee verskillende voorwerpe met mekaar vergelyk. Hier word weer eens pyle gebruik, maar nou dui die lengte van die lyn die relatiewe grootte van die grootheid wat ons vergelyk aan. Byvoorbeeld, as ons die spoed waarteen twee motors beweeg vergelyk, dan sal die volgende sketse aandui dat :

(i)



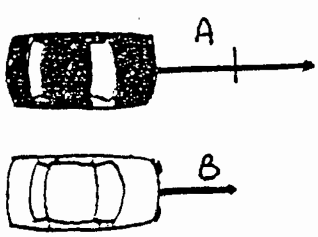
A en B dieselfde spoed het.

(ii)



B vinniger as A is.

(iii)

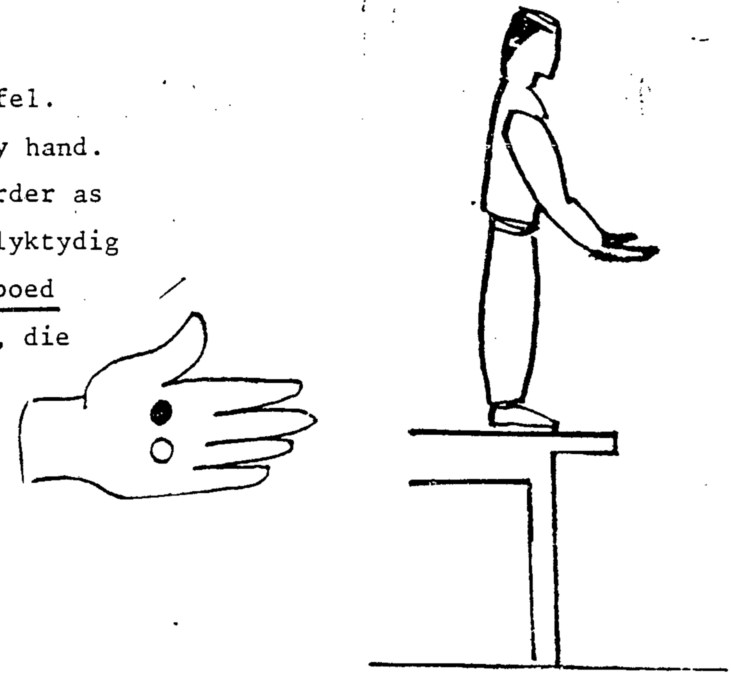


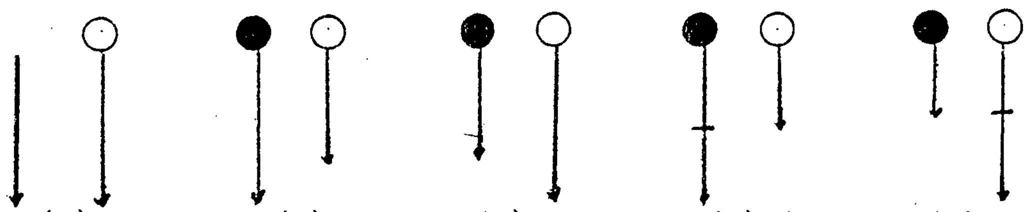
A tweemaal vinniger as B is.

AFDELING B: VRAE.

1.

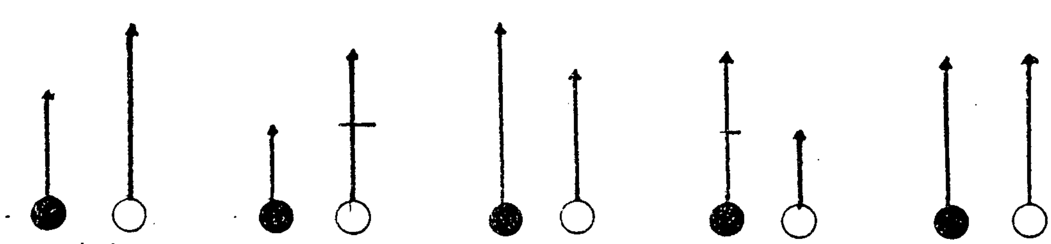
In die skets staan 'n seun bo-op 'n tafel. Hy het twee ewe groot albasters in sy hand. Die swart albaster is twee maal swaarder as die wit albaster. Hy laat hulle gelyktydig val. Die skets wat die relatiewe spoed waarmee die albasters die grond tref, die beste aandui, is :





(a) (b) (c) (d) (e)

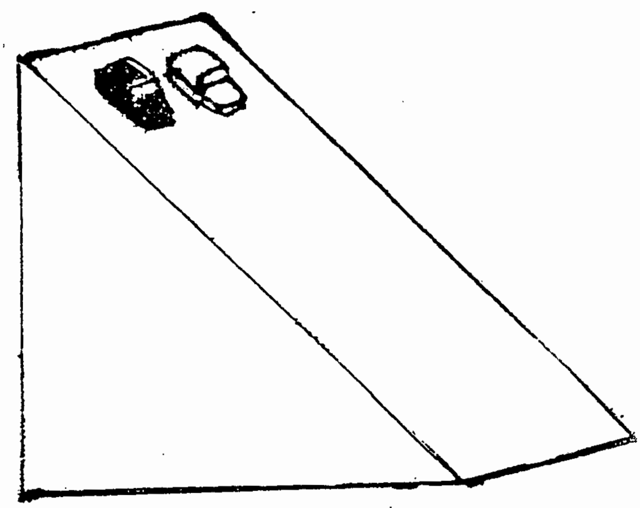
2. Die dogter in die skets het twee ewe groot albasters in haar hand. Die swart albaster is twee maal swaarder as die wit een. Sy gooi hulle vertikaal opwaarts. Die albasters verlaat haar hand met dieselfde spoed. Die skets wat maksimum hoogte wat die albasters bereik die beste aandui, is :

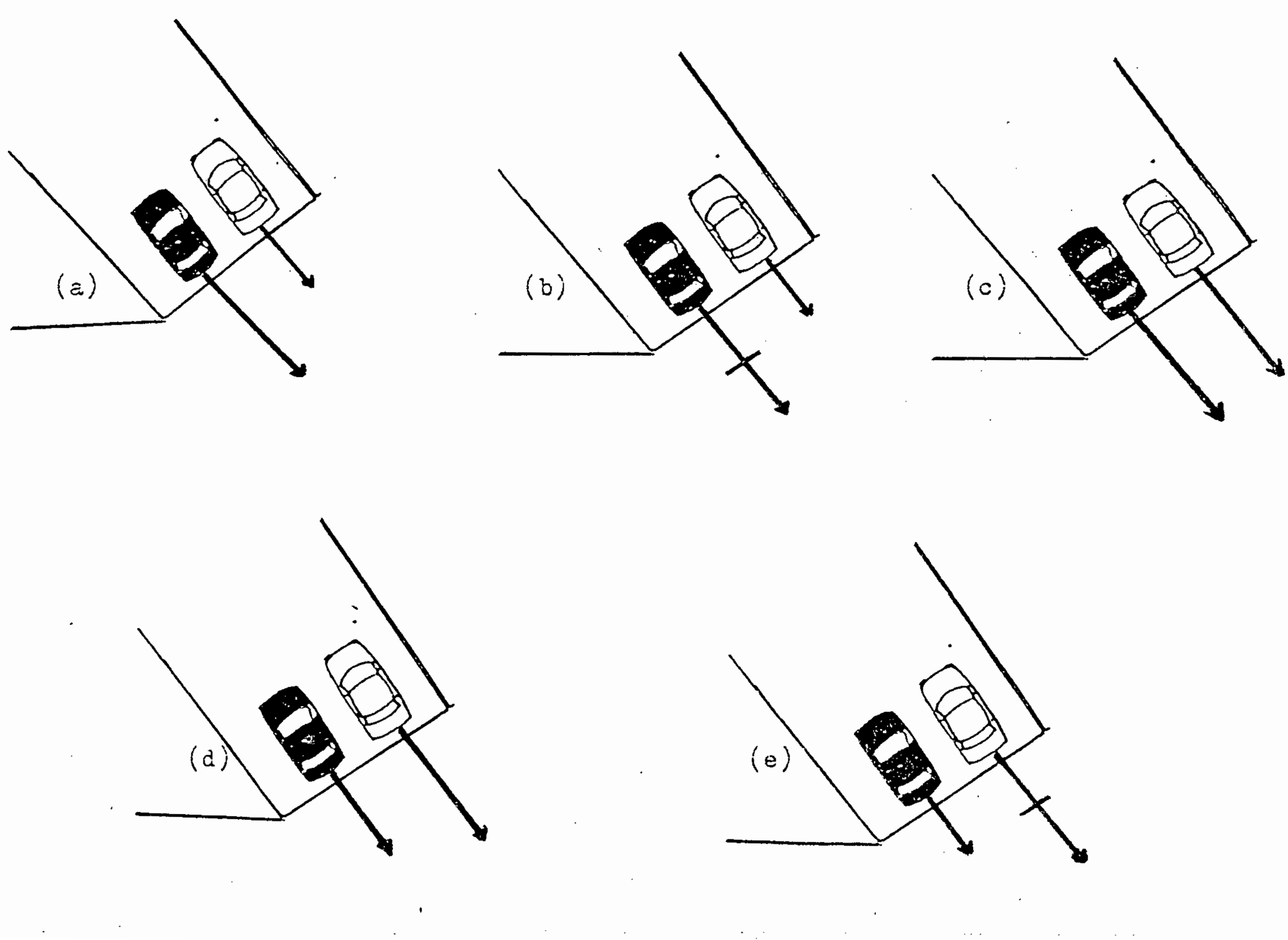


(a) (b) (c) (d) (e)

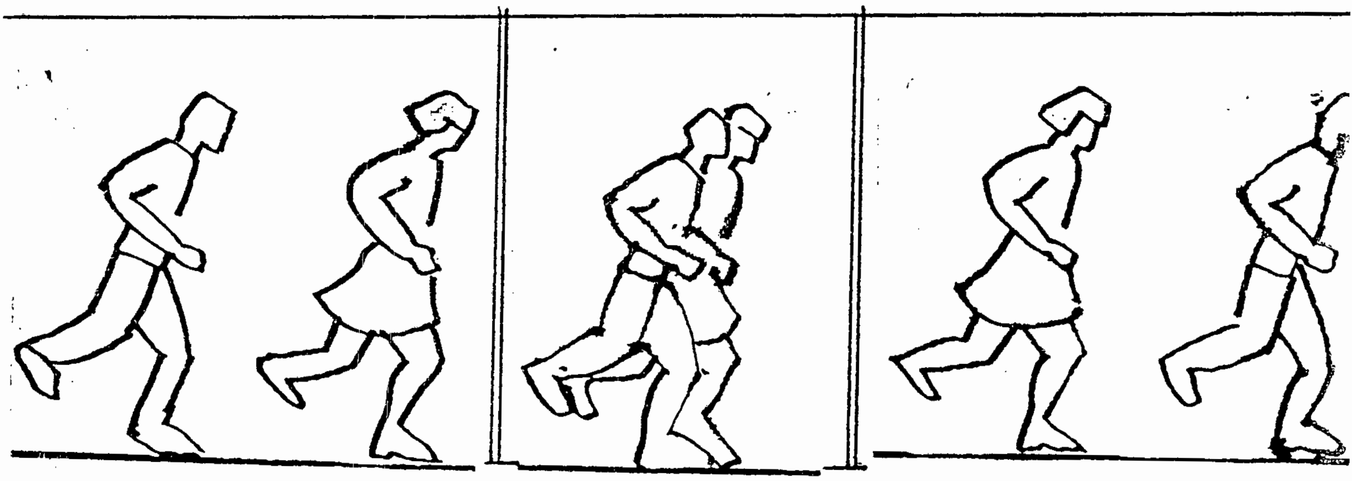
3.

In die skets word twee ewe groot motortjies deur 'n seun teen 'n helling geplaas om resies teen mekaar te jaag. Die swart motortjie is twee maal swaarder as die wit enetjie. Hy laat hulle op dieselfde oomblik vanaf dieselfde punt teen die helling los. Die skets wat die relatiewe spoed waarmee die motortjies die onderkant van die helling bereik, die beste aandui, is :

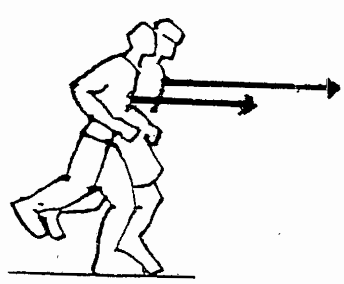




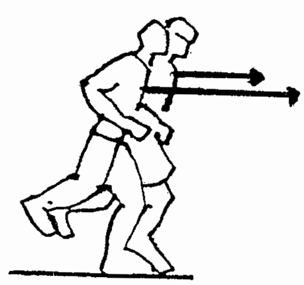
4.



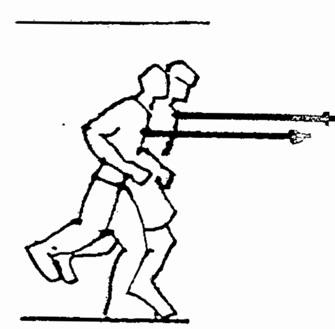
In die sketse hardloop 'n seun agter 'n dogter aan, haal haar in en hardloop by haar verby gedurende 'n wedloop. Die skets wat hulle spoed die beste weergee op die oomblik wanneer die seun langs die dogter is, is :



(a)



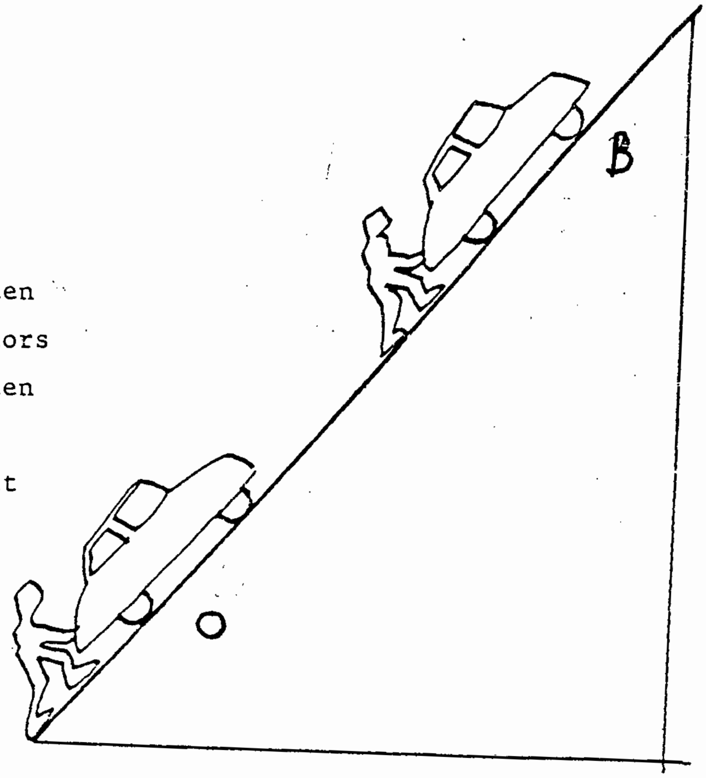
(b)

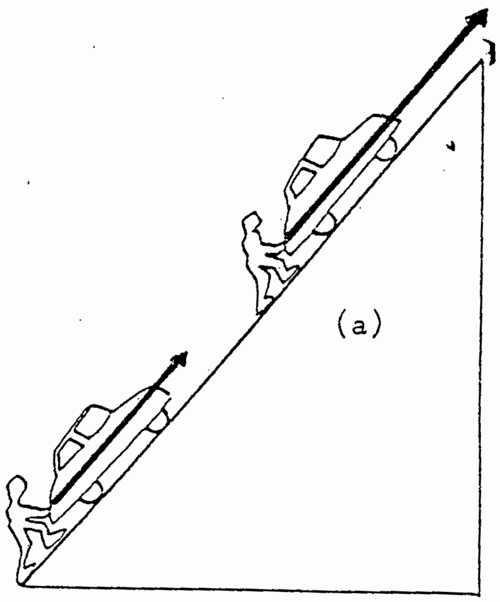


(c)

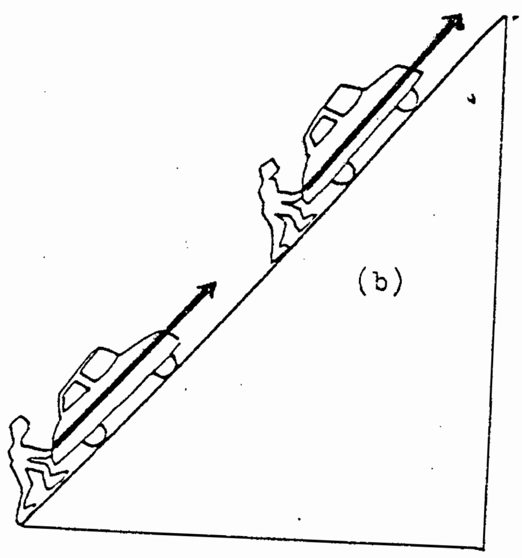
5.

In die skets word twee identiese motors teen 'n heuwel vasgehou deur twee mans. Die motors beweeg nie. Die motor by B is hoër op teen die heuwel as die motor by O. Die skets wat die kragte wat elkeen van die mans moet uitoefen om die motor vas te hou die beste aandui, is :

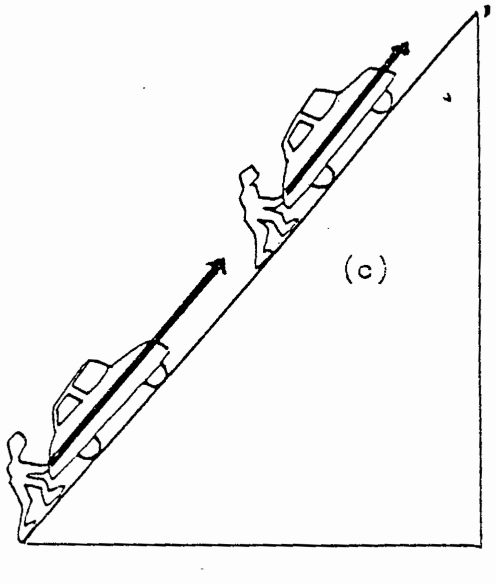




(a)



(b)



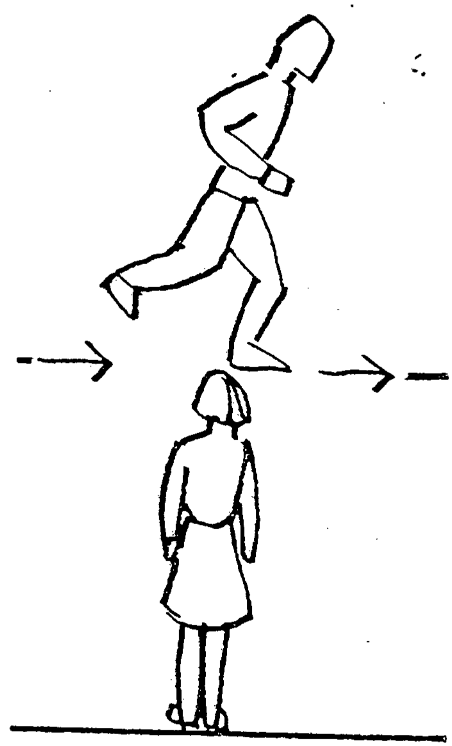
(c)

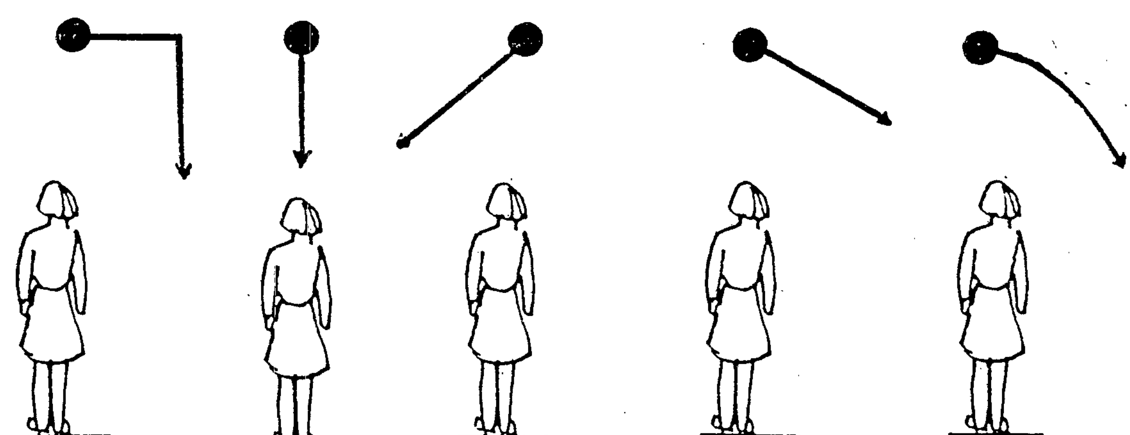
AFDELING C : INLIGTING

In hierdie afdeling word u gevra om die baan waarlangs 'n voorwerp met betrekking tot die grond of 'n stilstaande waarnemer ('n seun of dogter wat stil staan) sal beweeg te kies. Die vorm van die lyn dui die vorm van die baan aan en die pyl die rigting waarin die voorwerp beweeg, bv.  Die skets dui aan dat die bal in 'n kurwe na regs beweeg.

