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**A LONGITUDINAL STUDY OF THE
INFORMATION COMMUNICATION
PROCESS AMONG A DEFINED GROUP OF
BASIC AND APPLIED SCIENTISTS IN
SOUTH AFRICA**

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY
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JANETTE GRETCHEN SMITH

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DECLARATION

1. I know that plagiarism is wrong. Plagiarism is to use another's work and to pretend that it is one's own.
2. I have used the augmented Harvard convention for citation and referencing. Each significant contribution to, and quotation in, this assignment from the work, or works, of other people has been attributed, and has been cited and referenced.
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ABSTRACT

It is the premise of this thesis that science and technology influence the lives of all humans and that our collective economic wellbeing, social structure and technological advancement are all affected by the amount of understanding of what is *known* in science and in technology. It is further suggested that technological and scientific advance is largely dependent on the efficient communication of ideas and information as well as the amount and quality of interaction among scientists and technologists. Many factors are currently impacting on the information communication process, not least of which are the burgeoning information industry, globalisation, and rapid technological advances and it is submitted that effective communication of scientific and technological information is pivotal to the success of technological innovation and sustained economic growth and if South Africa is to succeed as a nation concerted efforts should be made to understand the process and develop an environment that promotes the effective exchange of scientific and technical information.

The purpose of this research project was to examine the constituent elements of the information communication process in basic and applied science in South Africa and to establish what cognitive, behavioural and environmental factors lead to the scientists' encounter with the communication process and the consequences of such an encounter. The aim was further to address the role of informal communication, the impact of information and communication technologies, and the effect that various structural and environmental changes that have occurred over the last decades, have had on the communication process.

The methodological approach of the study was based on a conceptual analysis of the literature integrated with an empirical investigation into the communication of information amongst a group of scientists in South Africa. The first component, while providing the basis for the conceptual framework that underpinned the empirical study, also served as a benchmark with which to compare the findings of the empirical study. The empirical investigation adopted a triangulated research design, with both qualitative and quantitative attributes. The specific method that was applied was a small-scale, but in-depth, survey of basic and applied scientists in the field of crystallography in South Africa. The decision to select this research community as the study population was based on the fact that this bounded group of scientists manifested a variety of attributes required to study the communication of information in science. This ranged from the

various ways that they applied crystallography to the variety of work environments. The mutable environment, which included factors such as increased globalisation, technological innovation and growth of electronic media, as well as the many structural and socio-political changes in South Africa, further prompted the researcher to adopt a longitudinal research design. Data was thus collected in both 1990/1 and 2001/2 by means of a series of focus group interviews, personal interviews, telephone interviews and e-mail questionnaires.

It clearly emerged from the study that the crystallographers' information communication behaviour was largely determined by their work environment which again determined their alignment on the basic to applied science continuum. Other factors such as level of seniority and position also played a significant role in the process. The success of the work dynamic largely depended on the presence of a group and collaborative work ethos, and strong leadership. A typical *gatekeeper* role emerged that ensured the cross fertilisation of ideas and new knowledge throughout the organisations. It was further seen that informal communication of information plays an important role in the science communication process in South Africa and in many circumstances face-to-face interpersonal communication is the preferred mode of communication. Informal communication networks and the *invisible college* phenomenon and scientific *elites* were all important factors and often the motivational force behind the information communication process within the crystallographic community.

The environmental and other changes that had occurred during the intervening years of the longitudinal study and which affected the communication process in South Africa were mostly the changing funding structures, organisational models, the effect of the escalating electronic environment and to a lesser extent political changes since 1994. While the more structured and profit orientated organisational models appeared to mostly have a negative impact, the change to a democratic government opened many communication channels that were previously closed to South Africans. The significant increase in the use of electronic modes and systems while not affecting the inherent structure of the communication process did create a far wider range of modes of communication and did have a positive influence on the ease of communicating and cooperating with particularly the international research community.

The theoretical framework and model that conclude the study clearly indicate that the crystallographers', and by analogy any scientist's, information communication behaviour is by no means a simply explainable phenomenon. The communication of information constitutes a very

complex social system with distinct communication and information flow patterns with many internal and external variables interacting synergistically. Information travels through diffuse paths, and individual information generating and seeking behaviour is the result of a network of interactions, involving personal attitudes and backgrounds, work-related roles and functions, specific tasks, situations, as well as the scientist's active role in the information communication system of basic and applied science. It further includes factors such as the scientist's place on the activity continuum (which can range from that of a sociometric star or gatekeeper role to that of quiescence).