AFDELING C : VRAE

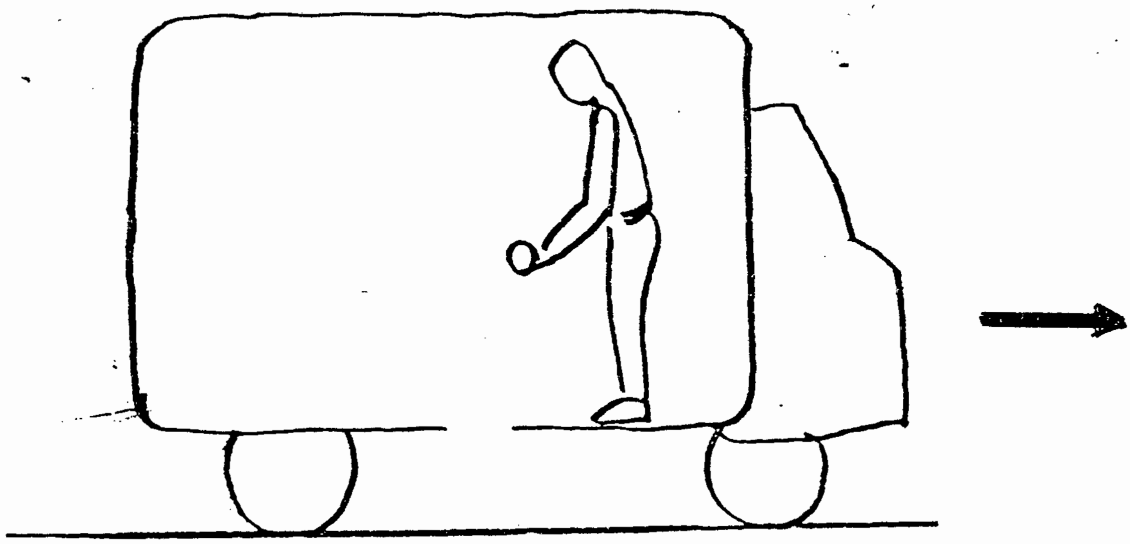
1. In die skets hardloop 'n seun na regs terwyl 'n dogter hom dophou. Op die oomblik wanneer hy langs haar is, laat hy 'n bal uit sy hand val. Die dogter sien hoedat die bal grond toe val. Die skets wat die baan waarlangs die dogter die bal sien val, die beste aandui, is :



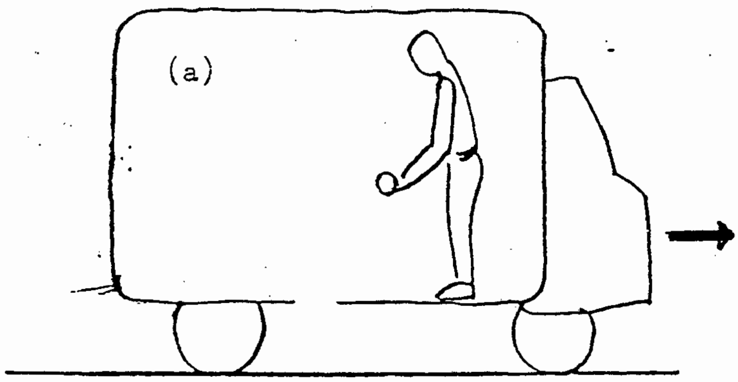


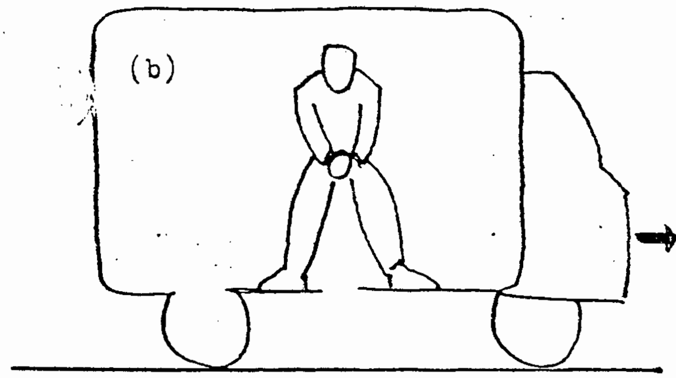
(a) (b) (c) (d) (e)

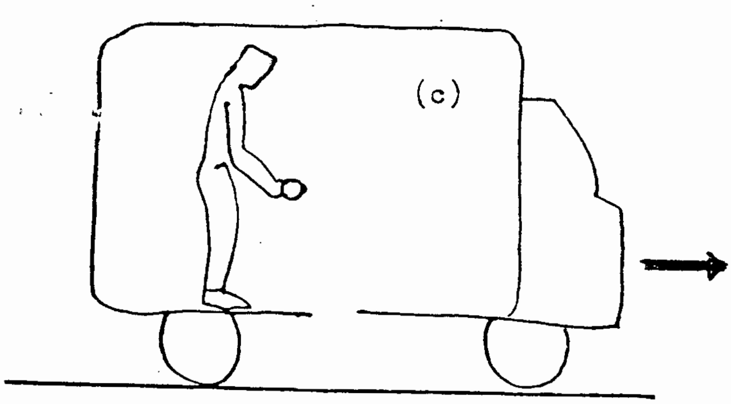
2.

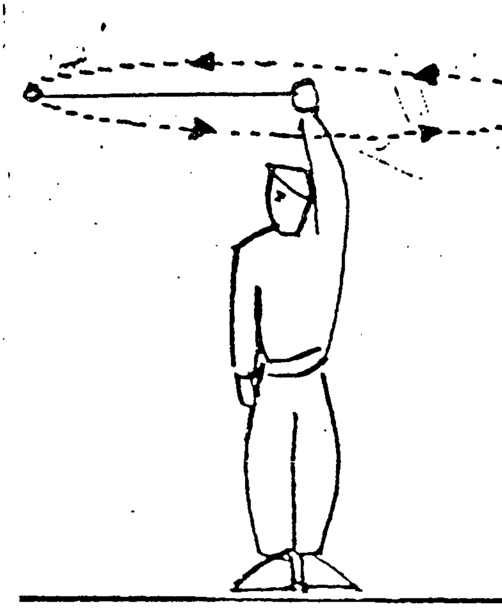


In die skets staan 'n seun binne in die vragruim van 'n toe vragmotor. Die vragmotor beweeg na regs teen 'n konstante spoed. Daar is 'n gat in die vloer van die bak en die seun wil 'n klip deur die gat laat val. Die skets wat aandui waar die seun moet staan om die klip uit sy hand deur die gat te laat val, is :



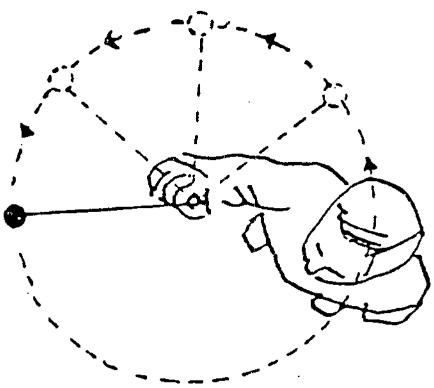




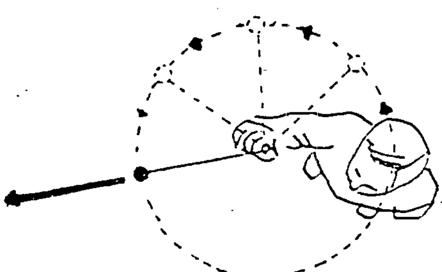


3. In die skets swaai 'n seun 'n bal, wat aan 'n tou vasgemaak is, om sy kop in 'n horisontale sirkel in die rigting soos aangedui.

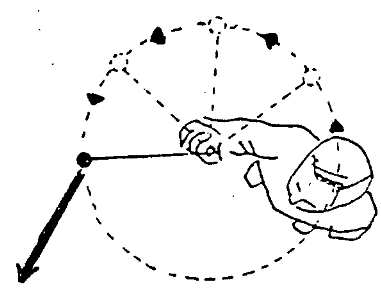
Van bo-af gesien sal dit so lyk :



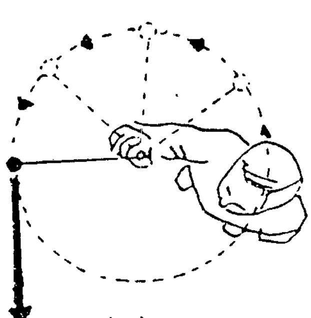
Hy los die tou wanneer die bal by A is. Die baan waarlangs die bal sal beweeg nadat hy dit laat los het, is :



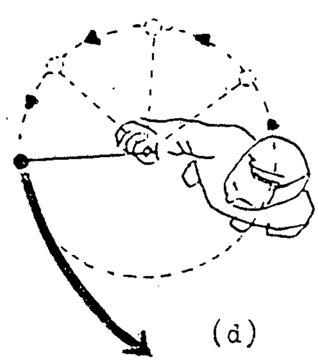
(a)



(b)

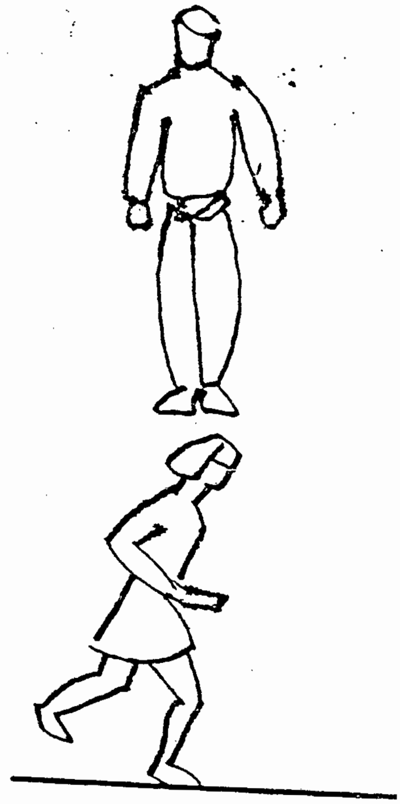


(c)

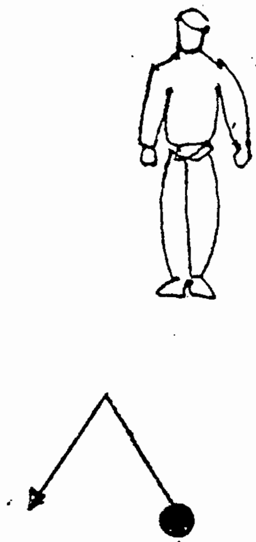


(d)

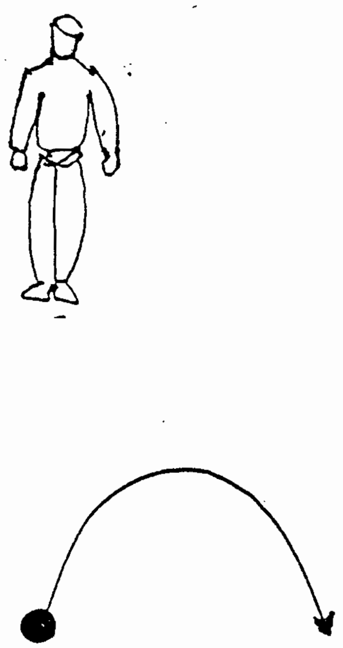
4. In die skets hardloop 'n dogter na regs by 'n seun verby. Op die oomblik wanneer sy regoor hom is, gooi sy 'n bal vertikaal opwaarts. Die skets wat die baan aandui waarlangs die seun die bal sal sien beweeg, is :



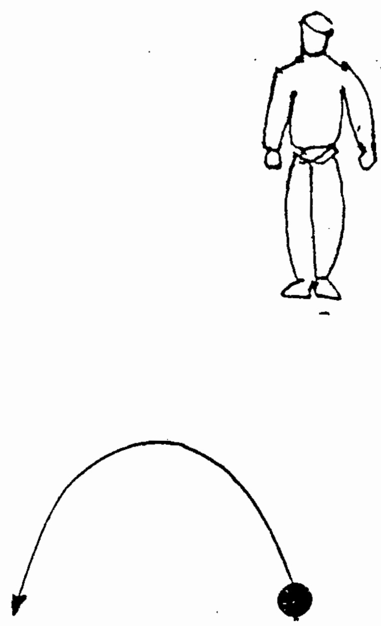
(a)



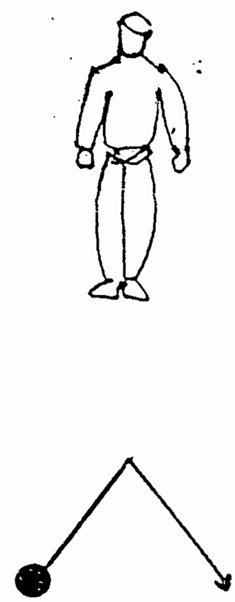
(b)



(c)

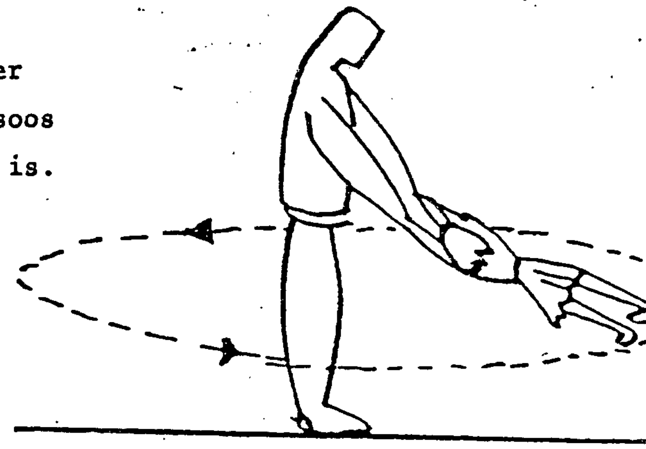


(d)

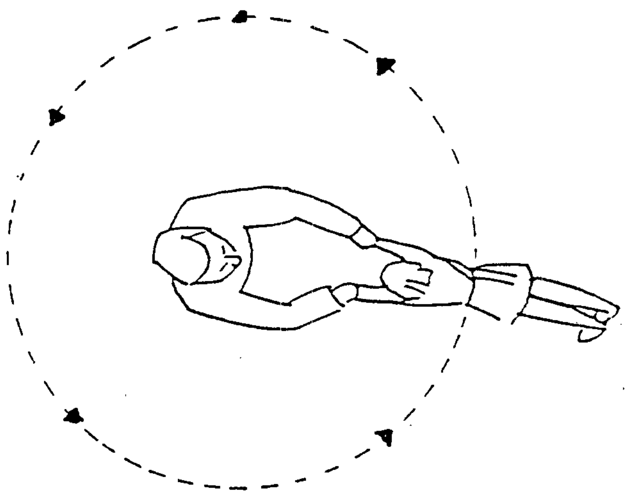


(e)

5. In die skets swaai 'n vader sy dogter speels in 'n sirkel in die rigting soos aangedui. Hy los haar as sy by A is.

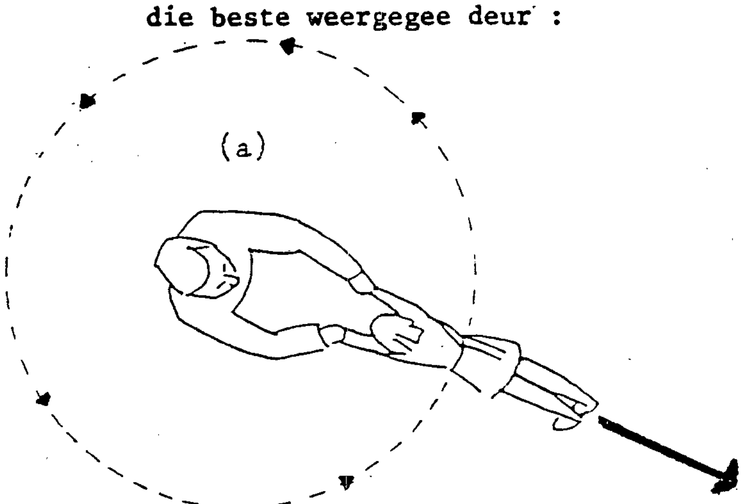


Van bo-af gesien sal dit so lyk :

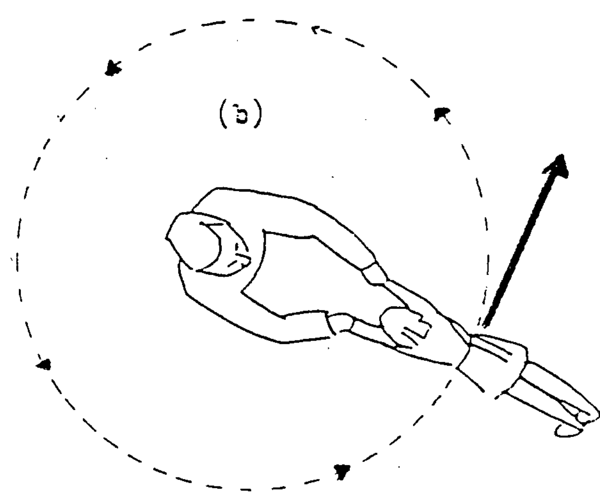


Die baan waarlangs sy sal beweeg nadat hy haar laat los het, word die beste weergegee deur :

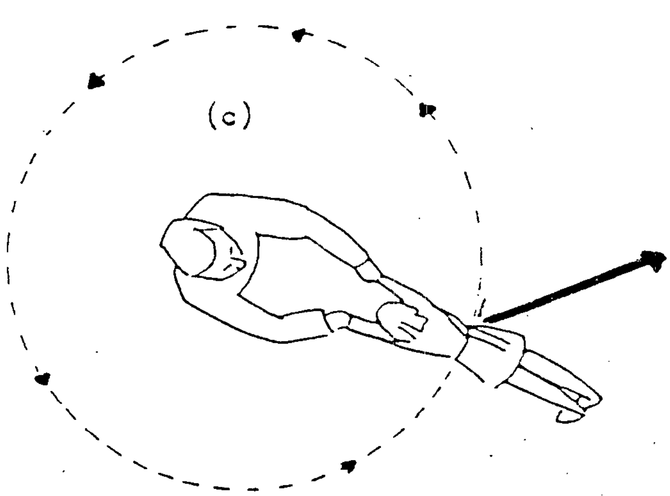
(a)



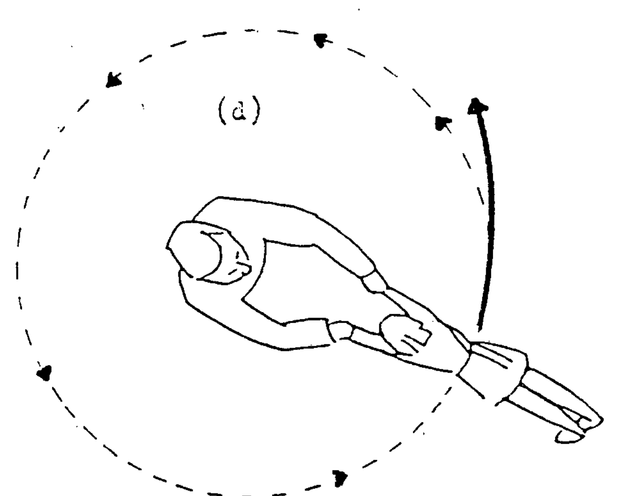
(b)



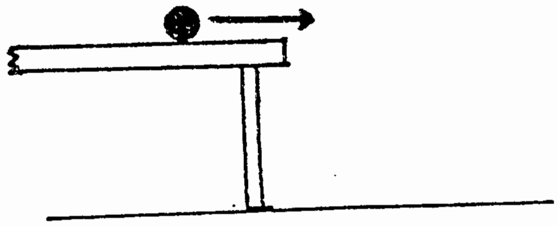
(c)

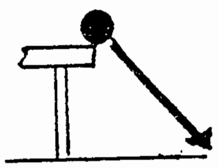


(d)

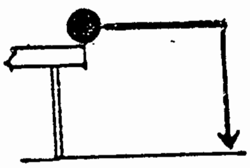


6. In die skets rol 'n bal vinnig oor 'n tafel in die aangeduide rigting. Dit val oor die rant. Die skets wat die baan waarlangs die bal grondtoe val die beste aandui, is :

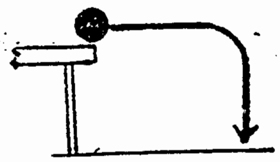




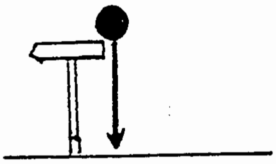
(a)



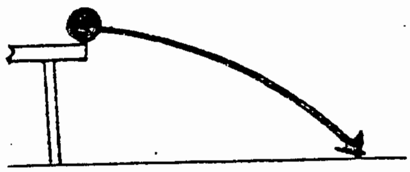
(b)



(c)

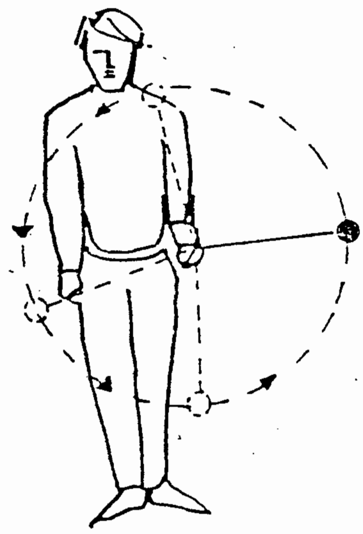


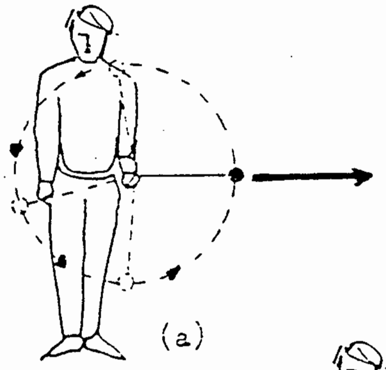
(d)



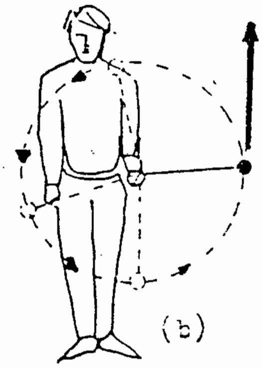
(e)

7. In die skets swaai 'n man 'n bal wat aan 'n tou vas is in 'n vertikale sirkel voor hom. Hy los die bal as dit by A is. Die baan waarlangs die bal sal beweeg nadat hy dit laat los, is :

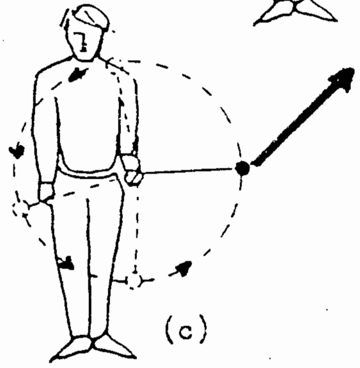




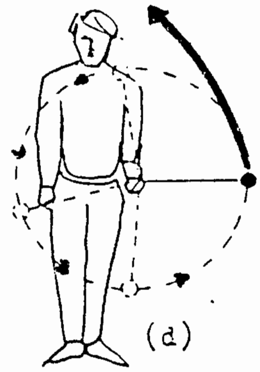
(a)



(b)



(c)

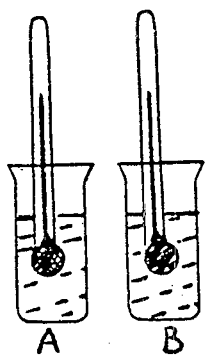


(d)

AFDELING D. : INLIGTING.

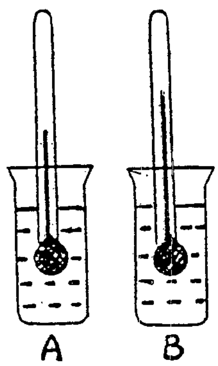
In die meeste vrae in hierdie afdeling word u gevra om die temperatuur van twee stowwe met mekaar te vergelyk. Dit kan u doen deur die lengte van die kwikkolom in twee identiese termometers te vergelyk, bv.

(i)



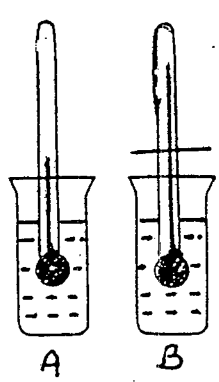
A en B het dieselfde temperatuur. Hulle is ewe "warm".

(ii)



B het 'n hoër temperatuur as A. B is "warmer" as A.

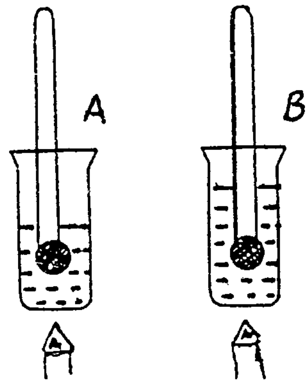
(iii)

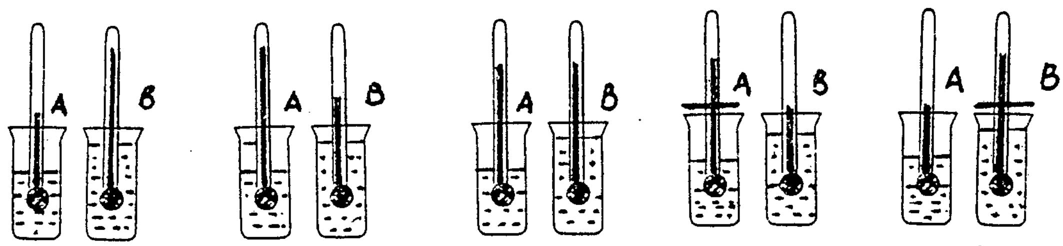


Die lesing op die termometer in B is twee maal hoër as die lesing op die termometer wat in A is.

AFDELING D : VRAE

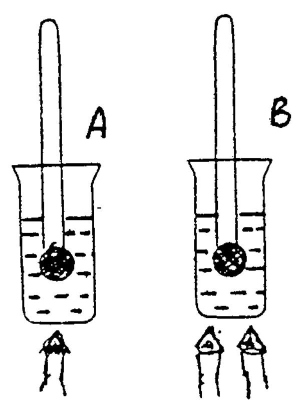
1. In die skets bevat die bekers dieselfde vloeistof en identiese termometers. Beker B bevat twee maal meer vloeistof as beker A. Die vloeistowwe in albei bekers kook. Die skets wat die lesings op die termometers die beste weergee, is :

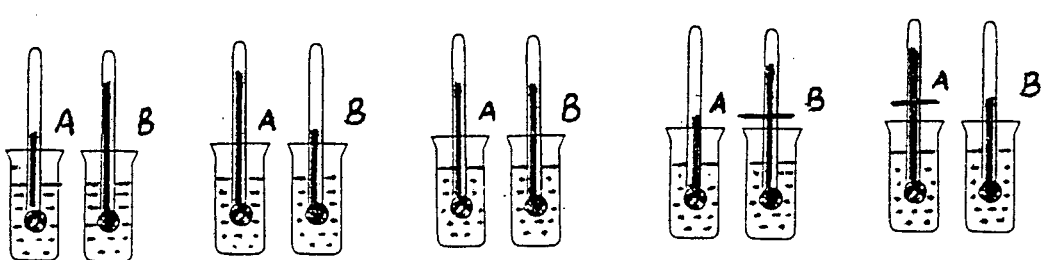




(a) (b) (c) (d) (e)

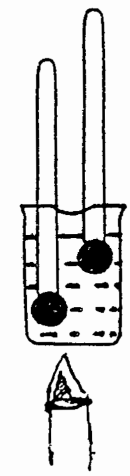
2. In die skets bevat die bekers dieselfde volume van dieselfde vloeistof en identiese termometers. Die bekers word met identise vlamme verhit. Beker B word met twee vlamme verhit. Albei vloeistowwe kook. Die skets wat die lesings op die termometers die beste weergee, is :

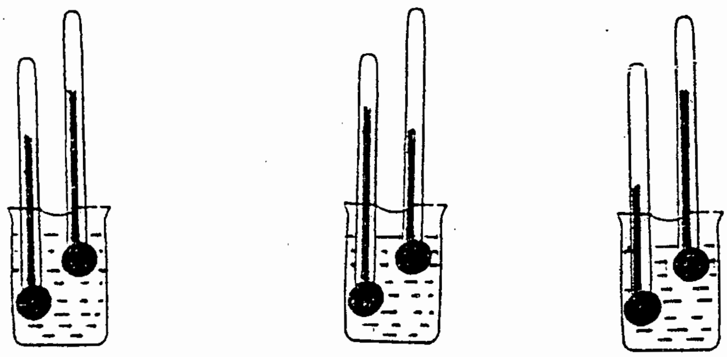




(a) (b) (c) (d) (e)

3. Die skets toon 'n beker met water wat oor 'n vlam kook. Twee identiese termometers word in die kokende water geplaas soos aangedui. Die skets wat die lesings op die termometers die beste vergelyk, is :

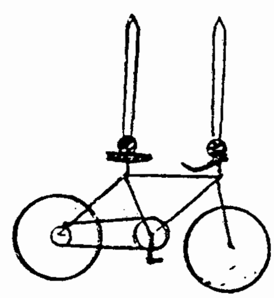




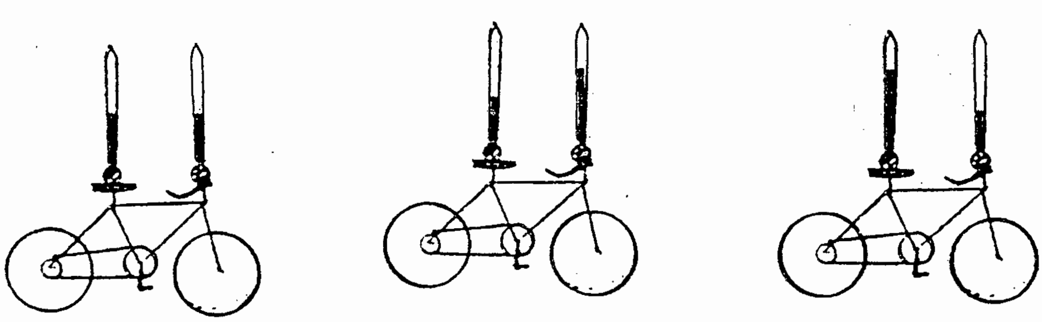
(a) (b) (c)

4.

Op 'n koue winteroggend gebruik 'n seun 'n termometer om die temperatuur van die plastiese saal van sy fiets te vergelyk met die temperatuur van die metaal stuurstang.

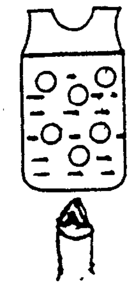


Die skets wat die lesings van die termometers die beste weergee wanneer dit op die saal en die stuurstang geplaas word, is



(a) (b) (c)

5.



Die skets toon water wat al 'n ruk lank in 'n beker kook. Borrels gas kom na die oppervlakte toe. Die borrels is heelwaarskynlik :

(a) lug
(b) waterstof- en suurstofgas
(c) waterdamp
(d) lug gemeng met waterstof- en suurstofgas
(e) 'n mengsel van stikstof- en suurstofgas.

INKCAZELO

Kulo olu vavanyo okanye kulo olu viwo ndiza kukucela ukuba unike olwakho uluvo malunga neentlobo zezinto ezine ezahlukeneyo.

Kwi Candelo A kufuneka uthelekise umahluko wemilinganiselo (sizes) wemisinga (forces) necala ethi imisinga ibheke isebenzele kulo. (Lo mahluko ndithetha ngawo, kufuneka uwuthelekise ngokubhekiselele kumlinganiselo wemisinga emibini, omnye komnye ubone ukuba nguwuphi omkhulu kunomnye)

KwiCandelo B kufuneka uthelekise umahluko wemilinganiselo yezinto ezimbini ezahlukeneyo phofu zilingane ngokobume umz. isanty sazo.

KwiCandelo C unyanzeleke ukuba ukhethe indlela ezakuhamba ngayo into emva kokuba kukho into eyenziweyo kuyo, okanye emva kokuba yenze into ethile.

KwiCandelo D ucelwa ukuba uthelekise amaqondo obushushu bezinto ezilulwelo ezibilayo kunye nenye into okanye ezinye nje izinto ezimbini.

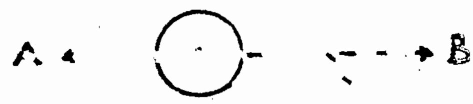
Xa uphendula le mibuzo kufuneka ne utikishe kulo ndawo ucinga ukuba yimpendulo eyiyo kweli phepha ulinikiweyo.

Nceda unike zonke inkcukacha ezifunwayo apha kweli phepha le mpendulo kuba kubalulekile oko.

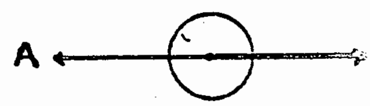
I-CANDELO A INKCAZELO

Kweli candelo umlinganiselo womsinga uboniswa ngobude betolo (arrow). Intloko yetolo ibonisa icala osebenzela ngakulo umsinga. Umzekelo, imisinga emibini u-A no B xa besebenza emzimbeni bangaboniswa kanje :

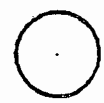
(i) Xa umsinga u-A ubheka kwicala elahlukileyo ku-B uba mncinane ku-B.



(ii) Apha umsinga u A no B bayalinga ngobukhulu kodwa babheka kumacala ehlukileyo.

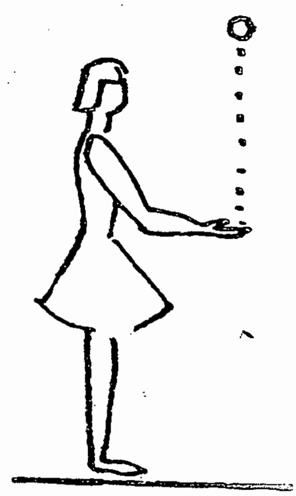


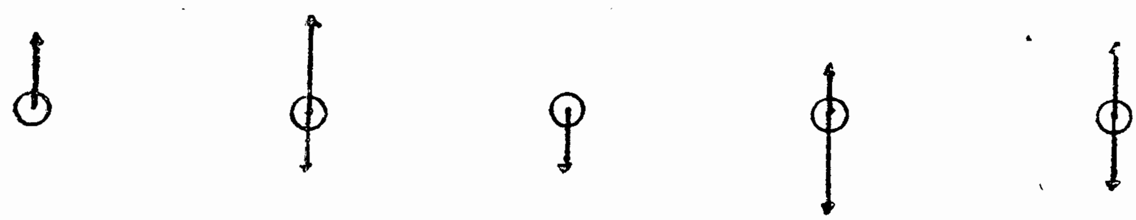
(iii) Apha akukho msinga uya ku-C.



I-CANDELO A : IMIBUZO

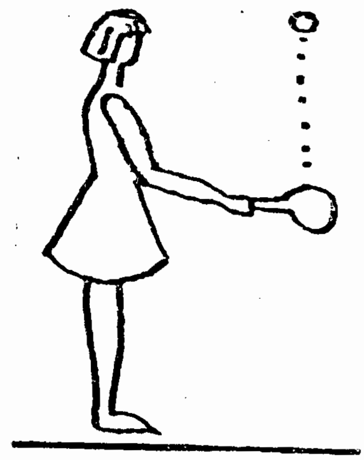
1. Lo mfanekiso ubonisa intombazana iphosa ibhola nqo phezulu. Umfanekiso obonisa kakuhle imisinga apha ebholeni, emva kokuba ibhola iphume kwangoko ezandleni zentombazana ngu :

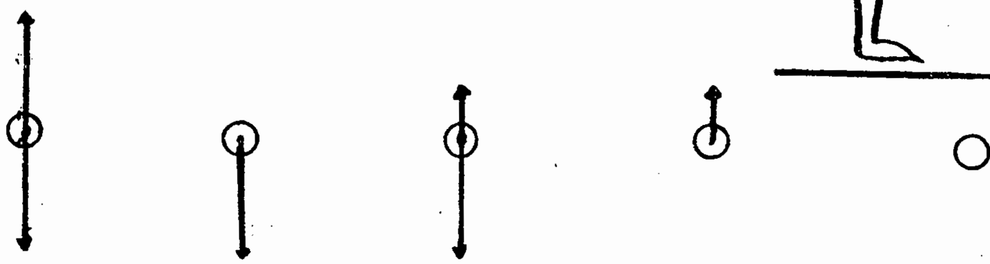




(a) (b) (c) (d) (e)

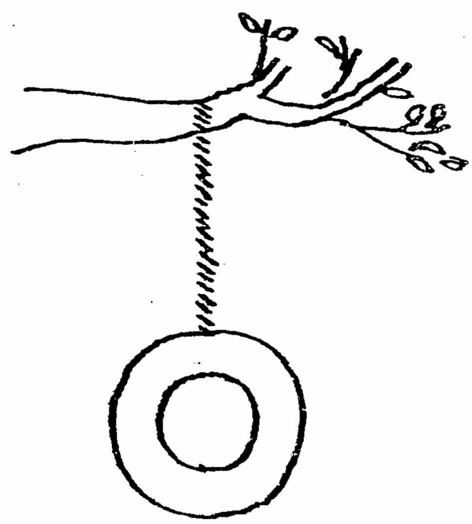
2. Lo mfanekiso ubonisa intombazana isebenzisa iphini ukubetha ibhola ibheke phezulu. Umfanekiso obonisa kakuhle umsinga osuka ebholeni xa ifike kweyona ndawo iphezulu phambi nje kokuba iqale ukubuyela emhlabeni ngu :

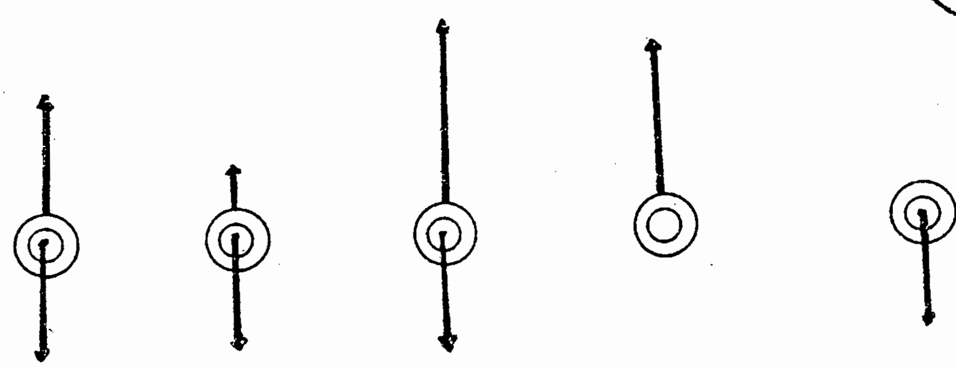




(a) (b) (c) (d) (e)

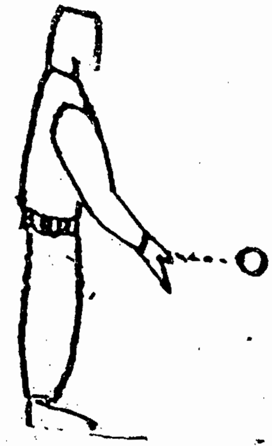
3. Lo mfanekiso ubonisa itayari elijingiswe ngentambo ebotshelelwe esebeni lomthi. Umfanekiso obonisa kakuhle nothelekisa imilinganiselo yemisinga ephuma isuka etayarini yile :

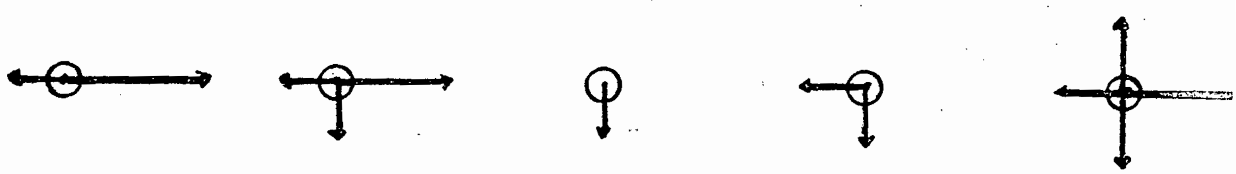




(a) (b) (c) (d) (e)

4. Lo mfanekiso ubonisa inkwenkwana igibisela ibhola, isuka kuyo ibheka phambili,. Umfanekiso obonisa kakuhle umsinga (ubandakanya ungqubulwano kunye nokunyamezela) usuka ebholeni emveni nje kokuba isukile ezandleni zenkwenkwe ngu :

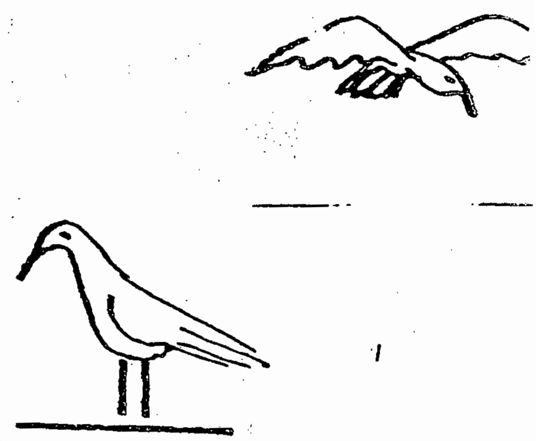


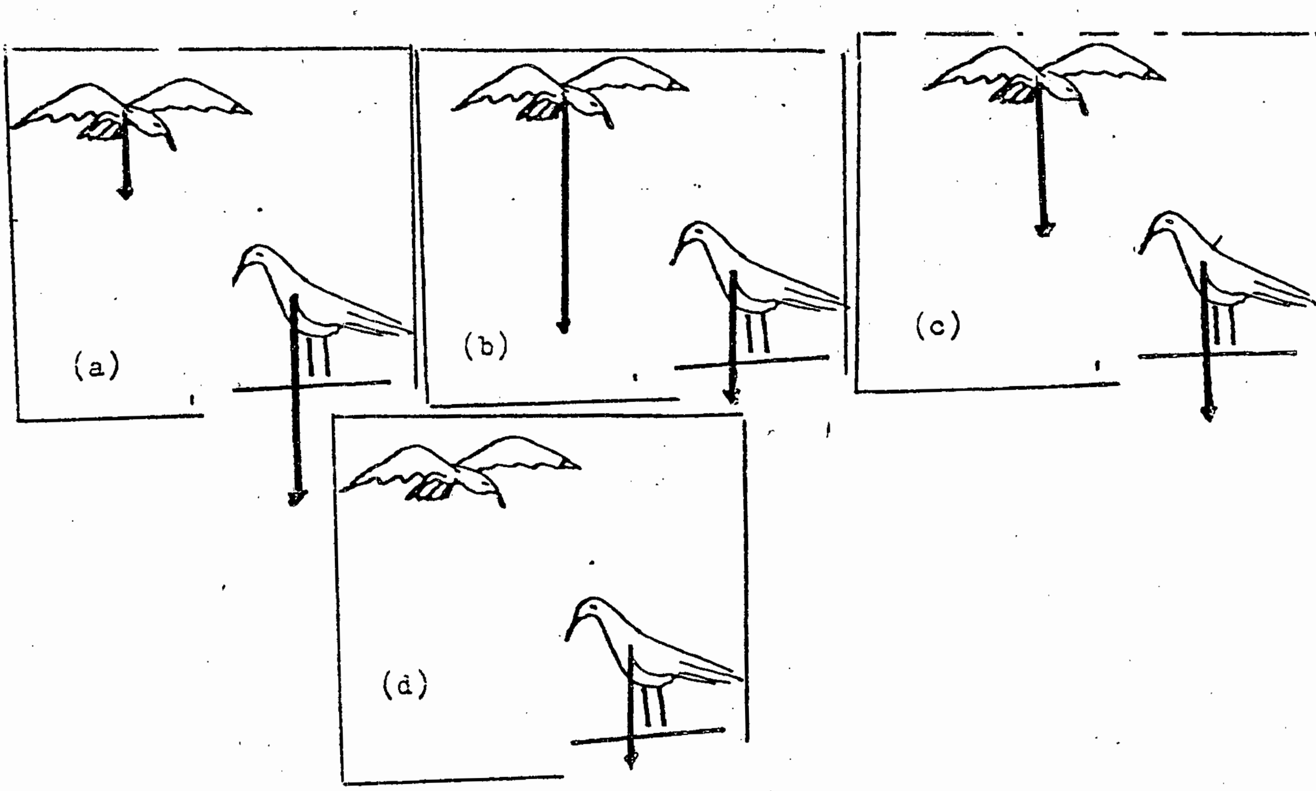


(a) (b) (c) (d) (e)

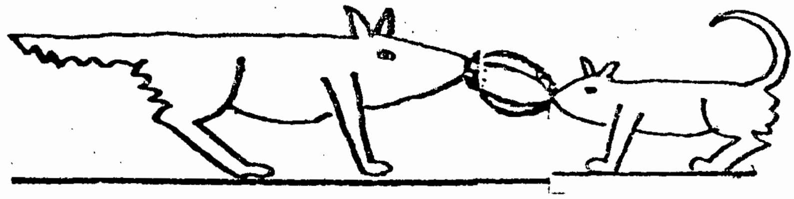
5.

Le mifanekiso ibonisa intaka enye ihleli emhlabeni okwesibini ibhabha nje emoyeni kangangekhulu leemitha (100 metres) ukunyuka. Imifanekiso ethelekisa kakuhle umlinganiselo onombizane womhlaba entakeni xa ihleli emhlabeni naxa ibhabhayo yile :

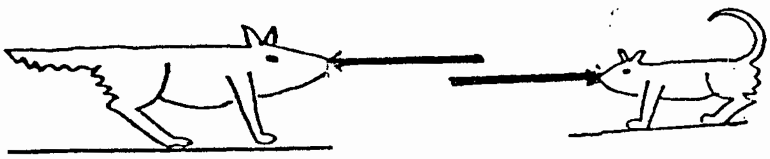


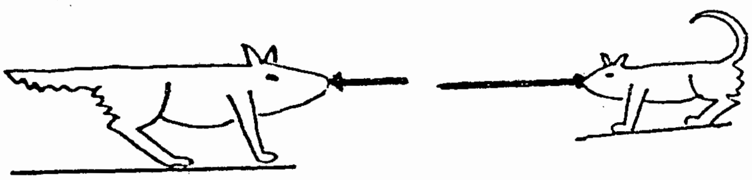


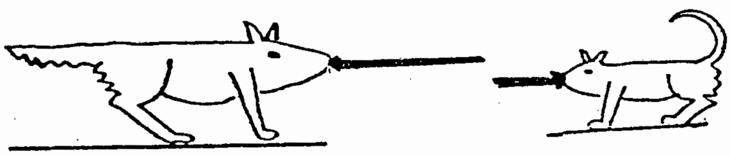
6.