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CHAPTER 1

SETTING THE SCENE

1.1. INTRODUCTION

Science and technology affect the lives of all humans in many important ways. Our collective economic wellbeing, social structure and technological advancement are all affected by the amount of understanding of what is *known* in science and in technology. It is further contended that technological innovation, a critical factor in the long-term economic growth of industrial societies, can only function successfully within a social environment that provides incentives and relevant information inputs into the innovative process. It is suggested that scientific and technological advance is largely dependent on the efficient communication of ideas and information as well as the amount and quality of interaction among scientists and technologists. With the growth of scientific and technological enterprise over the years, the information communication process in science and technology has likewise increased both in size and in complexity and this, in turn, has impacted on the effectiveness of the process.

1.2. RATIONALE FOR THE STUDY

Vast investments have been made by an array of organisations to provide systems to assist in the transfer and communication of scientific information. It is submitted that such large investments should be warranted and that the information systems serving the scientific and technical community should be designed to meet their real information communication needs. To achieve such objectives, information professionals should obtain an in-depth understanding of the scientific and technology communities they serve and study the information communication practices of these communities.

In practice, however, many information systems have evolved pragmatically, or have been based on data derived from studies that have not investigated all factors that affect the information communication behaviour of scientists in any depth. The researcher is thus in agreement with Von Seggern who has argued that many studies have not adopted a holistic approach that is based on the problem environment that motivates the information communication process as well as all underlying psychological and social factors that affect the system (1995:100). Many factors are currently impacting on the information communication process, not least of which are the burgeoning information industry, globalisation, and rapid technological advances. These aspects all

warrant investigation in addition to the fact that the outcomes from past studies might now be outdated and irrelevant to the rapidly evolving South African environment.

A factor that is of specific concern to the researcher is whether communication styles are changing as a result of the impact of advances in, and growth of, information communication technologies and systems. A further aspect that motivated the need for this investigation is the paucity of South African studies. The problems outlined above are compounded by the complexity of our society, real economic constraints and above all the fact that our science and technology community is geographically (and in the past also politically) isolated from the forefront of research.

1.3. SIGNIFICANCE OF THE RESEARCH PROJECT

It is the researcher's opinion that effective communication of scientific and technological information is pivotal to the success of technological innovation and sustained economic growth of any country. If South Africa is to succeed as a nation in the new millennium concerted efforts should be made to develop an environment that promotes the effective exchange of scientific and technical information. It is thus proposed that research studies that are based on sound theoretical principles should be conducted to examine the information communication patterns of specific science communities in South Africa. The data derived from such studies could then collectively provide a sound knowledge-base of the process which could be utilised to improve the exchange of scientific and technical information to the benefit of all in South Africa.

1.4. CONCEPT CLARIFICATION

A brief outline will be provided of the key concepts underlying the field of investigation and which will serve as the operational definitions for this study.

1.4.1. INFORMATION, KNOWLEDGE AND DATA

Information is probably one of the most loosely defined concepts that is used ubiquitously across various disciplines. The definitions range from those that are entrenched in a positivist framework, and which attribute only objective meaning to information, to more holistic approaches that view information as a constituent element of human communication and which focus on the adaptive and creative behaviour of humans when interacting with information. It is therefore not surprising that there is a plethora of literature covering the conceptual elements of information and its interrelated constructs, knowledge and data. It is, however, not the purpose of this thesis to provide an

exhaustive analysis of these concepts and only those definitions that were judged to be pertinent and relevant to the thesis topic were therefore examined to arrive at conceptual clarification¹.