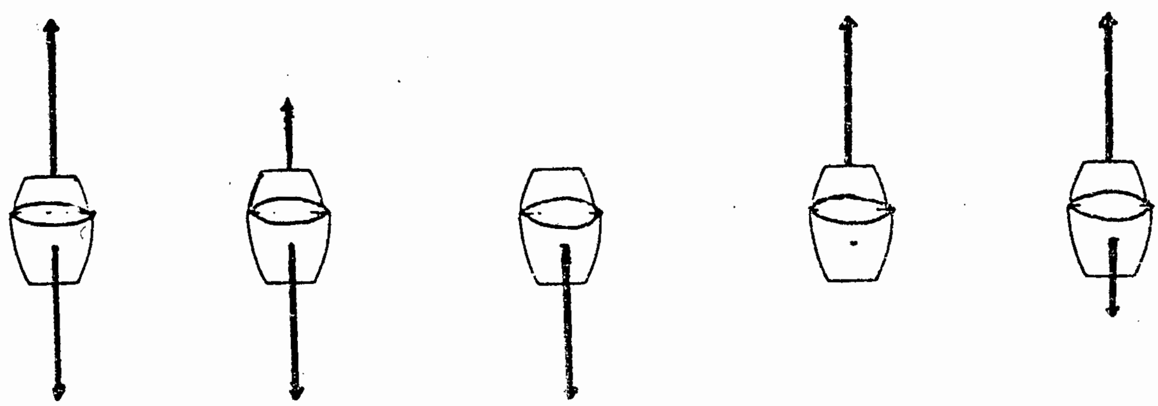
Lo mfanekiso ubonisa izinja ezimbini zitsala-tsalana ngengxowa. Azishukumi tu. Umfanekiso obonisa kakuhle amandla etsala ngawo inja nganye ngulo :

(a) 

(b) 

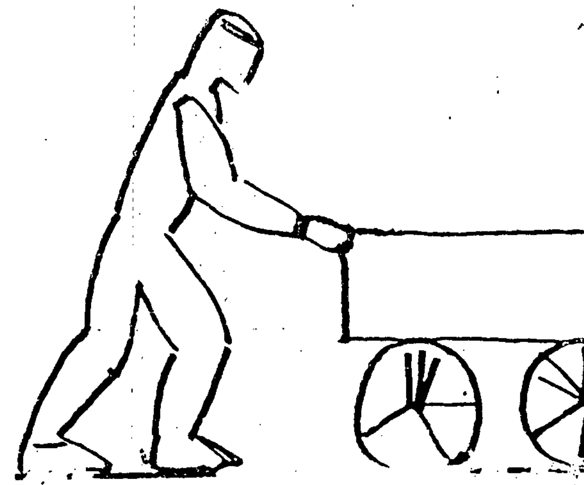
(c) 

7. Lo mfanekiso ubonisa umfazi ephethe i-emele ngesandla. Umanekiso obonisa kakuhle nothelekisa imisinga esebenza kwi-emele enamanzi ngulo :

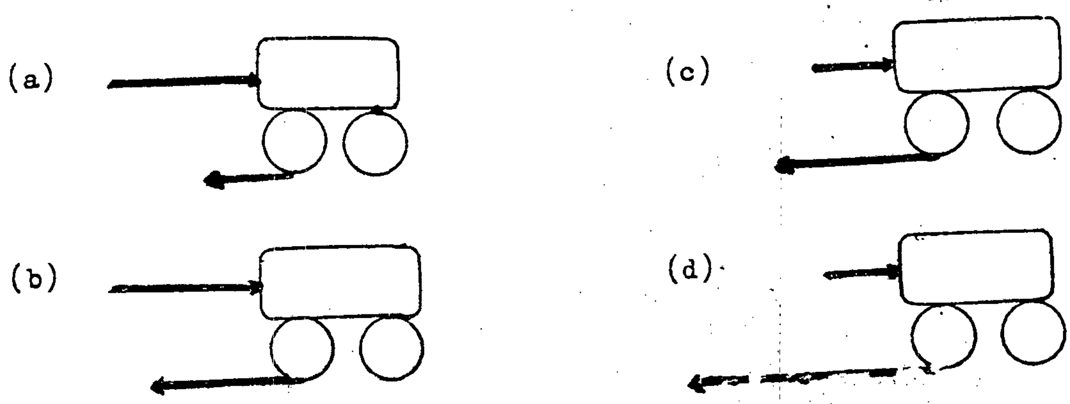


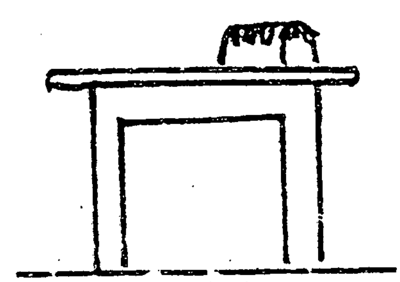
(a) (b) (c) (d) (e)

8.

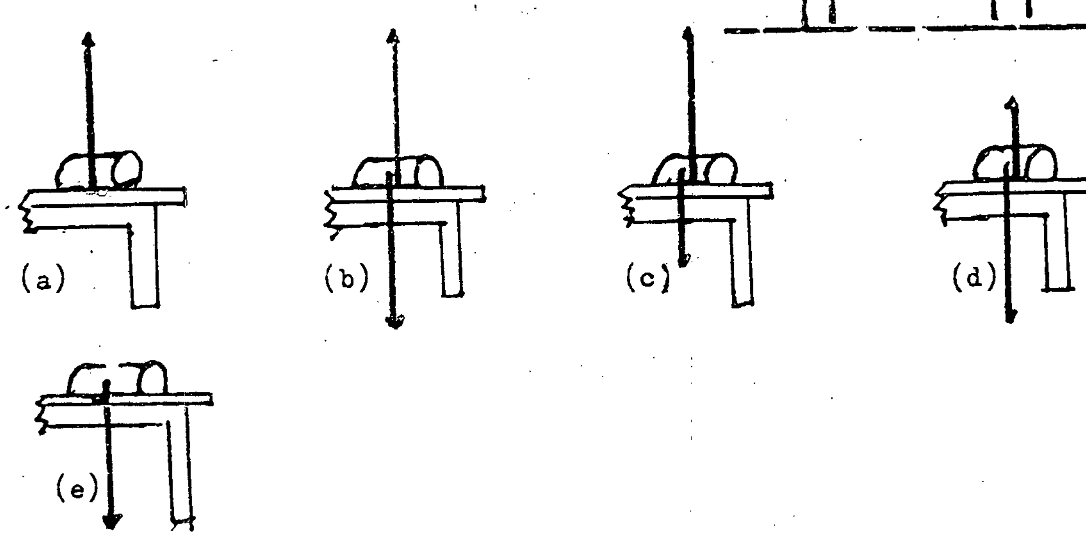


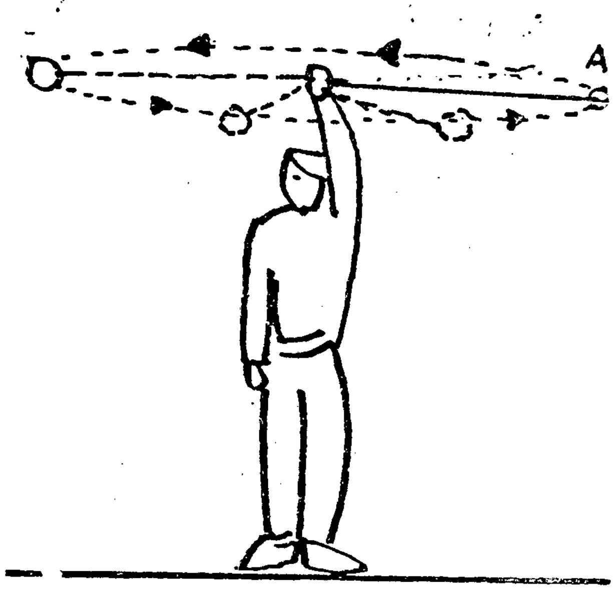
Lo ubonisa inkwenkwe ityhala inqwelo. Le nqwelo ayishukumi kuba ixinge esantini/emhlabeni. Umfanekiso obonisa kakuhle ubungakanani bamandla ale nkwenkwe etyhala ngawo xa uthelekiswa nemisinga engquzulanayo nephikisa ukuba mayishukume ngulo :



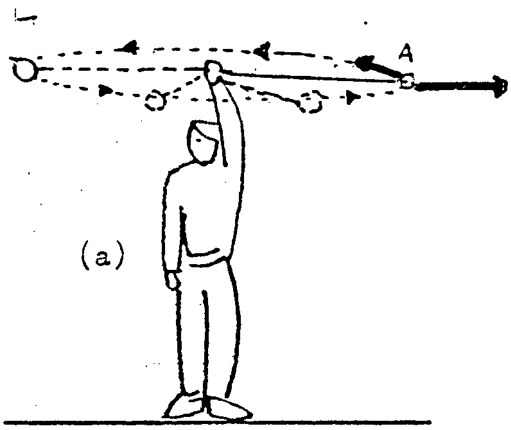


9. Lo mfanekiso ubonisa isonka esiphezu kwetafile. Umfanekiso obonisa kakuhle nothelekisa imisinga esebenza esonkeni ngulo :

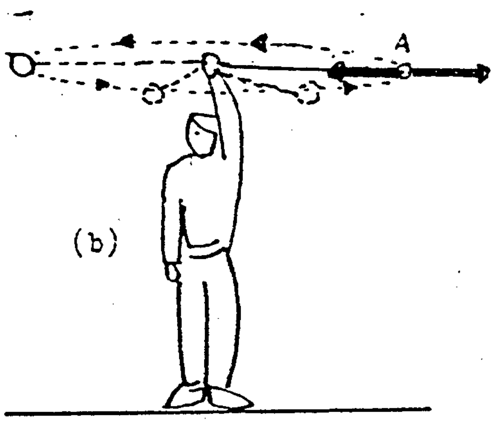




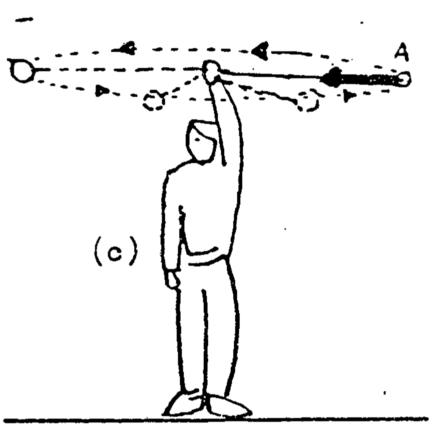
Lo mfanekiso ubonisa inkwenkwe ijikelezisa ibhola, ebotshelelwe entanjeni, eyijikelezisa entloko. Amandla omsinga asebenza kwibhola engu-A ngenxa yentshukumo eyenzekayo kuyo (ingashukunyiswanga okanye ingangqutyiswanga ntweni) :



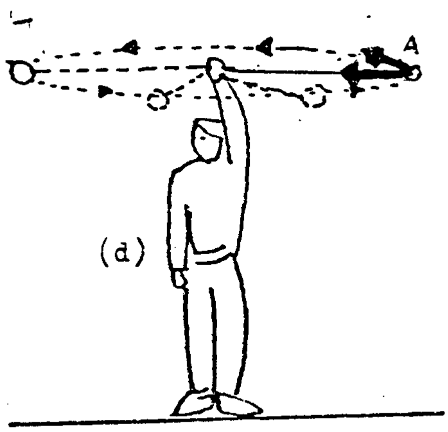
(a)



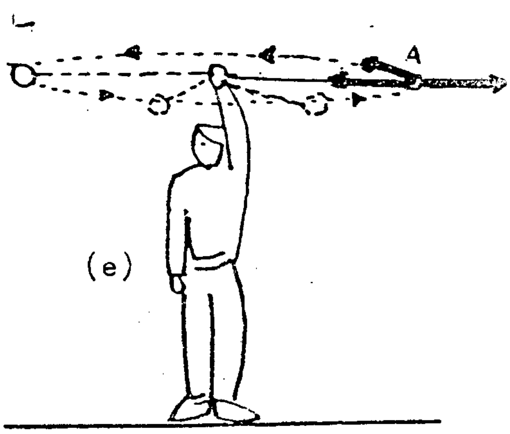
(b)



(c)

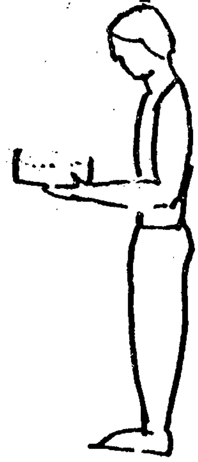


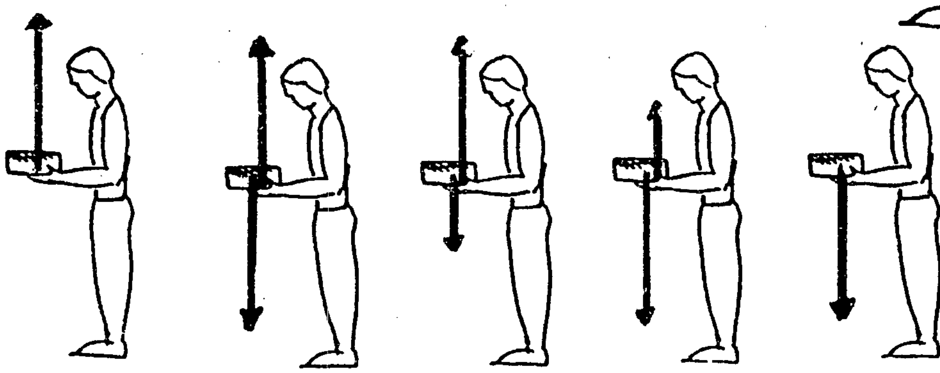
(d)



(e)

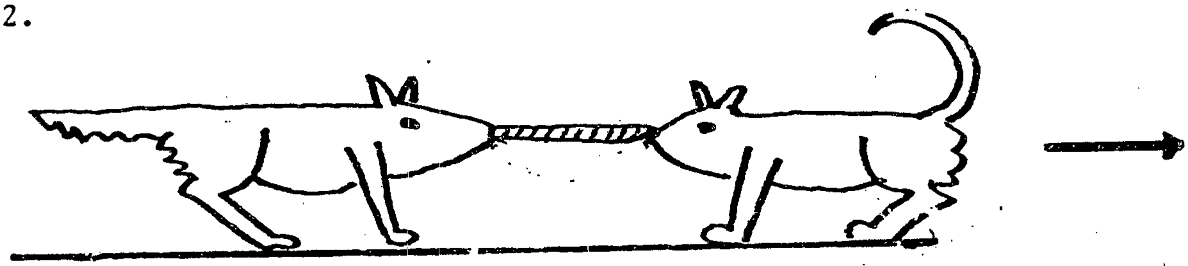
11. Lo mfanekiso ubonisa indoda ephethe isitena ngesandla. Umfanekiso obonisa kakuhle ukusebenza kwemisinga esiteneni ngulo :



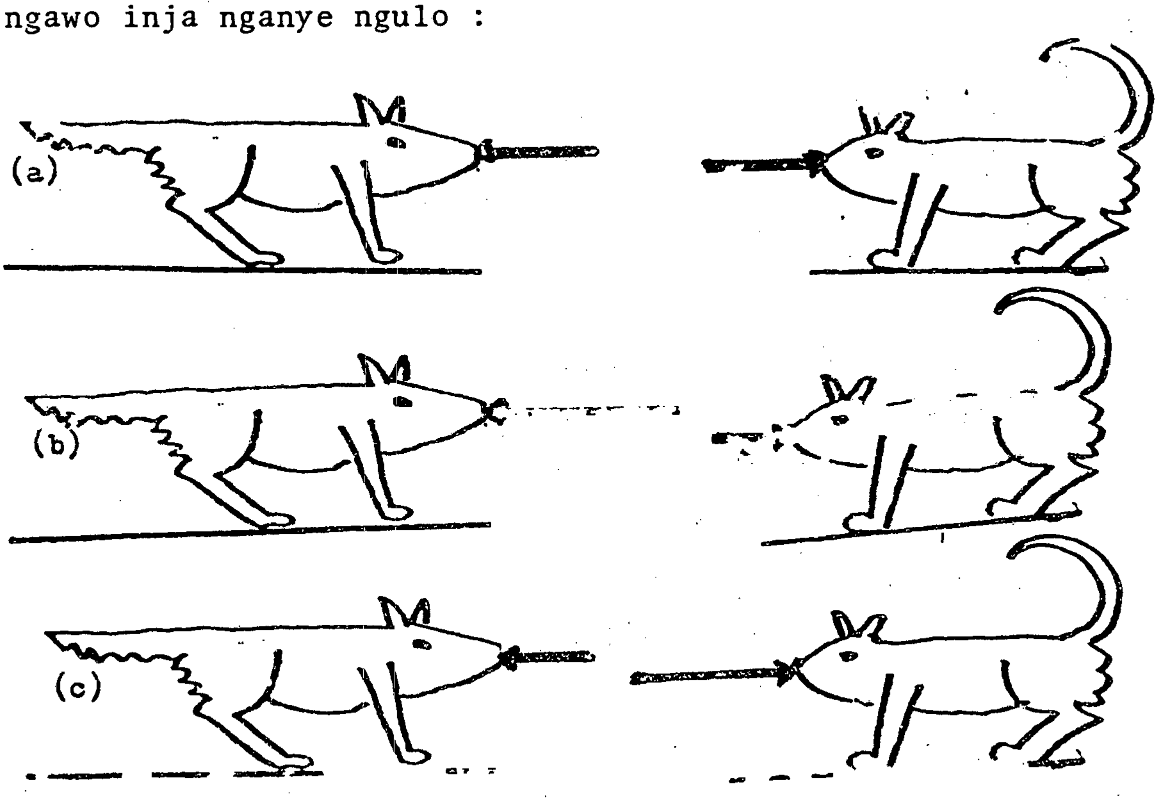


(a) (b) (c) (d) (e)

12.



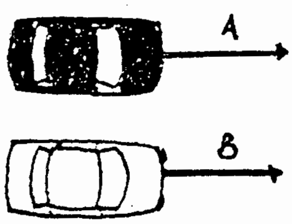
Lo mfanekiso ubonisa izinja ezimbini zitsala-tsalana ngentambo, iyileyo ibhekisa kwelayo icala. Zibheka zitshotshobela kancinci kwicala <u>langasekunene.</u> Umfanekiso obonisa kakuhle amandla etsala ngawo inja nganye ngulo :



ICANDELO B : INKCAZELO

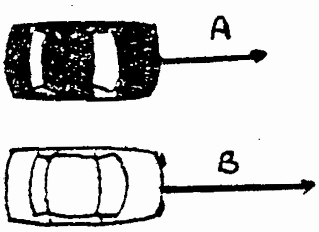
Kule mifanekiso kufuneka uthelekise ubungakanani bokulingana kwezinto ezifanayo. umz. amendu, umgama ohanjiweyo, njl., zizinto ezingafaniyo. Apha amatolo asetyenzisiwe, kodwa, ubude bemigca bubonisa ubungakanani bala mendu sizama ukuwathelekisa. Umzekelo, ukuba sithelekisa isantya ezihamba ngazo ezi moto, ngokuqinisekileyo le mifanekiso iyakubonisa ngolu hlobo :

(i)



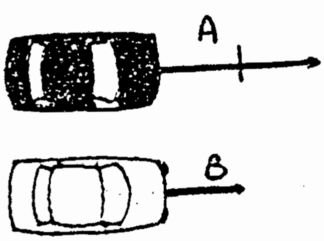
U-A no-B banesantya esilinganayo

(ii)



U-B ubaleka ngaphezu kuka-A

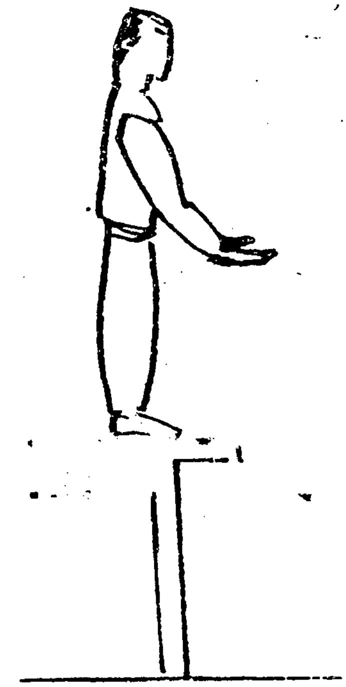
(iii)



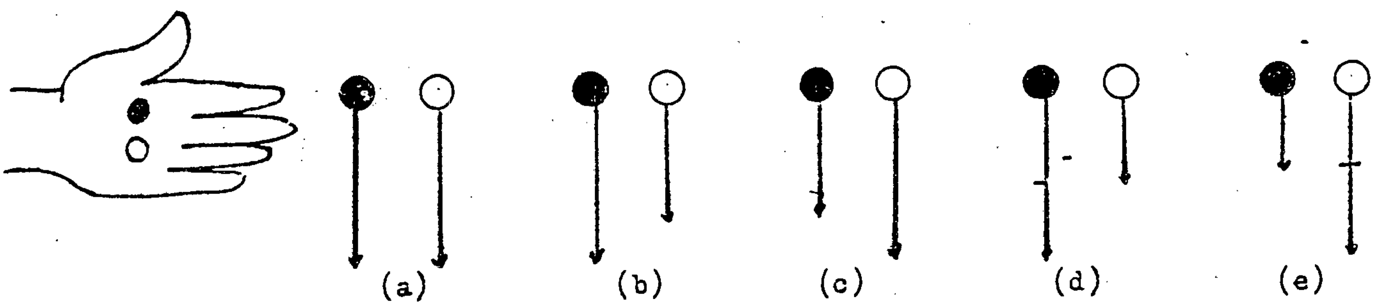
U-A ubaleka ngesantya esiphindwe kabini kwesika-B.

I-CANDELO B : IMIBUZO

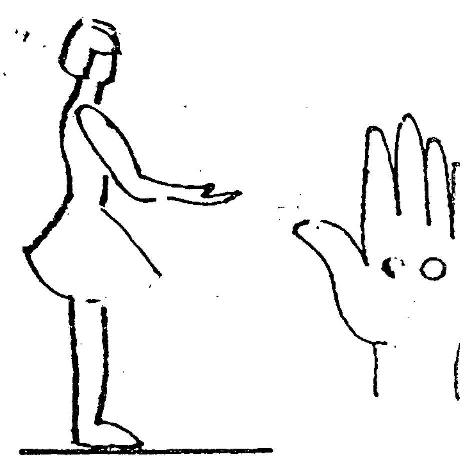
1.



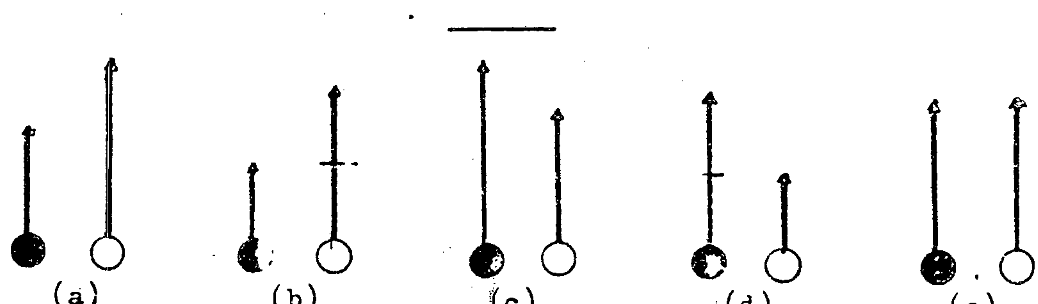
Lo mfanekiso ubonisa inkwenkwe ime phezu kwetafile. kwetafile. Inamabhastile amabini esandleni. Eli limnyama linobunzima obuphindwe kabini kunobelinye ibhastile elimhlophe. Uwalahla omabini ngaxeshanye phantsi. Umfanekiso obonisa nokwathelekisa izantya afike ngazo emhlabeni ngulo :



2.

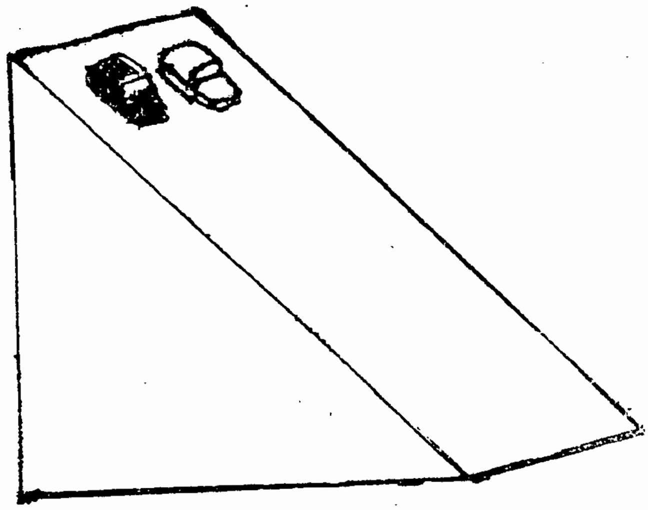


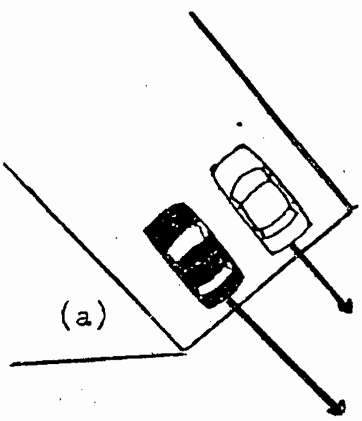
Lo mfanekiso ubonisa intombazana iphethe amabhastile amabini, elimnyama nelimhlophe. Elimnyama linobunzima obuphindwe kabini kunebhastile elimhlophe. Ngoku uwaphosa ngaxeshanye omabini phezulu ngesantya esilinganayo. Umfanekiso obonisa kakuhle ubude obufikelelwe ngala mabhastile omabini, ngulo :



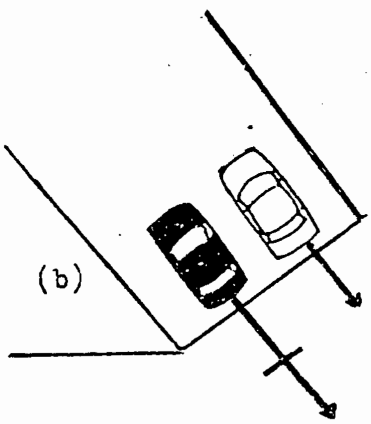
3.

Lo mfanekiso ubonisa imoto ezimbini ezimiswe yinkwenkwe ethambekeni, izithelekisa amendu azo. Le imnyama inobunzima obuphindwe kabini kunoba le imhlophe. Zisuka ndawonye ngaxeshanye kweli thambeka. Umfanekiso obonisa kakuhle izantya eziya ukufika ngazo ezantsi ngulo :

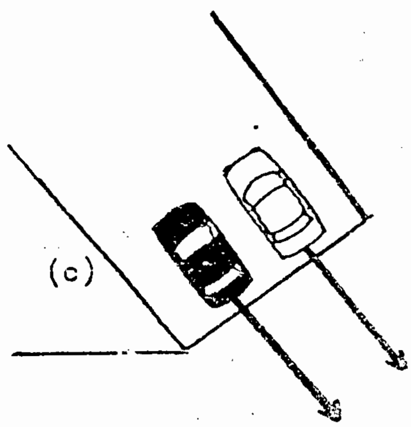




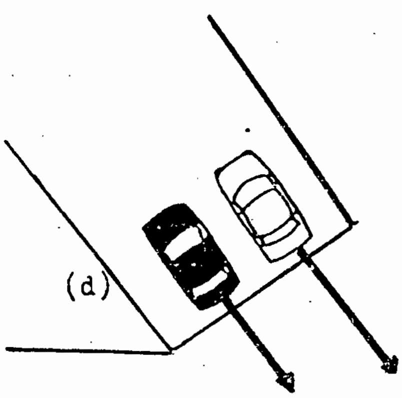
(a)



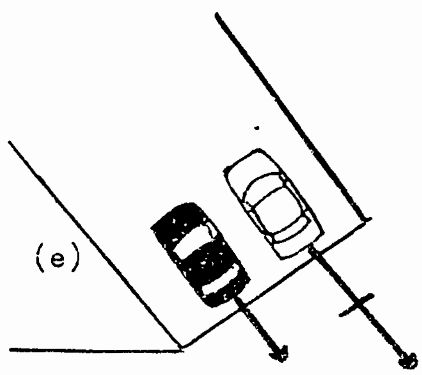
(b)



(c)

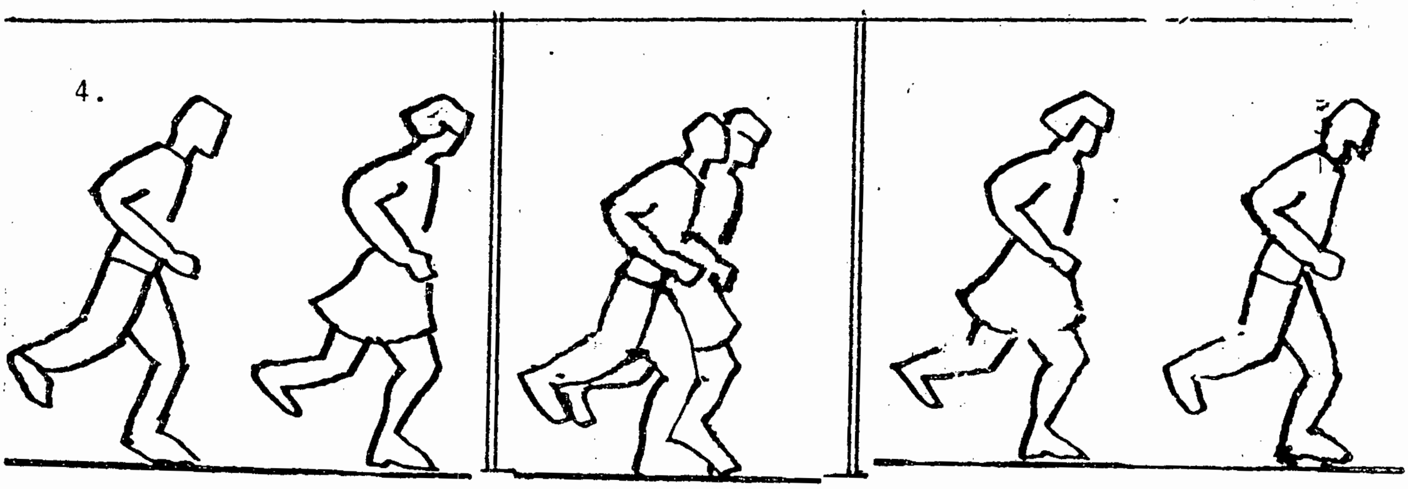


(d)

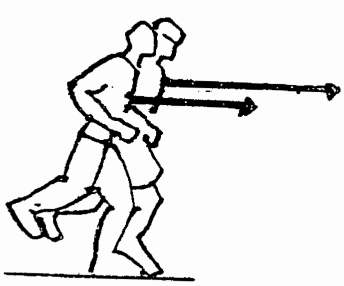


(e)

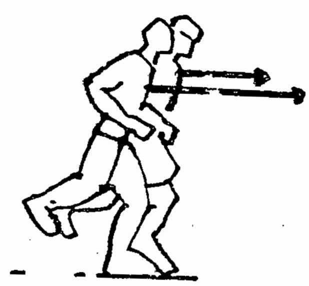
4.



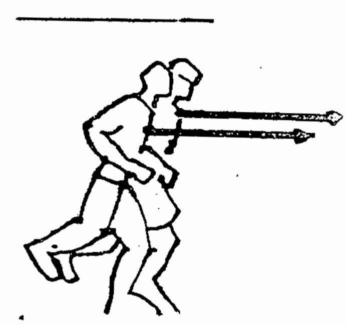
Le mifanekiso ibonisa inkwenkwe ebaleka emba kwenye, idlula intombazana elugqatswen. Umfanekiso othelekisa kakuhle isantya engelixesha le nkwenkwe ibaleka ecaleni kwentombazana ngul



(a)



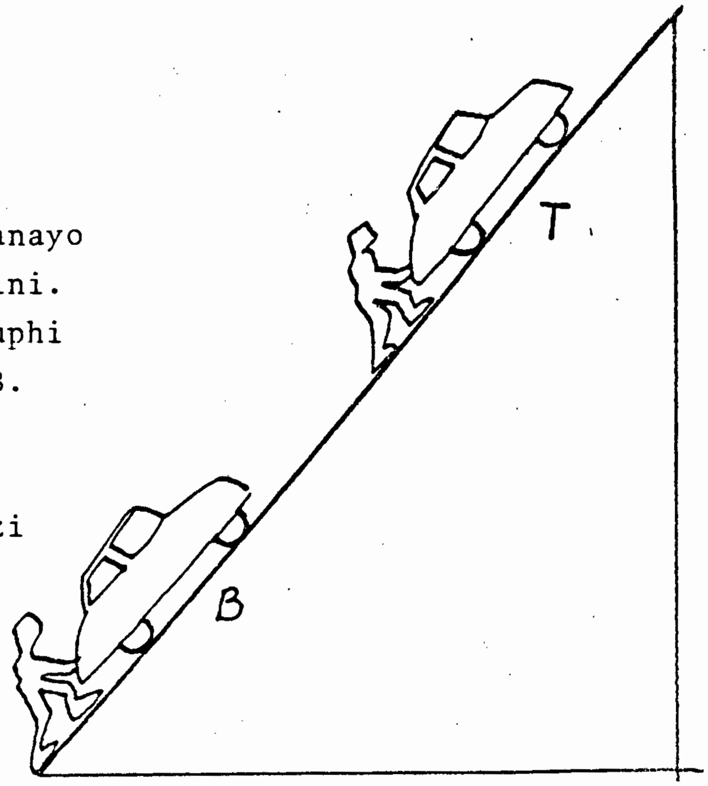
(b)

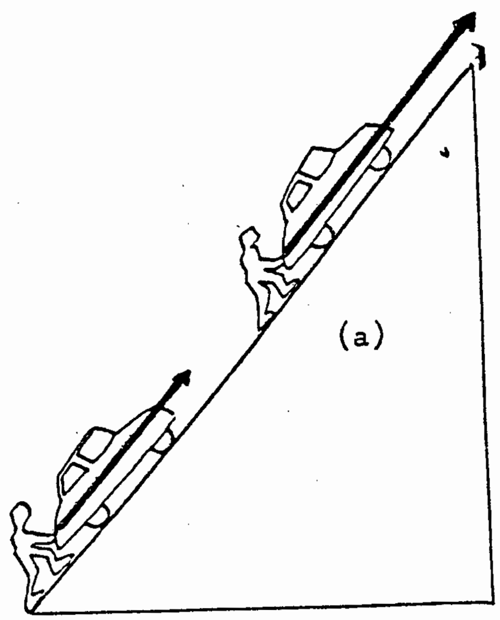


(c)

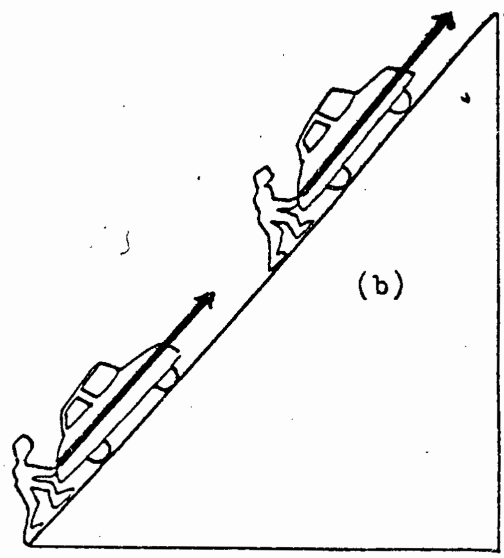
5.

Lo mfanekiso ubonisa iimoto ezifanayo zibanjwe ngamadoda amabini endulini. Ezi moto zimile. Le nqwelo ikufuphi no-T ingentla kwale ikufuphi no-B. Umfanekiso othelekisa kakuhle ubungakanani bamandla ekufuneka indoda nganye ibenawo ukubamba ezi moto ngulo :

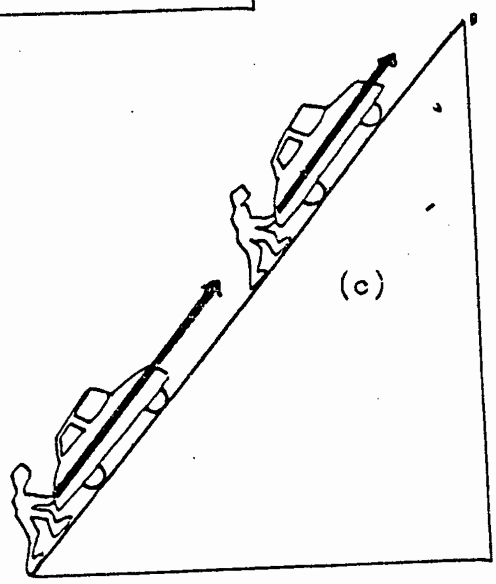




(a)



(b)



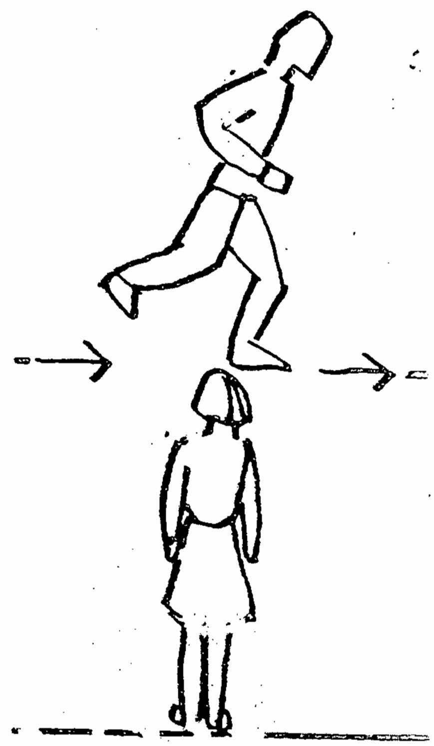
(c)

I-CANDELO C : INKCAZELO

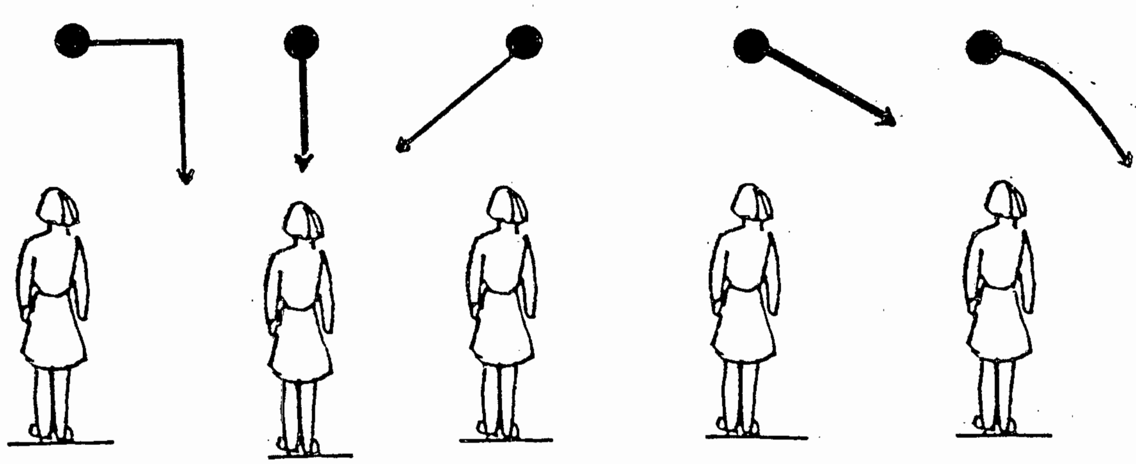
Kweli candelo ucelwa ukuba ukhethe eyona ndlela ethi into ihambe ngayo ukuya emhlabeni okanye njengoko ibonwa ngulo mntu (inkwenkwe/ intombazana) eme ngxi. Isimo somgca sibonakalisa isimo sendlela nentloko yetolo, kulo mgca ibonakalisa icala eya ngakulo loo nto.

Umzekelo  . Lo mfanekiso ubonakalisa indlela ehajwa yibhola bugoba isinga ngasekunene.

1. I-CANDELO C : IMIBUZO

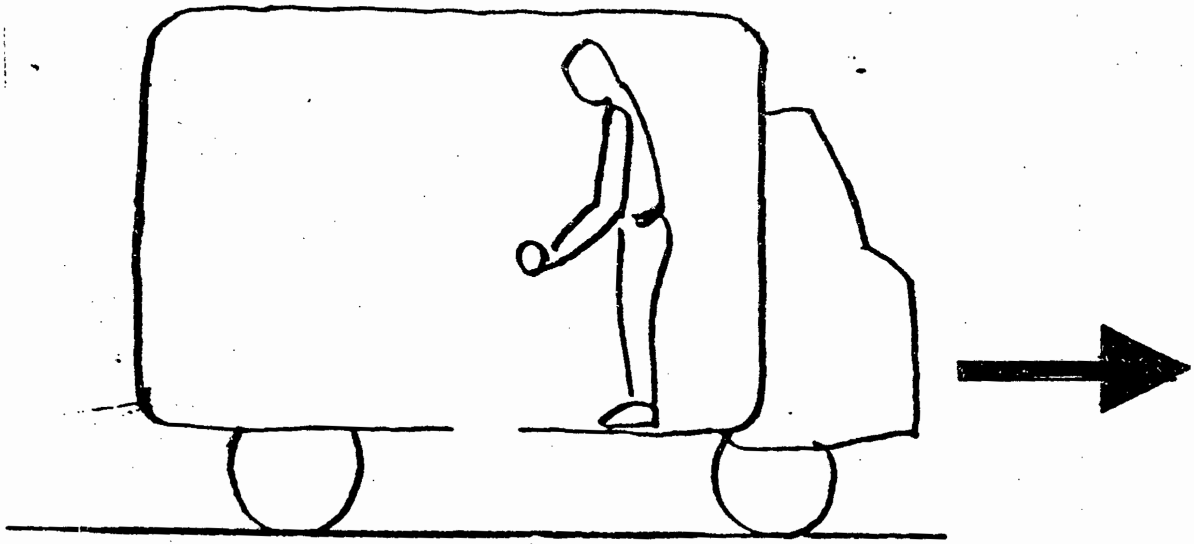


Lo mfanekiso ubonisa inkwenkwe ebalekela ngasekunene idlula le ntombazana, ilahla ibhola ebiyiphethe. Le ntombazana iyayibona le bhola xa iwayo. Umfanekiso obonisa kakuhle indlela le ntombazana ayibona ngayo le bhola za iwayo ngulo :

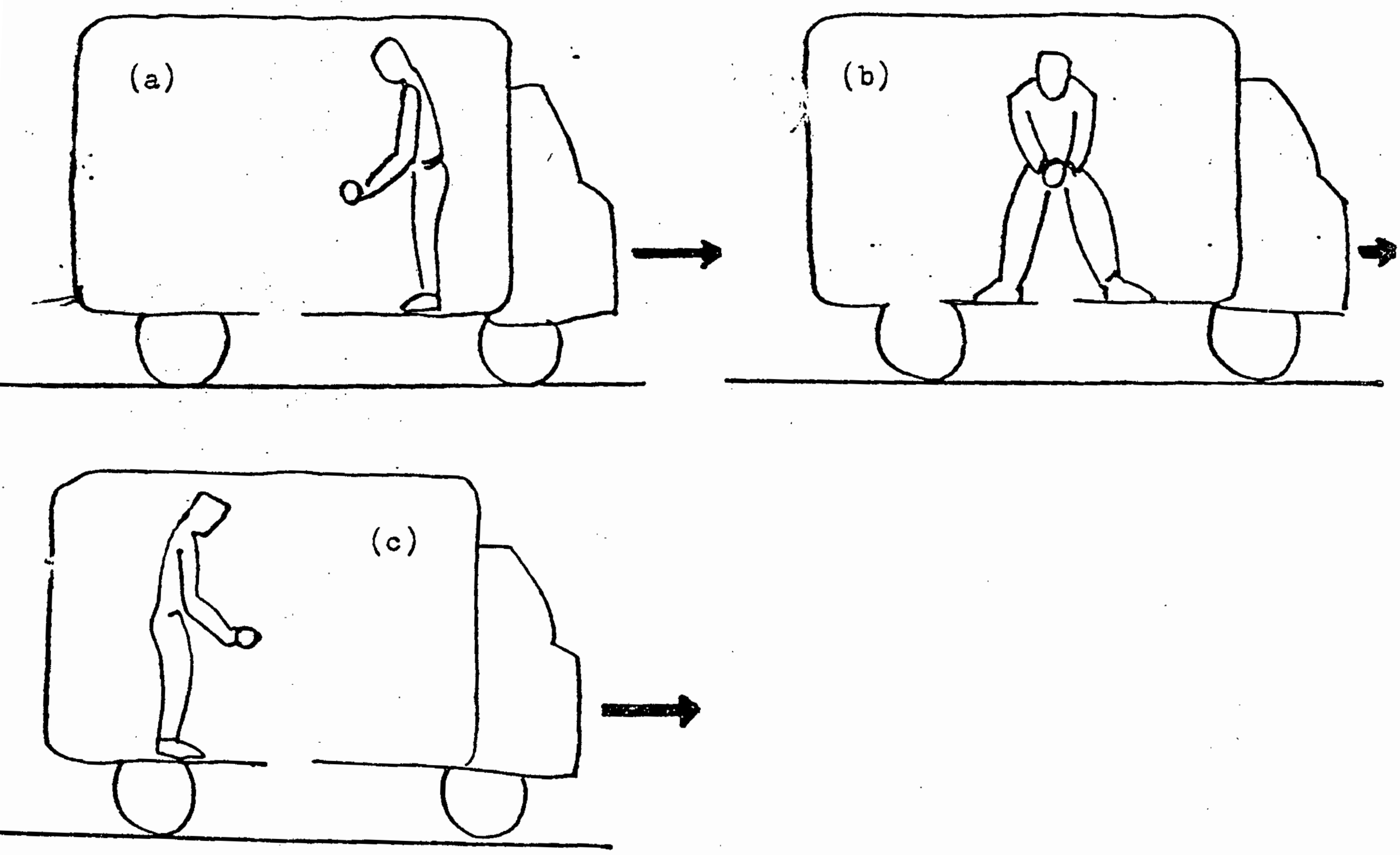


(a) (b) (c) (d) (e)

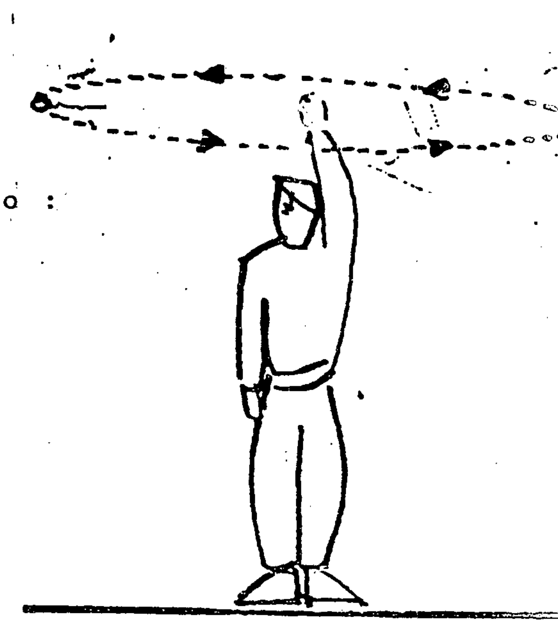
2.