Belkin (1978) provides a percipient analysis of the role of information in a recipient-controlled communication system where he refers to information as the message contained in the signals exchanged in the communication process. He suggests that the communication process is instigated when humans react to internal or external stimuli to resolve an anomaly encountered in their knowledge structure. It is his view that information is equivalent to a structural representation of knowledge which is "capable of changing the image structure of some recipient" (1978:82). Miller (2002:Introduction)² in turn proposes that information has no intrinsic meaning, and that in the progression from the industrial age through the information age into the *golden age* of knowledge, society has mistakenly attributed meaning to information rather than accepting that it merely "represents, provokes or evokes meaning" in others. According to Sveiby (1996) information on its own is static and meaningless; it is the message communicated by means of some or other mode and channel and meaning can only be attached to the message once it has been assimilated and interpreted by some or other person. The researcher further suggests that each individual's belief system, cognitive skills, sensory feelings (that is the reference framework of each person) has an affect on the meaning given to the information assimilated and this is why identical information will always be interpreted slightly differently by different people and even by the same person at different times or in different situations. The successful communication of information is therefore contingent on the ability of the receiver to interpret the information received which in turn will depend on the level of common understanding, conceptual development and reference frameworks between sender and recipient.

From the above it is clear that meaning can only be construed from information by human intervention - it is at this stage that it becomes knowledge. Knowledge, therefore "involves the mental processes of comprehension, understanding and learning that go on in the mind and only in the mind" (Wilson, 2002:Knowledge and information). The concept *knowledge* thus implies that human intervention has taken place that orders, interprets, understands, discusses and adds value and meaning to information. Wilson further refers to Polanyi's (1958) concept of tacit knowledge and he submits that because all knowledge is uniquely imbedded in individuals it is by

¹ See for example Artandi, 1973; Belkin, 1978; Belkin & Robertson, 1976; Brookes, 1974; Davenport & Prusak, 1998; Jurisica, 2000; Miller, 2002; Smith, 1981; Sveiby, 1996; Villegas, 2000; Wersig & Windel, 1985; Wiig, 1999; Wilson, 2002; and Ziman, 1969 for more definitive expositions.

² Section headings are used as reference indicators for resources in electronic format that do not indicate page numbers.

nature always tacit. The researcher therefore suggests that the only way that tacit knowledge can be *transformed* into so-called explicit knowledge is when individuals partition certain components of their knowledge and transform that into communicable messages. Such messages would then consist of information, if it is contextualised, or data if it merely consists of simple facts. Data can thus be equated to the lowest level of known facts with no intrinsic meaning. They are discrete, objective facts about events that have not been interpreted and are presented without a context (Davenport & Prusak, 1998). If organised, analysed, synthesised, interpreted and structured they become information³.

Another differentiation that has been presented of these concepts is the level of abstraction, subjectivity and value added, with data ranging at the lowest level and knowledge at the highest. With increased levels of value that is added the levels of ambiguity and abstraction also increases. It is thus suggested that data, information and knowledge can be seen as points along a continuum of increasing value and human contribution. The researcher further suggests that knowledge can be seen as the building block and foundation of all intelligent human activity. It is only once we have acquired understanding, meaning and interpretation that we move away from a senseless accumulation of facts to the state that judgments can be made and meaningful, intelligent, decisions taken.

1.4.2. SCIENCE, BASIC AND APPLIED SCIENCE

The concept *science* refers to any systematic body of knowledge, a particular branch of knowledge, and in its most general sense as *the state of knowing*. The concept, however, is generally used in the literature and in ordinary conversation in a more restrictive sense with the implied meaning that it is the "branch of study in which facts are observed and classified, and usually quantitative laws are formulated and verified; and which involves the application of mathematical reasoning and data to natural phenomena" (South Africa. Department of Arts, Culture, Science and Technology, 1996:108; see also Babbie & Mouton, 2001: 4-15). The concept *pure or basic science* is generally restricted to the fundamental aspects of knowledge without practical applications, while applied science, refers to the practical application of science.

For the purposes of this dissertation the concept *basic science* will be adopted to express the more

³ Although most authorities believe that for data to be transformed into information, it has to acquire context, some also state that information can be independent of context. Others again state that it is data that is communicated and that human interpretation transforms it into information, which when assimilated into a person's reference framework acquires meaning and becomes knowledge.

fundamental or theoretical aspects of science and the concept science will be used in its more restricted sense as relating to that branch of knowledge based on objective principles and which is primarily concerned with the functions of the physical world. It will further be viewed as the generic term that incorporates both basic and applied science.