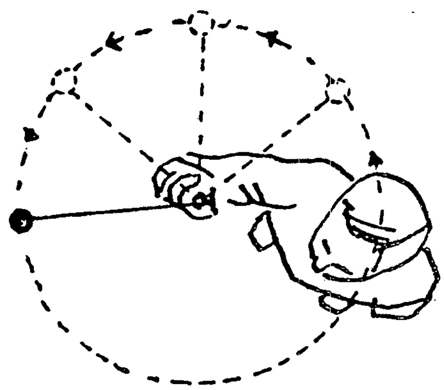
Lo mfanekiso ubonisa inkwenkwe emileyo emva kwinqwelo evalekileyo. Le nqwelo iya ngasekunenen ngesantya esithile. Kukho umngxuma phantsi kule nqwelo kwaye le nkwenkwe ifuna ukulahla ilitye ngalo mngxuma. Umfanekiso obonisa apho kufuneka le nkwenkwe ime ngayo :



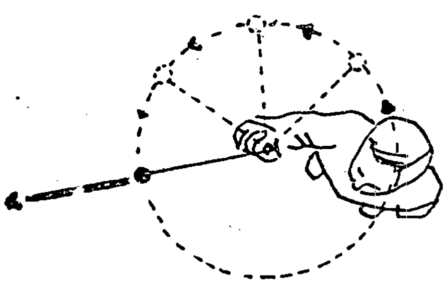
3. Lo mfanekiso ubonisa inkwenkwe ejikelezisa ibhola, ebotshelelwe entanjeni. Le bhola ijikeleziswa phezu kwentloko. Xa lo mfanekiso ujongwe, wavelwa ngentla ubonakala ngolu hlobo :



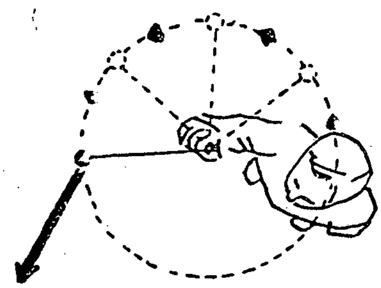
Xa ivelelwe ngentla yobonakala ngolu hlobo :



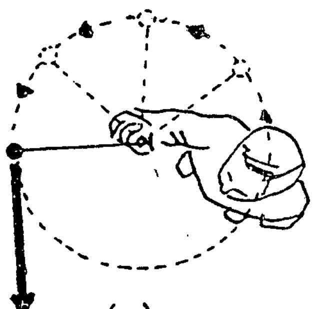
Uyeka intambo ihambe xa ibhola yona iku-A.
Indlela ehanjwa yibhola emva kokuba ikhululwe yile :



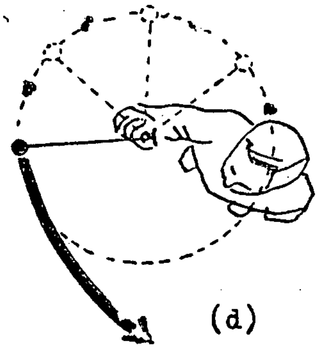
(a)



(b)

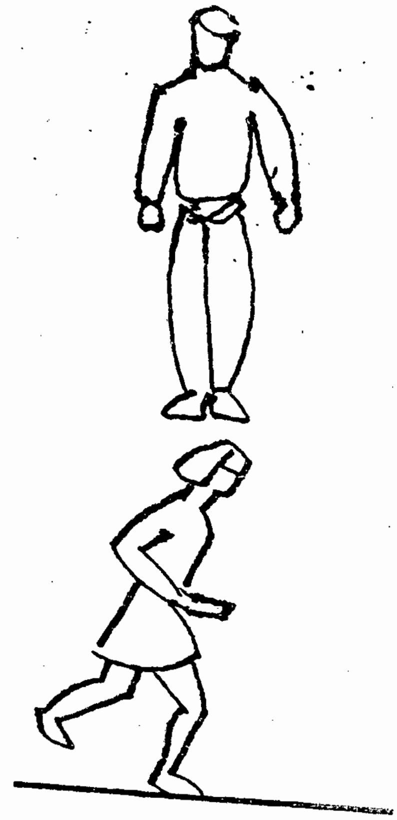


(c)

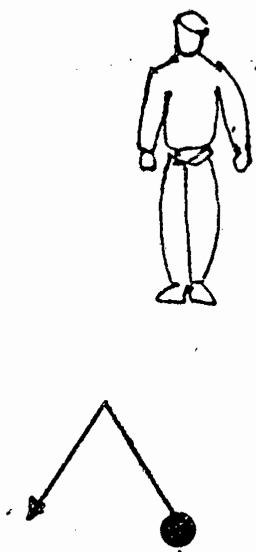


(d)

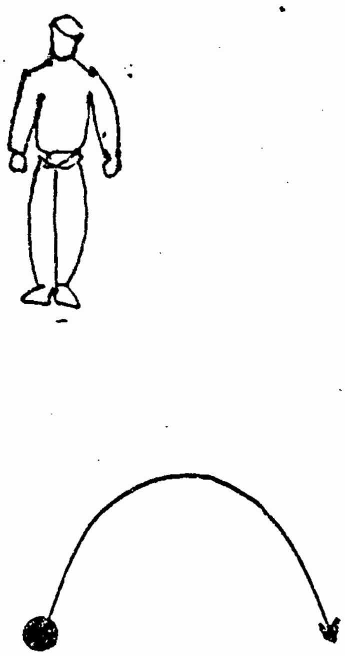
4. Lo mfanekiso ubonisa intombazana ebalekela ngasekunenene idlula enkwenkweni. Xa kanye idlula enkwenkweni igibisela ibhola ngokuthe ngqo ibheke phezulu. Umfanekiso oyibonisa kakuhle indlela <u>inkwenkwe</u> eyibona ngayo indlela ehanjwa yibhola ngulo :



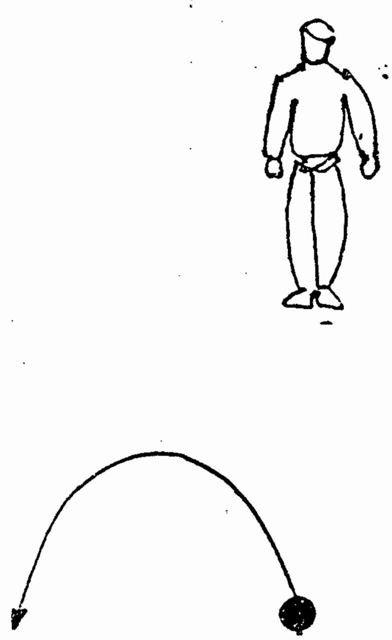
(a)



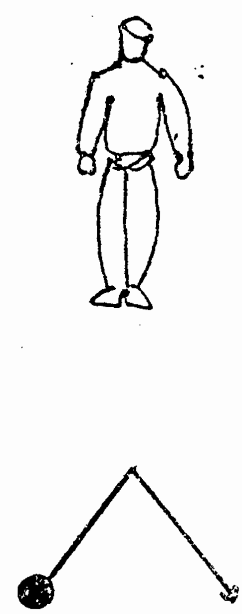
(b)



(c)

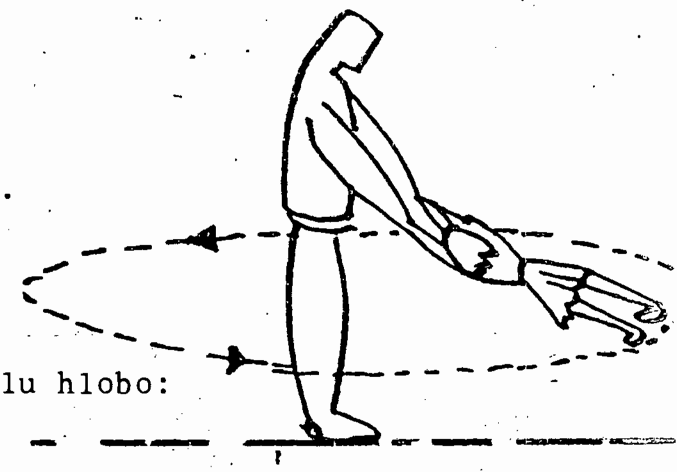


(d)

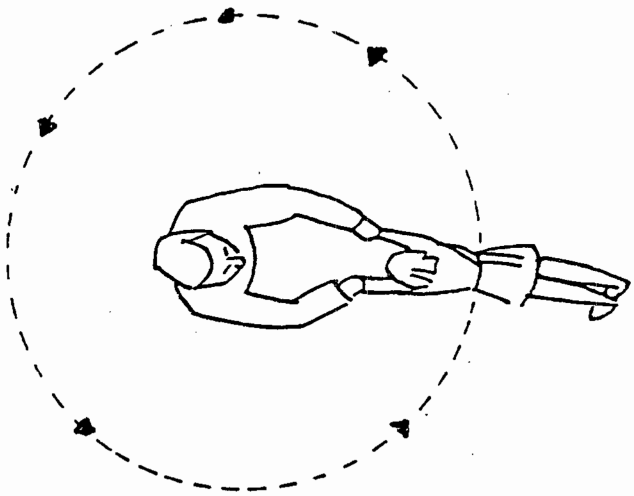


(e)

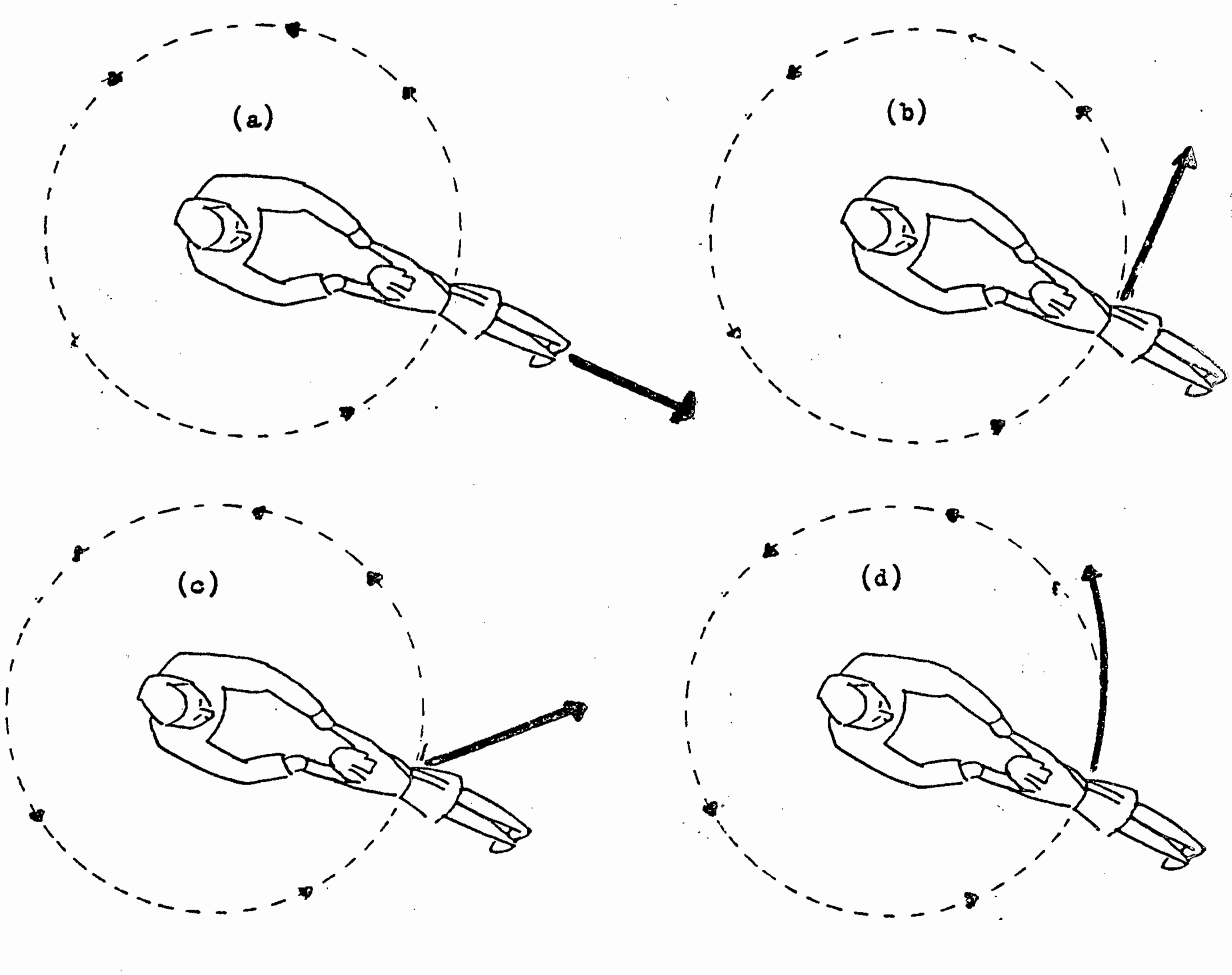
5. Lo mfanekiso ubonisa intombazana edlaliswa ngokujikeleziswa nguyise.



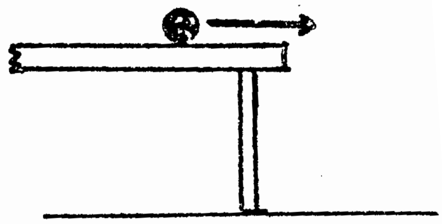
Xa ivelelwe ngentla yobonakala ngolu hlobo:

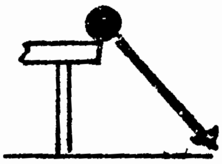


Uyise uyayiyeka xa iku-A. Umfanekiso obonisa kakuhle indlela eyakuhanjwa yintombazana yakuba iyekiwe yile:

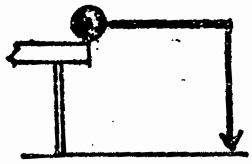


6. Lo mfanekiso ubonisa ibhola iqengqeleka ngamandla phezu kwetafile, ibheka kwicala langasekunene.Yakufika esiphelweni setafile iyawa. Indlela eya kuhamba ngayo ukuya emhlabeni ibonakaliswe kakuhle apha :

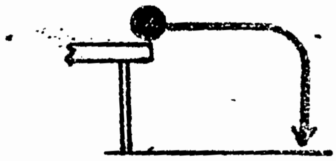




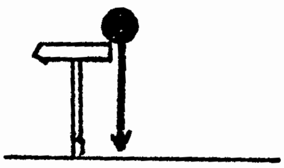
(a)



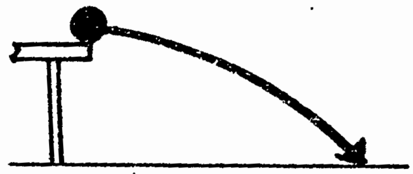
(b)



(c)

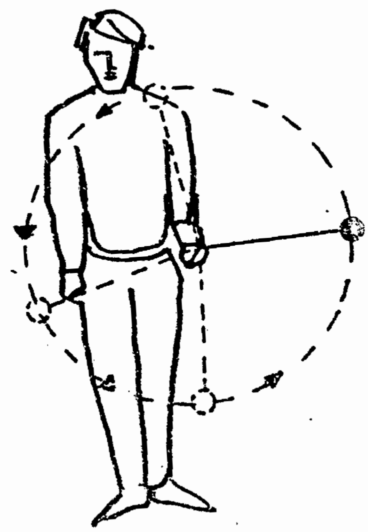


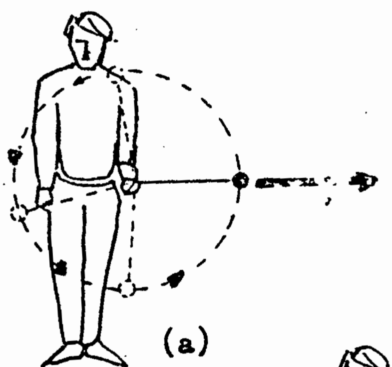
(d)



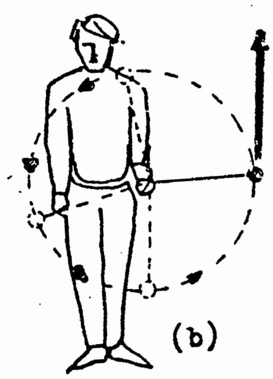
(e)

7. Lo mfanekiso ubonisa indoda ijikelezisa ibhola ebotshelelwe kumtya ophambi kwayo Uyayiyeka intambo ihambe xa ibhola iku-A. Indlela eza kuhamba ngayo ibhola xa iyekiwe yile :

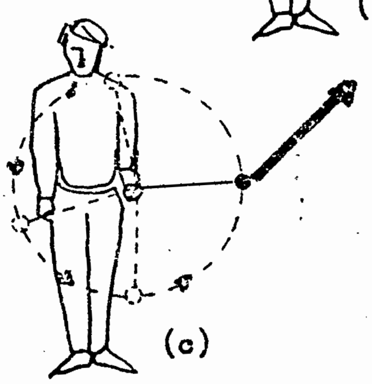




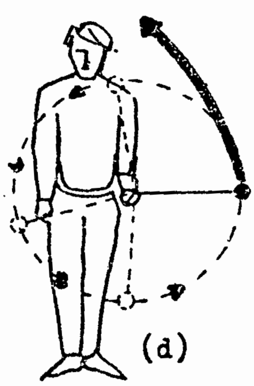
(a)



(b)



(c)

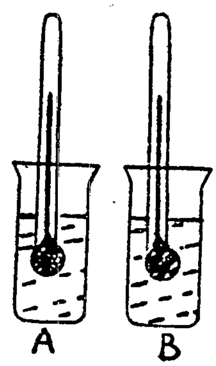


(d)

ICANDELO D : INKCAZELO

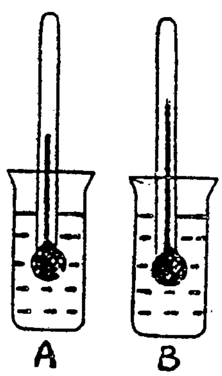
Kweli candelo, kufuneka uthelekise amaqondo amabini obushushu. Oku kuthelekisa uya kwenza ngokuthi uthelekise ubude bendawo ehanjwa yintsimbi yezixhobo zokulinganisa iqondo lobushushu kwizixhobo, zokulinganisa iqondo lobushushu ezimbini ezifanayo.

(i)



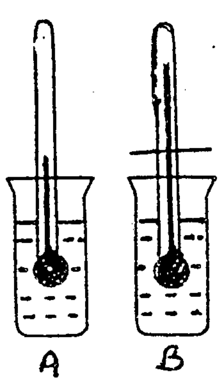
uA noB bakwiqondo lobushushu
uA noB bakwiqondo elifanayo
Zombini ziyalingana ngobushushu

(ii)



Iqondo lobushushu lika-B lingaphezulu kuna ku-A.
U-B ushushu kuno-A.

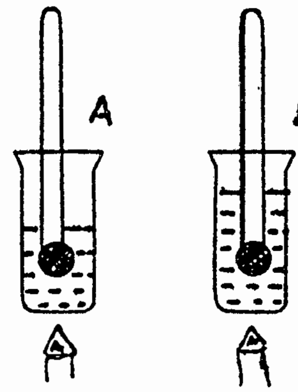
(iii)

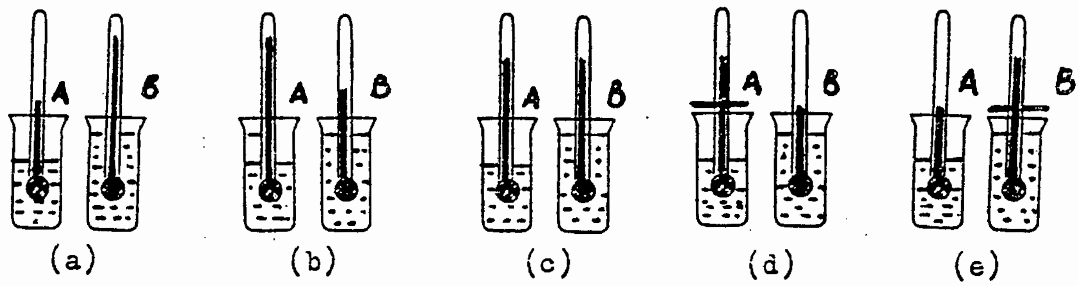


Ubude bendawo ehanjwa yintsimbi yesixhobo sokulinganisa iqondo lobushushu ku-B, bulingana nobuka-A, buphinda-phindwe kabini.

1.

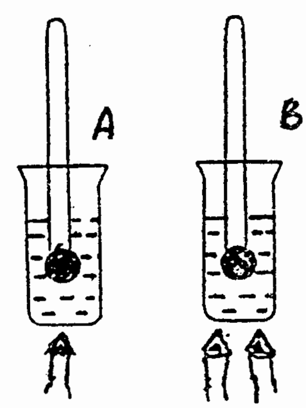
Lo mfanekiso ubonisa iibhikha (beakers) ezimbini ezinamanzi ngokulinganayo zinezixhobo ezimbini ezifanayo zokulinganisa iqondo lobushushu. Ibhikha B inamanzi aphindwe ngokubini kuno-A. La manzi kwezibhikha zombini abiliswa ngomlilo olinganayo, zombini zibila ngokufanayo.. Umfanekiso othelekisa kakuhle iqondo lobushushu kwezi zixhobo ngulo :

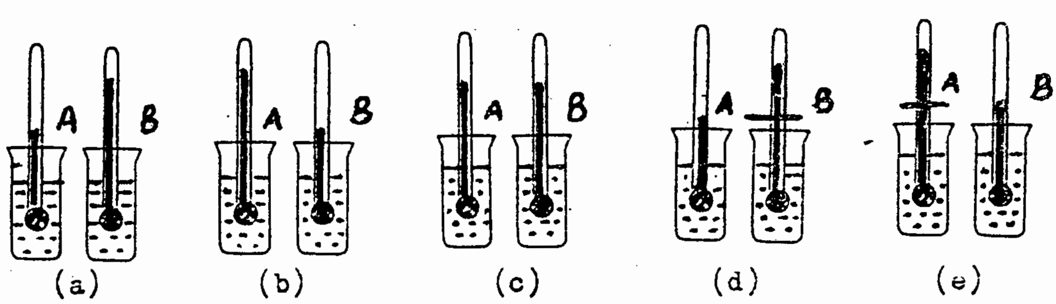




2.

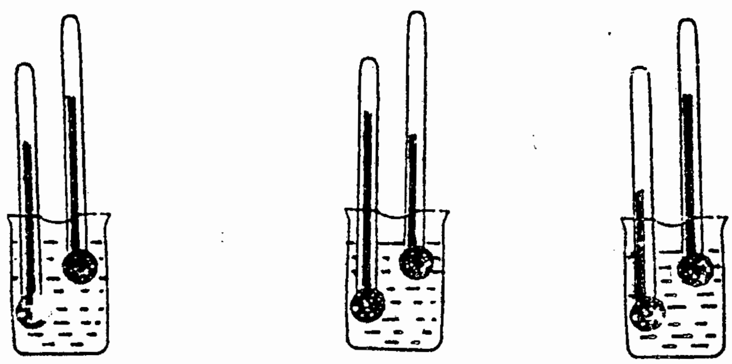
Lo mfanekiso ubonisa iibhikha ezimbini ezinamanzi alinganyao nezixhobo ezifanayo zokulinganisa iqondo lobushushu. La manzi abiliswa ngobushushu obulinganayo. UBhikha A ubaselwa ngomlilo omnye kodwa zombini zombini ziyabila. Umfanekiso othelekisa kakuhle amaqondo obushushu kwezi zixhobo ngulo :





3.

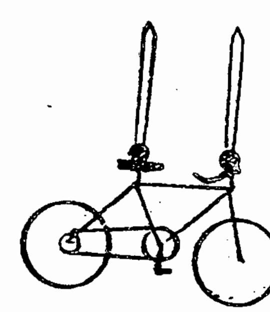
Lo mfanekiso ubonisa amanzi abilayo emlilweni. Izixhobo ezimbini ezifanayo zokulinganisa iqondo lobushushu (thermometer) zifakwe emanzini abilayo nje ngoko uzibona. Umfanekiso othelekisa kakuhle ubungakanani bobushushu kwezi zixhobo ngulo :

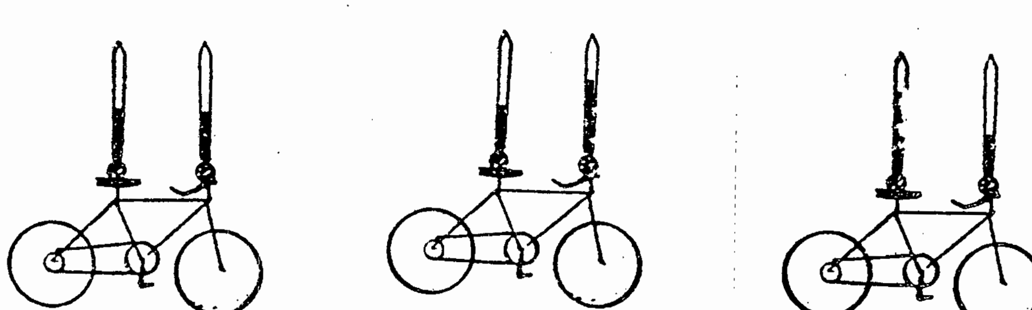


(a) (b) (c)

4.

Nentsasa ebandayo yobusika inkwenkwe isebenzisa isixhobo sokulinganisa ubushushu (thermometer) ukuthelekisa ubushushu kwisali yeplastiki kunye nobushushu bemiphambo yentsimbi yebhayisekike. Umfanekiso othelekisa kakuhle amaqondo obushushu kwizixhobo ngulo :

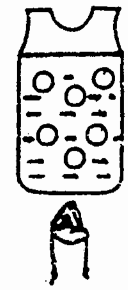




(a) (b) (c)

5.

Lo mfanekiso ubonisa mamanzi esekuluthuba ebila kwibhikha (beaker). Amaqamza egesi/omoya anyukela ngaphezulu. La maqamza athanda ukuba nezi zinto zilandelayo :



(a) Umoya (air

(b) Ihaydrojini (hydrogen) nomongomoya (oxygen)

(c) Umphunga

(d) Umoya oxutywe nehaydrojini kunye nomongomoya

(e) INaytrojini (nitrogen) nomongomoya (oxygen) zixutyiwe.

APPENDIX B: STATISTICAL DATA

SAMPLE STATISTICS.

A. Cape and Transkei: Standard and Sex.

Origin	Standard	Sex: Boys	Girls	Total
Cape	4	123	158	281
	5	135	159	294
	6	124	150	274
	7	161	149	310
	8	164	97	261
	9	218	196	414
	Total	925	909	1834
Transkei	4	74	78	152
	5	67	99	166
	6	72	77	149
	9	7	18	25
	Total	220	272	492

B. Cape: Town and Country: Standard and Sex.

Area	Standard	Sex: Boys	Girls	Total
Town	4	78	111	189
	5	97	111	208
	6	86	101	187
	7	110	102	212
	8	116	63	179
	9	140	128	268
	Total	627	616	1243
Country	4	45	47	92
	5	38	48	86
	6	38	49	87
	7	51	47	98
	8	48	34	82
	9	78	68	146
	Total	298	293	591

C. Cape: Town and Country: Language groups.

Area	Standard	Language			
		Afr.	Eng.	Other	Total
	4	89	97	2	189
	5	107	98	3	208
Town	6	87	99	1	187
	7	82	127	3	212
	8	75	97	7	179
	9	150	117	1	268
	Total	590	635	17	1242
	4	81	10	1	92
	5	75	9	2	86
Country	6	76	9	3	88
	7	97	1	0	98
	8	82	0	0	82
	9	133	10	3	146
	Total	544	39	9	592

D: Questionnaire response statistics.

Question A 1.

	Options. a	b	c	d	e	Total.
Overall	34	33	6.3	12	14.7	100
Cape.	31.2	32.7	1.8	13.4	20.8	99.9
Transkei.	44.4	19.0	17.9	9.1	9.7	100.1
Cape:						0
Std.4	27	33.8	1.8	12.5	24.9	100
Std.5	22.1	38.1	1	14.6	24.1	99.9
Std.6	45.3	25.9	2.6	13.1	13.1	100
Std.7	41.3	26.1	4.8	10.6	17.1	99.9
Std.8	28	49.8	3.4	11.9	6.9	100
Std.9 Sc.	16.6	57	4.3	10.6	11.5	100
Std.9 NSc.	39.7	27.4	5	17.9	10.1	100.1
						0
Afrikaans.	28	43	2.5	11.3	15.2	100
English.	36.2	31.3	4.2	13.7	14.6	100
						0
Boys.	29.7	41.3	3.6	11.6	13.8	100
Girls.	33.1	31.9	2.8	14.1	18.2	100.1
						0
Town.	27.5	41.9	2	12.4	16.3	100.1
Country.	32.7	39.5	2.4	11.6	13.8	100
						0
Transkei:						0
						0
Std.4.	52	20.4	15.1	4.6	7.9	100
Std.5	48.8	12.2	22.6	5.5	11	100.1
Std.6.	31.8	25	15.5	17.6	10.1	100
						0
Boys.	47.2	20.3	13.7	10.4	8.5	100.1
Girls.	42.1	17.9	21.4	7.9	10.7	100

Question A 2.

Options.

	a	b	c	d	e	
Overall	27.5	19.1	18.2	17.2	18	100
						0
Cape.	28.5	15.9	22.2	14	19.3	99.9
Transkei.	22.6	24.9	14.6	31	6.9	100
						0
Cape:						0
						0
Std.4	34.5	14.2	24.9	8.9	17.4	99.9
Std.5	28.6	18	20.4	9.5	23.5	100
Std.6	22.3	15.4	21.2	24.2	16.8	99.9
Std.7	30.8	16.9	18.8	16.6	16.9	100
Std.8	27.3	21.5	15.8	9.6	25.8	100
Std.9 Sc.	32.8	19.6	11.5	7.2	28.9	100
Std.9 NSc.	23.5	19.6	19	20.7	17.3	100.1
						0
Afrikaans.	29.4	17.8	17	14.6	21.2	100
English.	26.9	18.8	18.5	12.3	23.5	100
						0
Boys.	26.4	17	17.2	11.9	27.4	99.9
Girls.	31.3	18.4	20.8	15.3	14.2	100
						0
Town.	31.7	17.2	19.4	12.8	18.9	100
Country.	27.4	15.3	18.8	17.3	21.2	100
						0
Transkei:						0
						0
Std.4.	19.7	28.3	13.2	28.3	10.5	100
Std.5	22.9	24.7	6	39.8	6.6	100
Std.6.	25.2	21.8	25.9	23.8	3.4	100.1
						0
Boys.	20.7	22.5	18.3	31.5	7	100
Girls.	24.2	27	11.5	30.6	6.7	100

Question A 3.

Options.

	a	b	c	d	e	
Overall	17.2	12.3	15.2	19.7	35.5	99.9
Cape.	12.4	17	12.1	16.2	42.2	99.9
Transkei.	5.4	4.5	13.5	48.1	28.5	100
Cape:						
Std.4	11.1	20.4	12.2	17.9	38.4	100
Std.5	15.6	16.3	11.6	10.2	46.3	100
Std.6	10.3	14.3	12.5	21	41.9	100
Std.7	20.3	13.2	17.4	15.5	33.5	99.9
Std.8	24.7	14.7	19.7	6.6	34.4	100.1
Std.9 Sc.	48.9	7.7	16.2	2.6	24.7	100.1
Std.9 NSc.	12.3	11.2	19.6	14	43	100.1
						0
Afrikaans.	26.8	13.9	16.5	9	33.8	100
English.	17.6	12.7	13.3	15.4	40.9	99.9
						0
Boys.	22.4	13.4	14.8	9.6	40	100.2
Girls.	18	15.2	15.9	16	35	100.1
						0
Town.	24.8	13.3	16.2	10.2	35.5	100
Country.	19.5	16.4	16.6	12.5	35	100
						0
Transkei:						0
						0
Std.4.	5.3	2.6	12.6	50.3	29.1	99.9
Std.5	4.8	3.6	13.3	54.8	23.5	100
Std.6.	6	7.4	14.8	38.3	33.6	100.1
						0
Boys.	3.3	2.8	11.8	42.9	39.2	100
Girls.	7.1	5.9	15	52.4	19.8	100.2

Question A 4.

Options.

	a	b	c	d	e	
						0
Overall	30.7	39.3	8.8	13.2	8	100
						0
Cape.	33.1	39.3	8.6	11.6	7.4	100
Transkei.	60.9	8.2	8.2	18.6	4.1	100
						0
Cape:						0
						0
Std.4	35	41.8	8.2	10	5	100
Std.5	31.3	41.2	8.2	9.5	9.9	100.1
Std.6	33	34.8	9.5	15.4	7.3	100
Std.7	21.3	45.5	7.1	13.2	12.9	100
Std.8	8.8	59	13.4	11.1	7.7	100
Std.9 Sc.	6	67.2	6.4	8.9	11.5	100
Std.9 NSc.	26.3	41.9	8.9	14.5	8.4	100
						0
Afrikaans.	20.8	48.5	10.2	11.4	9	99.9
English.	21	49.7	6.6	11.6	11.2	100.1
						0
Boys.	16.3	54.9	10.2	10	8.7	100.1
Girls.	30.7	39	7.4	13.5	9.4	100
						0
Town.	25.1	46.8	9.7	11	7.8	100.4
Country.	23.4	48.4	9.6	10.3	8.3	100
						0
Transkei:						0
						0
Std.4.	68.9	9.9	7.3	10.6	3.3	100
Std.5	58.2	8.5	7.9	20.6	4.8	100
Std.6.	55.8	6.1	9.5	24.5	4.1	100
						0
Boys.	57.8	7.6	10.9	20.9	2.8	100
Girls.	63.5	8.7	6	16.7	5.2	100.1

Question A 5.

Options.

	a	b	c	d	
Overall	23.9	39.6	21.3	15.3	100.1
					0
Cape.	24.3	35.5	21	19.2	100
Transkei.	10.6	49.5	15.4	24.5	100
					0
Cape:					0
					0
Std.4	20	32.9	19.6	27.5	100
Std.5	26.6	37.9	24.2	11.3	100
Std.6	26.3	35.6	18.9	19.3	100.1
Std.7	26.5	41.1	22.3	10	99.9
Std.8	32.6	39.8	24.5	3.1	100
Std.9 Sc.	36.2	29.4	30.6	3.8	100
Std.9 NSc.	22.9	44.7	19	13.4	100
					0
Afrikaans.	31.3	38.9	21.7	8.1	100
English.	26.1	34.2	27.3	12.4	100
					0
Boys.	31.2	34.1	25.9	8.8	100
Girls.	23.2	40.3	19.6	16.9	100
					0
Town.	27.8	38.9	22.7	10.6	100
Country.	29.2	37.9	19.9	13.1	100.1
					0
Transkei:					0
					0
Std.4.	9.3	45.7	14.6	30.5	100.1
Std.5	14.1	53.4	14.7	17.8	100
Std.6.	8.2	49	17	25.9	100.1
					0
Boys.	8.1	51.2	16.1	24.6	100
Girls.	12.8	48	14.8	24.4	100

Question A 6.

Options.

	a	b	c	
Overall	49.8	18.8	31.3	99.9
				0
Cape.	39.5	14.7	45.8	100
Transkei.	38.1	34.4	27.5	100
				0
Cape:				0
				0
Std.4	32.9	16.4	50.7	100
Std.5	35.7	14.3	50	100
Std.6	50.4	13.5	36.1	100
Std.7	63.5	10.3	26.1	99.9
Std.8	67	15.3	17.6	99.9
Std.9 Sc.	74	14	11.9	99.9
Std.9 NSc.	49.2	21.2	29.6	100
				0
Afrikaans.	57	12.6	30.3	99.9
English.	58.7	14.4	26.9	100
				0
Boys.	60.2	14.3	25.5	100
Girls.	45.4	15	39.6	100
				0
Town.	52.6	14.4	32.9	99.9
Country.	52	13.4	34.6	100
				0
Transkei:				0
				0
Std.4.	43.4	33.6	23	100
Std.5	34.9	40.4	24.7	100
Std.6.	36.1	28.6	35.4	100.1
				0
Boys.	39.6	35.8	24.5	99.9
Girls.	36.8	33.2	30	100

Question A 7.

Options.

	a	b	c	d	e	
Overall	25	18.1	23.2	14.1	19.7	100.1
						0
Cape.	16.4	23	29	10.2	21.4	100
Transkei.	8.6	8.6	31	44.1	7.7	100
						0
Cape:						0
						0
Std.4	12.9	24.7	32.6	12.9	16.8	99.9
Std.5	19.7	20.1	29.6	9.9	20.7	100
Std.6	16.5	24.5	24.5	7.7	26.7	99.9
Std.7	34.5	22.9	17.7	3.9	21	100
Std.8	39.6	19.6	13.5	0.4	26.9	100
Std.9 Sc.	59.6	10.2	8.1	0	22.1	100
Std.9 NSc.	24.6	19.6	17.9	10.1	27.9	100.1
						0
Afrikaans.	33.6	18.9	16.3	4.5	26.7	100
English.	32.9	21	24.1	4.2	17.7	99.9
						0
Boys.	34.2	20.1	20.2	3.6	22	100.1
Girls.	24	21	22	9.3	23.7	100
						0
Town.	30.4	20.1	19.9	6.3	23.3	100
Country.	27.9	20.4	15.4	7.5	28.7	99.9
						0
Transkei:						0
						0
Std.4.	7.2	6.6	26.3	53.9	5.9	99.9
Std.5	9	6.6	30.1	47	7.2	99.9
Std.6.	9.5	12.9	36.7	30.6	10.2	99.9
						0
Boys.	6.6	10.3	39	36.6	7.5	100
Girls.	10.3	7.1	24.2	50.4	7.9	99.9

Question A 8.

Options.

	a	b	c	d	
Overall	22.4	32.7	20.3	24.6	100
					0
Cape.	25.9	24.2	29	20.9	100
Transkei.	21.6	21	20.7	36.7	100
					0
Cape:					0
					0
Std.4	20.7	20	37.9	21.4	100
Std.5	22.2	21.8	35.4	20.7	100.1
Std.6	35.4	31	13.1	20.4	99.9
Std.7	25.8	42.3	10	21.9	100
Std.8	18	43.7	13.4	24.9	100
Std.9 Sc.	5.5	59.6	13.2	21.7	100
Std.9 NSc.	30.7	31.8	17.9	19.6	100
					0
Afrikaans.	21.5	36.6	18.1	23.8	100
English.	22.5	43.5	15.6	18.5	100.1
					0
Boys.	20.1	36.4	20.3	23.2	100
Girls.	25.2	34.2	20.6	20	100
					0
Town.	24.1	33.6	19.8	22.5	100
Country.	20.6	32.4	22.4	24.6	100
					0
Transkei:					0
					0
Std.4.	21.9	16.6	24.5	37.1	100.1
Std.5	17.7	19.5	24.4	38.4	100
Std.6.	25.7	27	12.8	34.5	100
					0
Boys.	22.1	17.8	23.9	36.2	100
Girls.	21.2	23.6	18	37.2	100

Question A 9.

Options.

	a	b	c	d	e	
Overall	7.8	17.9	6.7	12.1	55.5	100
Cape.	4.8	10.9	4.7	12.5	67	99.9
Transkei.	26.9	12.5	8	9.7	43	100.1
						0
Cape:						0
						0
Std.4	6.8	14.3	4.3	18.2	56.4	100
Std.5	4.1	8.8	6.8	9.5	70.7	99.9
Std.6	3.7	9.6	2.9	9.9	73.9	100
Std.7	1.3	20.4	7.8	13.9	56.6	100
Std.8	0.4	24.6	11.5	13.5	50	100
Std.9 Sc.	0.4	44.7	7.2	7.7	40	100
Std.9 NSc.	3.9	16.8	3.4	17.3	58.7	100.1
						0
Afrikaans.	1.8	22.7	8.3	10.7	56.4	99.9
English.	2.3	17.7	5.2	11.4	63.4	100
						0
Boys.	2.5	20.5	7.6	11.6	57.8	100
Girls.	3.4	18.2	5.2	13.9	59.4	100.1
						0
Town.	2.7	20.7	6.3	13.9	56.3	99.9
Country.	2.8	20.1	7.9	12.3	56.9	100
						0
Transkei:						0
						0
Std.4.	38.8	11.8	9.2	7.9	32.2	99.9
Std.5	23.8	11.6	9.1	10.4	45.1	100
Std.6.	18.1	14.1	5.4	10.7	51.7	100
						0
Boys.	24.1	11.8	6.6	8	49.5	100
Girls.	29.2	13	9.1	11.1	37.5	99.9

Question A 10

Options.

	a	b	c	d	e	
						0
Overall	26.1	12.9	8.4	25.8	26.8	100
						0
Cape.	30.5	8.3	5.1	28.8	27.4	100.1
Transkei.	17.2	15.9	19.6	34.4	12.9	100
						0
Cape:						0
						0
Std.4	31.3	8.2	4.3	30.6	25.6	100
Std.5	29.9	11.2	4.8	23.8	30.3	100
Std.6	30.4	5.1	6.2	32.2	26	99.9
Std.7	25.8	15.2	6.5	26.1	26.5	100.1
Std.8	35.6	15.7	4.6	12.3	31.8	100
Std.9 Sc.	23.4	18.3	3.8	8.5	46	100
Std.9 NSc.	20.1	11.7	7.8	30.2	30.2	100
						0
Afrikaans.	27.7	14.6	5.5	21.2	31	100
English.	31	10	4.8	21.4	32.8	100
						0
Boys.	32.8	14.4	4.4	16.8	31.6	100
Girls.	24.2	9.8	6.3	30.4	29.4	100.1
						0
Town.	25.4	13.9	5.1	23.7	31.9	100
Country.	27	13.1	6.8	24.6	28.5	100
						0
Transkei:						0
						0
Std.4.	19.1	23.7	17.8	25.7	13.8	100.1
Std.5	17.6	13.3	18.8	41.8	8.5	100
Std.6.	14.9	10.8	22.3	35.1	16.9	100
						0
Boys.	19.7	13.1	19.2	35.7	12.2	99.9
Girls.	15.1	18.3	19.8	33.3	13.5	100

Question A 11

Options.

	a	b	c	d	e	
Overall	6.5	28.4	12.8	19.8	32.5	100
Cape.	2.9	20.5	12.2	27.1	37.2	99.9
Transkei.	24.4	14.4	3.7	9.7	47.8	100
						0
Cape:						0
						0
Std.4	2.1	17.4	9.6	30.6	40.2	99.9
Std.5	4.1	23.1	10.9	29.3	32.7	100.1
Std.6	2.6	20.8	16.4	21.2	39.1	100.1
Std.7	1.6	36.5	14.8	19	28.1	100
Std.8	1.1	42.9	21.1	16.9	18	100
Std.9 Sc.	0	58.3	15.7	11.9	14	99.9
Std.9 NSc.	2.2	26.3	20.7	27.9	22.9	100
						0
Afrikaans.	2.4	36.5	16.6	21.3	23.2	100
English.	1.3	33.5	14	17.9	33.3	100
						0
Boys.	1.6	39.8	17.8	18.4	22.4	100
Girls.	2.4	23.7	12.5	26.5	34.9	100
						0
Town.	2.2	34.1	15.6	22.4	25.8	100.1
Country.	2.6	30.1	18	25	24.3	100
						0
Transkei:						0
						0
Std.4.	30.7	19.3	2.7	7.3	40	100
Std.5	25.5	10.9	3.6	6.7	53.3	100
Std.6.	16.8	13.4	4.7	15.4	49.7	100
						0
Boys.	17.8	13.1	5.6	8	55.4	99.9
Girls.	29.9	15.5	2	11.2	41.4	100

Question A 12

Options.

	a	b	c	
				0
Overall	11.3	11.4	77.3	100
				0
Cape.	7.9	7.2	84.9	100
Transkei.	33.5	33.1	33.3	99.9
				0
Cape:				0
				0
Std.4	8.9	7.8	83.3	100
Std.5	6.8	7.8	85.4	100
Std.6	8	5.8	86.1	99.9
Std.7	4.5	5.5	90	100
Std.8	2.3	2.7	95	100
Std.9 Sc.	0.4	1.3	98.3	100
Std.9 NSc.	7.3	8.4	84.4	100.1
				0
Afrikaans.	3.9	4.7	91.5	100.1
English.	5.4	4.8	89.8	100
				0
Boys.	3	4.3	92.6	99.9
Girls.	8	6.9	85	99.9
				0
Town.	5.4	5.4	89.2	100
Country.	4.4	5.9	89.7	100
				0
Transkei:				0
				0
Std.4.	32.5	37.1	30.5	100.1
Std.5	30.9	33.9	35.2	100
Std.6.	37.6	28.2	34.2	100
				0
Boys.	32.4	31.5	36.2	100.1
Girls.	34.5	34.5	31	100

Question B 1.