1.4.3. COMMUNICATION OF SCIENTIFIC INFORMATION

There is no doubt that communication plays an all pervasive and crucial role in any science community and as Abelson (1980:60), a previous editor of *Science*, has stated, "without communication there would be no science". Communication of scientific information should further not be separated from the broader concept of communication, but viewed as a distinct type of communication which is central to the advancement of science. "Only when theory or discovery is either validated or invalidated by the scientific community has science taken place, and that is a process of communication" (Osburn, 1989:278). It should be seen as a social system with a distinct formal and informal structure of institutions and behavioural patterns that controls the interactive flow and generation of scientific information. It is the "totality of publications, facilities, occasions, institutional arrangements, and customs which affect the direct or indirect transmission of scientific messages among scientists" (Menzel in Walker & Hurt, 1990:x). It is a complex process involving several components and elements that interact synergistically and at its simplest it provides the mechanism to transmit intellectual and creative activity from one scientist to another (Shaughnessy, 1989:69).

1.5. FACTORS THAT IMPACT ON THE COMMUNICATION OF INFORMATION IN BASIC AND APPLIED SCIENCE

It is generally accepted that the cumulative corpus of knowledge in science underpins all scientific advancement. The communication and transfer of information is thus an essential component of scientific research and Garvey (1979:126) in his seminal work on information communication in science has suggested that the aim of all scientists is to contribute to the body of knowledge in their field and to achieve this it is important that they actively communicate with fellow scientists.

J.D. Bernal (1901-1970), in addition to being one of the most eminent British scientists of his time and a pioneer of X-ray crystallography, made a considerable contribution to scientific communication and documentation and throughout his life advocated the importance of the communication of information in science (Muddiman, D. 2003). During the late 1940's he

worked with John Kendrew (another crystallographer from Cambridge and future Nobel Prize winner) on a study of the reading habits and information needs of scientists. The outcome of this research was his seminal paper to the Royal Society Scientific Information Conference in 1948 wherein he advocated, amongst others, that more research should be conducted wherein the perspectives and behaviour of scientists should be studied (Bernal, 1949). Bernal clearly indicated in this and subsequent work that the study of the information communication and behaviour of scientists is of fundamental importance for scientific development (Bernal, 1959).

Scientific research is essentially a corporate activity and a distinctive feature and accepted social norm of the scientific community is the concept of a "communality" of ideas, i.e. a shared commodity that belongs to everyone (Kronick, 1988:222). It has further been suggested that the most important function of the communication process is to provide a cumulative record of knowledge in science. Such a record of knowledge serves a normative function, and it constitutes a reference point from which new theory is promulgated and to which new evidence may be added (Gläser, 2003:39; Walker and Hurt, 1990:xiv).

In addition to this dependence on the formal structure of knowledge there is also strong reliance on informal communication networks. The important role of informal communication of information in science has been highlighted by a number of researchers following the early work of Price (1963) on *invisible colleges*. The popularity of interpersonal communication lies in the interactive nature of the exchange process and the stimulation that collegiate interaction provides.

Various studies have further indicated that there is a positive correlation between high levels of communication with colleagues and high performance levels and that performance increases if informal communication links are encouraged. A number of indicators have therefore suggested that scientists who belong to large informal networks are more actively engaged in collaborative research and publication collaboration, they have stronger citation links, they are more innovative, their ideas are transmitted more effectively and they generally have more influence on research than their counterparts who do not belong to such informal networks (Bouazza, 1989; Crane, 1972; Fry, 2006; Garvey, 1979; Garvey & Griffith, 1968, 1971, 1972; Garvey et al. 1970, 1974; Griffith & Miller, 1970; Griffith & Mullins, 1972; Griffith, et al. 1971; Hertzum & Pejtersen, 2000; Tenopir & King, 2004).

It has been shown that there are distinct differences between the communication patterns of applied

and basic scientists. While applied scientists tend to transfer information vertically through different levels of expertise, basic scientists communicate with persons at the same levels of expertise (Salasin & Cedar, 1985b:103). The publication of research findings is further the most important end-product of research in basic science (Von Seggern, 1995:97; Ziman, 1969:318-9), and in applied science the main objective of research is to provide the best solution to a problem, or to produce new procedures and products (Allen, 1977:2; Pinelli, 1991:12).

A fundamental prerequisite to understanding the communication of information among scientists would be to examine the variables that affect the communication process and information-seeking behaviour. A wide diversity of factors has been listed in the literature, of which Paisley's (1968:2) seminal model of such factors has probably laid the foundation for all current thinking on the topic. The factors or variables that have generally received the most attention and which are considered to exert the greatest influence on communication behaviour are: the scientist's personal attitudes and cognitive attributes, his/her discipline and whether the nature is basic or applied; type of work environment and employing organisation; job function; and finally the years of professional experience and status within the organisation (Pinelli, 1991:11-12; Westbrook, 1993:546-547).