	Options.					Total
	a	b	c	d	e	
Overall	29.2	11.6	3.7	50.6	4.9	100
						0
Cape.	28.5	10.8	2.2	54.6	3.8	99.9
Transkei.	23.3	17.9	10.4	35.6	12.7	99.9
						0
Cape:						0
						0
Std.4	10	11.4	3.9	69.4	5.3	100
Std.5	23.1	15.6	2	54.1	5.1	99.9
Std.6	53.5	5.1	0.7	39.9	0.7	99.9
Std.7	34.8	9.4	1	53.5	1.3	100
Std.8	34.1	8.4	1.1	53.6	2.7	99.9
Std.9 Sc.	39.1	6	0.9	52.3	1.7	100
Std.9 NSc.	20.7	14	2.8	60.3	2.2	100
						0
Afrikaans.	34.9	8.3	1.3	53	2.4	99.9
English.	39.6	10.6	1	46.9	1.9	100
						0
Boys.	42.5	9	0.8	47.1	0.6	100
Girls.	19.3	10.9	2.8	62.1	5	100.1
						0
Town.	34.4	8.6	0.8	53.1	3.1	100
Country.	24.7	10.1	2	61.1	2	99.9
						0
Transkei:						0
						0
Std.4.	18	19.3	11.3	35.3	16	99.9
Std.5	22.9	18.7	8.4	36.7	13.3	100
Std.6.	29.3	15.6	11.6	34.7	8.8	100
						0
Boys.	23.8	17.6	7.1	42.9	8.6	100
Girls.	22.9	18.2	13	29.6	16.2	99.9

Question B 2.

	Options. a	b	c	d	e	Total
						0
Overall	20.7	47.4	8.5	10.7	12.8	100.1
						0
Cape.	24.3	47.7	6.8	9.7	11.5	100
Transkei.	22	28.7	19	17	13.4	100.1
						0
Cape:						0
						0
Std.4	24.6	56.2	4.6	7.1	7.5	100
Std.5	24.2	45.7	9.6	10.6	9.9	100
Std.6	24.2	41	6.2	11.4	17.2	100
Std.7	22.3	53.2	3.9	9.7	11	100.1
Std.8	13.8	59	5.7	6.5	14.9	99.9
Std.9 Sc.	12.8	57.4	4.3	6.4	19.1	100
Std.9 NSc.	17.9	53.6	5	14	9.5	100
						0
Afrikaans.	18.2	54	5.5	9.5	12.8	100
English.	22	46.4	6.6	8.5	16.6	100.1
						0
Boys.	18.8	43.6	7.6	11.1	18.8	99.9
Girls.	21.9	60.7	3.7	7.3	6.4	100
						0
Town.	18.3	53.2	5.6	10.2	12.7	100
Country.	17.9	58	5.2	9.6	9.4	100.1
						0
Transkei:						0
						0
Std.4.	31.1	25.3	15.2	12.6	15.9	100.1
Std.5	18.2	29.1	23.6	17	12.1	100
Std.6.	16.9	31.8	17.6	21.6	12.2	100.1
						0
Boys.	23.7	26.1	21.3	15.6	13.3	100
Girls.	20.6	30.8	17	18.2	13.4	100

Question B 3.

	Options.					Total
	a	b	c	d	e	0
						0
Overall	16.4	38.6	13.8	11.1	20.1	100
						0
Cape.	17.7	39.1	12.1	12.9	18.2	100
Transkei.	12.5	26.1	19.9	13	28.5	100
						0
Cape:						0
						0
Std.4	17.1	38.8	6	14.6	23.5	100
Std.5	22.4	41.2	9.9	11.6	15	100.1
Std.6	13.3	37.3	20.7	12.5	16.2	100
Std.7	15.2	45.5	12.9	10.3	16.1	100
Std.8	16.9	47.1	12.6	7.3	16.1	100
Std.9 Sc.	20	46.4	12.8	6.4	14.5	100.1
Std.9 NSc.	17.9	36.9	12.3	10.1	22.9	100.1
						0
Afrikaans.	16.7	45.9	12.4	8.7	16.3	100
English.	18.7	40	15.6	11.3	14.4	100
						0
Boys.	21.1	45.9	15	8	10	100
Girls.	13.8	38.1	9.8	13.1	25.2	100
						0
Town.	19.7	40.2	13.8	8	18.3	100
Country.	14.2	47.8	8.3	10.9	18.8	100
						0
Transkei:						0
						0
Std.4.	7.9	25.7	25.7	13.8	27	100.1
Std.5	15.9	20.7	15.2	11.6	36.6	100
Std.6.	13.6	32.7	19	13.6	21.1	100
						0
Boys.	11.5	28.2	19.1	12	29.2	100
Girls.	13.4	24.4	20.5	13.8	28	100.1

Question B 4.

	Options. a	b	c	Total
				0
Overall	6.2	67.4	26.3	99.9
				0
Cape.	3.9	61.9	34.2	100
Transkei.	18.4	53.8	27.9	100.1
				0
Cape:				0
				0
Std.4	3.2	54.1	42.7	100
Std.5	5.4	52.4	42.2	100
Std.6	3	80.4	16.6	100
Std.7	3.5	81.3	15.2	100
Std.8	0.8	84.3	14.9	100
Std.9 Sc.	1.3	74.5	24.3	100.1
Std.9 NSc.	5	72.6	22.3	99.9
				0
Afrikaans.	3.1	75.2	21.7	100
English.	2.3	73.3	24.4	100
				0
Boys.	2.6	76.4	21	100
Girls.	3.7	65.6	30.6	99.9
				0
Town.	3.2	74.4	22.4	100
Country.	3	68.6	28.4	100
				0
Transkei:				0
				0
Std.4.	23.8	49.7	26.5	100
Std.5	14.5	49.7	35.8	100
Std.6.	17	62.6	20.4	100
				0
Boys.	18.6	54.8	26.7	100.1
Girls.	18.2	53	28.9	100.1

Question B 5.

	Options.			Total
	a	b	c	
Overall	46.8	38.2	14.9	99.9
				0
Cape.	45.2	40.5	14.3	100
Transkei.	40.7	30.7	28.5	99.9
				0
Cape:				0
				0
Std.4	44.4	39.8	15.8	100
Std.5	40.1	46.9	12.9	99.9
Std.6	51.5	34.2	14.3	100
Std.7	54.8	37.1	8.1	100
Std.8	46.7	45.2	8	99.9
Std.9 Sc.	49.1	44.9	6	100
Std.9 NSc.	55.9	31.3	12.8	100
				0
Afrikaans.	48.7	40.9	10.4	100
English.	48.1	42.5	9.4	100
				0
Boys.	42.9	47.6	9.5	100
Girls.	54.4	32.8	12.8	100
				0
Town.	52	37.6	10.4	100
Country.	45.7	42.7	11.6	100
				0
Transkei:				0
				0
Std.4.	48	27	25	100
Std.5	40.7	25.3	34	100
Std.6.	33.1	40.7	26.2	100
				0
Boys.	40.4	29.8	29.8	100
Girls.	41	31.5	27.5	100

Question C 1

Options.

	a	b	c	d	e	
Overall	6.7	28.9	20.6	9.8	34	100
						0
Cape.	4.8	31.1	22.5	9.1	32.5	100
Transkei.	14.1	33.1	14.1	8	30.7	100
						0
Cape:						0
						0
Std.4	4.6	37	20.3	9.6	28.5	100
Std.5	3.1	32.7	22.1	10.2	32	100.1
Std.6	7	23.2	25.1	7.4	37.3	100
Std.7	5.5	30	22.3	9.7	32.6	100.1
Std.8	4.2	19.9	24.1	13.8	37.9	99.9
Std.9 Sc.	2.6	22.3	16.7	10.7	47.6	99.9
Std.9 NSc.	7.3	25.7	26.3	10.6	30.2	100.1
						0
Afrikaans.	5.7	26.1	20.2	9.9	38.1	100
English.	2.9	25.6	25.4	10.4	35.6	99.9
						0
Boys.	3.8	20.7	19.2	13	43.3	100
Girls.	5.8	34.8	25.5	7.4	26.5	100
						0
Town.	5.8	28.4	19.9	10.9	35.5	100.5
Country.	5.9	28.6	18.8	10.1	36.5	99.9
						0
Transkei:						0
						0
Std.4.	12.5	32.9	12.5	7.2	34.9	100
Std.5	13.3	29.7	17	7.3	32.7	100
Std.6.	16.6	37.2	12.4	9.7	24.1	100
						0
Boys.	11	34.3	11.9	8.1	34.8	100.1
Girls.	16.7	32.1	15.9	7.9	27.4	100

Question C 2

Options.

	a	b	c	
Overall	26.7	62.2	11.1	100
				0
Cape.	28.6	60.7	10.7	100
Transkei.	14.1	73.9	12	100
				0
Cape:				0
				0
Std.4	24.6	64.1	11.4	100.1
Std.5	26.9	64.6	8.5	100
Std.6	34.6	52.9	12.5	100
Std.7	28.4	58.1	13.5	100
Std.8	36.8	52.5	10.7	100
Std.9 Sc.	29.6	63.1	7.3	100
Std.9 NSc.	29.8	60.1	10.1	100
				0
Afrikaans.	30.1	58.9	11	100
English.	32.1	57.5	10.4	100
				0
Boys.	35.8	57.7	6.5	100
Girls.	24	61	15	100
				0
Town.	28.7	59.4	11.9	100
Country.	28.1	62.7	9.2	100
				0
Transkei:				0
				0
Std.4.	11.3	79.5	9.3	100.1
Std.5	8.5	80	11.5	100
Std.6.	23.6	61.1	15.3	100
				0
Boys.	15.4	75.5	9.1	100
Girls.	13.1	72.6	14.3	100

Question C 3

Options.

	a	b	c	d	
					0
Overall	21.4	20.6	11.7	46.4	100.1
					0
Cape.	22.9	18.1	7.5	51.5	100
Transkei.	17.3	13.8	27.9	41	100
					0
Cape:					0
					0
Std.4	20	17.9	6.8	55.4	100.1
Std.5	27.2	19	9.9	43.9	100
Std.6	21.1	17.4	5.6	55.9	100
Std.7	22.3	22.3	8.4	47.1	100.1
Std.8	22.7	27.3	7.7	42.3	100
Std.9 Sc.	22.7	29.2	7.3	40.8	100
Std.9 NSc.	17.9	26.8	7.8	47.5	100
					0
Afrikaans.	23.4	23.3	8.5	44.8	100
English.	23.3	21.6	7.1	48	100
					0
Boys.	25.6	28.4	9.5	36.5	100
Girls.	18	16.3	5.8	59.1	99.2
					0
Town.	20.7	24.5	7.1	47.6	99.9
Country.	22.6	22.2	8.9	46.3	100
					0
Transkei:					0
					0
Std.4.	12.7	14.7	29.3	43.3	100
Std.5	19.4	13.9	27.9	38.8	100
Std.6.	19.9	12.8	26.2	41.1	100
					0
Boys.	18.8	13	21.7	46.4	99.9
Girls.	16.1	14.5	32.9	36.5	100

Question C 4

Options.

	a	b	c	d	e	
Overall	34	14.7	20.8	22.9	7.6	100
						0
Cape.	30	18	20.6	23.9	7.5	100
Transkei.	57.1	12.5	11.6	12.1	6.6	99.9
						0
Cape:						0
						0
Std.4	32.4	18.5	20.3	21.4	7.5	100.1
Std.5	29.3	17.7	20.7	24.5	7.8	100
Std.6	28.3	17.7	20.8	26	7.2	100
Std.7	32.1	14.3	17.2	25.3	11	99.9
Std.8	27.4	10.4	26.6	29.7	5.8	99.9
Std.9 Sc.	22.9	8.7	37.7	26	4.8	100.1
Std.9 NSc.	23	19.7	18.5	28.1	10.7	100
						0
Afrikaans.	28.7	13.8	25.3	24.1	8.2	100.1
English.	27.2	15	22.1	29.3	6.4	100
						0
Boys.	26.4	8.5	32.5	26.9	5.8	100.1
Girls.	30.5	22.2	13	24.4	9.9	100
						0
Town.	28.6	13.4	24.1	24.8	9.1	100
Country.	29.1	17.3	24.2	21.6	7.8	100
						0
Transkei:						0
						0
Std.4.	65.8	11.4	10.1	7.4	5.4	100.1
Std.5	51.2	11.4	13.3	15.7	8.4	100
Std.6.	55	15	11.4	12.9	5.7	100
						0
Boys.	54.1	8.3	16.1	15.6	5.9	100
Girls.	59.6	16	8	9.2	7.2	100

Question C 5

Options.

	a	b	c	d	
Overall	14.6	25.1	19.3	41	100
					0
Cape.	9.9	29	16	45.1	100
Transkei.	31.7	16.6	11.4	40.3	100
					0
Cape:					0
					0
Std.4	11.4	28.1	14.2	46.3	100
Std.5	8.2	30.6	15.3	45.9	100
Std.6	10.3	28.1	18.6	43	100
Std.7	9.4	29.1	19.1	42.4	100
Std.8	10.9	26.8	25.3	37	100
Std.9 Sc.	10.8	19.9	39.4	29.9	100
Std.9 NSc.	11.2	27.5	22.5	38.8	100
					0
Afrikaans.	8.5	28.3	22.8	40.4	100
English.	12	25.8	22.5	39.7	100
					0
Boys.	9.9	29.3	28.2	32.5	99.9
Girls.	10.5	25.4	14.5	49.6	100
					0
Town.	9.3	27.8	22.4	40.5	100
Country.	8.9	29.2	20.6	41.3	100
					0
Transkei:					0
					0
Std.4.	36	12	12.7	39.3	100
Std.5	30.9	22.4	11.5	35.2	100
Std.6.	28.2	14.8	9.9	47.2	100.1
					0
Boys.	30.7	16.1	9.3	43.9	100
Girls.	32.5	17.1	13.1	37.3	100

Question C 6

Options.

	a	b	c	d	e	
Overall	14.1	2.7	7.6	30.2	45.4	100
						0
Cape.	14.8	2.2	7.8	27.5	47.8	100.1
Transkei.	21.8	6.4	7.5	45.2	19.2	100.1
						0
Cape:						0
						0
Std.4	14.6	3.2	7.1	24.6	50.5	100
Std.5	16.3	1.7	8.2	25.5	48.3	100
Std.6	13.4	1.5	8	32.8	44.3	100
Std.7	10.5	0.3	5.6	29.7	53.9	100
Std.8	8.6	1.6	9	20.7	60.2	100.1
Std.9 Sc.	8.3	1.3	5.2	21.8	63.3	99.9
Std.9 NSc.	12.4	2.8	10.1	30.9	43.8	100
						0
Afrikaans.	11.7	1	6.9	24.8	55.5	99.9
English.	11.4	1.6	7.8	28.7	50.6	100.1
						0
Boys.	8.1	1.1	7	14.4	69.4	100
Girls.	16.3	2.4	8	38.9	34.5	100.1
						0
Town.	13	6.9	24.8	54.3		99
Country.	11.4	1.7	7.3	26.2	53.3	99.9
						0
Transkei:						0
						0
Std.4.	18.1	9.4	7.4	47	18.1	100
Std.5	21.7	3.6	6.6	42.2	25.9	100
Std.6.	25.9	6.5	8.6	46.8	12.2	100
						0
Boys.	20	4.9	8.3	49.3	17.6	100.1
Girls.	23.3	7.6	6.8	41.8	20.5	100

Question C 7

Options.

	a	b	c	d	
Overall	12.6	16.1	26.7	44.6	100
					0
Cape.	9	15.6	26.4	49	100
Transkei.	27.6	17.4	15.6	39.4	100
					0
Cape:					0
					0
Std.4	10.7	15.4	26.8	47.1	100
Std.5	8.8	15.6	24.8	50.7	99.9
Std.6	7.4	16	27.6	49	100
Std.7	9.8	18.6	25.5	46.1	100
Std.8	5.9	15.7	35.4	42.9	99.9
Std.9 Sc.	10	14	40.6	35.4	100
Std.9 NSc.	8.5	14.8	29	47.7	100
					0
Afrikaans.	8.1	16.3	30	45.6	100
English.	9.1	15.7	30.7	44.5	100
					0
Boys.	8.3	19.5	33.6	38.6	100
Girls.	9.3	12.1	25.5	53.2	100.1
					0
Town.	7.3	15.4	29	48.3	100
Country.	9.4	15.6	32.6	42.4	100
					0
Transkei:					0
					0
Std.4.	27.2	17.7	16.3	38.8	100
Std.5	28.7	19.5	11.6	40.2	100
Std.6.	26.8	14.5	19.6	39.1	100
					0
Boys.	27.4	18.4	14.4	39.8	100
Girls.	27.8	16.5	16.5	39.1	99.9

APPENDIX C: CHECK LISTS

Appendix C

Checklists for the Science Teacher

Ross Tasker

Appendix C1: A checklist for planning science activities

1 General

Class level: 3 4 5 6 7 Ability: Low Mid High Mixed
No. in class: Work: individually____ in pairs____ groups of____

---

2 Background Thinking

2.1 What in particular do I want to achieve? (Knowledge, manipulative skill, experimental design, attitude)

2.2 What will be the most effective kind of activity to achieve this? (Experimentation, demonstration, exploration, problem solving, project)

2.3 Exactly how will this activity achieve its purpose?

2.4 Are the pupils ready for this activity?
(a) Do they have the background ideas that I expect them to have?

(b) Do they have the required skills for the activity? (Manipulation, observation, classification, graph or data interpretation)

---

3 Setting up and Carrying out the Activity

3.1 How will I convey my purpose for the activity to the pupils?

3.2 What instructions will I need to give the pupils so that the activity will be carried out as I intend?

3.3 How will I present the instructions? (Blackboard, chart, list of tasks, diagram, flow charts, etc.)

3.4 What level of language will I need to use?

3.5 How can I highlight critical design features of the activity so that its main points will not be missed?

3.6 What opportunities need to be provided to learn or review pre-requisite skills?

3.7 What equipment is needed?

3.8 How will the equipment be made available to the pupils?

3.9 How much time should the activity take?

4 Handling the Outcomes

4.1 What directions do I need to give pupils for recording what they are doing, what they observe and what they think it all means?

4.2 What will I do if there is a mismatch between my intended results and the pupils' results and thinking?

OR 4.2 How can other unexpected results and thinking be directed to those of the activity's purpose?

5 Using the Outcomes

5.1 Where will I go from here?

5.2 What alternative activities could I use to further challenge pupils' thinking if necessary?

Appendix C2: A checklist to evaluate a science activity

1 General

Evaluation by SELF COLLEAGUE

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2 Background Thinking

2.1 What purpose for the activity did pupils adopt? (The teacher's or another?)

2.2 How was this shown? (Observation, questioning, individuals etc.)

2.3 Did the kind of activity suit the purpose?

2.4 Were the pupils ready for the activity? Did they have:
(a) appropriate background ideas?
(b) the skills required to carry out the activity as expected?

---

3 Carrying out the Activity

3.1 Did pupils have any trouble working out what to do? If so, what caused the trouble (language, comprehension, unfamiliar equipment, etc)?

3.2 Did pupils appear to really understand what they were doing? (Did pupils understand the design features of the activity?)

3.3 Were there any unexpected problems with using the equipment or materials?

3.4 Did pupils have the skills required to carry out the activity as expected?

3.5 Did the students have enough time to do the activity?

---

4 Handling the Outcomes

4.1 Did the pupils get their *own* results? What did they do with them?

4.2 Were the results 'expected' by the teacher?

4.3 How were the results and thinking of the pupils related to the purpose of the activity — did they draw their own conclusions?

4.4 Did pupil conclusions match those expected by the teacher? If not, was the teacher aware of the mismatch and were any such mismatches effectively considered by the class?

Appendix C3: A checklist for pupil evaluation of a science activity

Please answer the following questions in terms of how *you* see the activity.

1 What were you trying to find out or show?

2 Were the instructions easy to follow?

3 Which words did you find hard?

4 Did you know exactly what to do?

5 Was anything hard to do or understand?

6 If you asked for help, whom did you ask?

7 Why that person?

8 When you did each part of the activity, did you really know what you were doing?

9 If you talked to other pupils about the activity, which parts did you talk about?

10 What were the results *you* got from the activity? What did your results mean to you?

11 When you got a result, did you think it was what the teacher expected you to find out?

12 What did you do with your results?

13 What have the results to do with what you were trying to find out, show, or prove?

14 Did you really understand what you were doing during the activity?