Paisley (1980:122-123) has further suggested that the way and medium in which information is communicated have a profound effect on the communication process. This would include the perceived quality, availability, accessibility and ease of use of channels of communication as well as the users' interaction with the information systems that provide access to them.

It is clear that the system of scientific communication that has evolved over several centuries is now undergoing a transformation catalysed by a number of environmental, economic, and structural factors. Of the most pervasive are those caused by the effect of increased collaborative practices, the pressures that new publication formats create, ever changing and often decreasing funding models, and structural changes in employing organisations (see for example: Andrews et al., 2005; Correia & Teixeira, 2005; Crawford & Stucki 1990; De Gooijer, 1993; Hurd, 2000; Shaugnessy, 1989; Von Seggern, 1995). The effect of all these factors is further compounded by the electronic environment that we live in. The ubiquitous adoption of information technology has affected the communication system in a number of ways, ranging from new modes of one-to-one communication to electronic modes of publication, to the impact of the Internet and the World Wide Web (Walsh, et al., 2000:1295).

The question thus arises to what extent this has affected information communication behaviour. Has it created fundamental qualitative and quantitative changes to the communication of information in science and affected behavioural patterns, or has it been absorbed into the process as many other innovations have in the past? The real effect of all these factors on the communication behaviour of scientists is therefore a point of debate and area for further investigation. The researcher is further of the opinion that South Africa presents a number of unique environmental, socio-political and other factors that could impact on the information communication process in science and that there is a specific need to investigate all the factors mentioned above and their interrelationships within a South African setting.

1.6. STATEMENT OF THE RESEARCH PROBLEM, GOALS AND OBJECTIVES

The problem that this study thus investigates is the general lack of knowledge concerning the information communication process among South African science communities, the effect of information communication on scientific endeavour, and the effect that the escalating growth of electronic media and systems, as well as structural, political and other changes have had on the process in South Africa. It further follows that the purpose of this research project is to examine the constituent elements of the information communication process within a specific research community in basic and applied science in South Africa, to establish useful predictive measures of communication behaviour, and to infer appropriate assumptions about the role of information in the communication process in science in South Africa. It will, further, establish what cognitive and behavioural factors lead to the scientist's encounter with the communication process and the consequences of such an encounter.

The role of informal communication, the impact of information and communication technologies, and the effect of various structural and environmental changes during the last few decades on the communication process will specifically be addressed. The latter aspect motivated the adoption of a longitudinal research design to examine the change in communication behaviour over the decade spanning the period from 1990/1 to 2001/2.

1.7. RESEARCH QUESTIONS THAT UNDERPIN THE STUDY

As it is proposed to partially embed this research project in a qualitative research paradigm, no attempt will be made to state formal hypotheses. However, research questions will be posed to serve as the framework for the study. The research questions evolved from the researchers

concern with the role of the communication of information on scientific endeavour in South Africa, together with problems identified when the literature in the field was studied, and the general awareness of the impact of the rapid growth of information and information technologies and other structural and socio-political changes on the communication process in South Africa.

Thus the primary research question that motivated this project relates to

- **What constitutes the information communication process among a bounded community of basic and applied scientists in South Africa?**

and this is further amplified by the following subsidiary questions

- **What cognitive, behavioural and environmental factors drive the communication process in science in South Africa?**
- **What factors impact most on the communication process?**
- **What environmental and other changes have occurred during the intervening years of the longitudinal study that affected the communication process in South Africa?**
- **What is the role of informal communication of information in South Africa?**

1.8. RESEARCH DESIGN AND METHODOLOGY

The study is based on a conceptual analysis of the factors outlined above and an empirical investigation into the communication of information amongst a defined group of basic and applied scientists. The conceptual component of the study was derived from a critical analysis and synthesis of the pertinent literature in the field and an analysis of the underlying theoretical principles. This component served a dual function, first it provided the basis for the conceptual framework that underpinned the empirical study, and secondly it served as a benchmark with which the findings of the empirical study were compared.

The empirical investigation was conducted within a triangulated research design utilising both qualitative and quantitative approaches. This is generally recommended as the combination of quantitative and qualitative methods can achieve convergence between the positive attributes of each approach and this should enrich the study and improve validity (Bryman, 1988:95; Layder, 1993:108).

The emphasis of the empirical research project was on investigating "property-disposition"

relationships rather than "stimulus-response" relationships (Frankfort-Nachmias & Nachmias, 1996:318) to establish the factors that have the most impact on the communication of information among scientists in South Africa. The researcher further decided to utilise a small-scale survey approach (approximating the depth attributes of case studies) as the main research design.

1.8.1. TIME DIMENSION

The explosive growth of electronic media and communication technologies, as well as the many structural and socio-political changes in South Africa prompted the researcher to design a study that would, in addition to obtaining an in-depth understanding of the information communication process, also map the impact of the changing environment that include factors such as increased globalisation and technological innovation on the scientific community in South Africa. The researcher thus adopted a longitudinal research design and gathered data pertaining to the topic in 1990/1 and again in 2001/2 to establish trends and changes in communication patterns over the designated time span.

1.8.2. DEFINITION OF THE POPULATION

A population is a theoretically specified aggregation of study elements, which should be defined early in the study (Frankfort-Nachmias & Nachmias, 1996:179). It is evident that the communication of information is a complex and dynamic activity and care should be taken to select the correct study population to adequately measure the various interacting phenomena. The researcher thus made personal contact and obtained advice from a number of well-known international researchers in this field, viz. Susan Crawford, Belver C. Griffith, T.J. Allen, and Yoshinari Tsuda. They all suggested that the research population should consist of a bounded, finite population of scientists that are subjected to a wide range of influencing variables.

These factors prompted the researcher to select the crystallographic research community in South Africa as the ideal target population for this study. The rationale for this decision is that the study and application of crystallography ranges from the basic study of the field, to its utilisation as an analytical tool in a number of areas of science, to its application in applied science and technology. A further factor that informed this decision was the fact that the crystallographers in South Africa conduct research in one of three types of organisation: universities, research institutes, and R & D facilities in industry. This bounded group of scientists thus manifests the variety of attributes required to study all the factors that relate to the communication of information. It was a fortuitous coincidence that John Bernal, who was an early proponent of the need to

investigate the information communication process in science within a humanistic framework, was also an eminent crystallographer of his time.

The International Union of Crystallography's *World directory of crystallographers* (1986; 1997) lists all registered crystallographers by country and it also provides addresses and the crystallographers' biographical details. This publication was selected as the appropriate sampling frame from which to select the study sample. The 100 crystallographers that were listed under the South African entry (1986) at the start of the longitudinal study was considered to provide a sufficiently small population to study the entire group in depth, but also large enough to allow significant investigation of the various factors that could influence information communication behaviour.

1.8.3. DATA COLLECTING TECHNIQUES

Data collecting procedures using questioning techniques are generally regarded to be the most effective method to use to obtain both objective and subjective information and to ascertain a subject's opinions or attitudes on given matters. This data collecting technique divides essentially into self-administered questioning methods and interview techniques. Interviews can be conducted with individuals or with groups and may be in person or by means of communications media such as the telephone, electronic mail or some other electronic medium (Babbie, 1995:272-273).

As mentioned, a longitudinal approach was adopted. The researcher thus collected data on the topic in 1990/1 and again in 2001/2 by means of a series of focus group interviews, personal interviews, telephone interviews and e-mail questionnaires.

1.8.4. DATA ANALYSIS

As the researcher had collected both qualitative and quantitative data she had to apply both qualitative and quantitative data analysis techniques. It thus follows that the data analysis should be based on an integration of inductive and deductive logical principles (the former being the basis of qualitative data analysis and the latter the premise on which quantitative data analysis is usually based (Babbie & Mouton, 2001:273). A further argument for integrating the two approaches is given by Dey (1993:3) who is of the opinion that although qualitative data deals with meanings that are analysed through conceptualisation and quantitative data deals with numbers that are analysed through statistics; the two forms are interrelated and mutually dependent.

All responses, both qualitative and quantitative, were initially captured using the dBASE™ database management software and Microsoft's Excel spreadsheet software. A record structure was created that accommodated the various fields ranging from the respondents' structured responses to their unstructured qualitative responses. The quantitative data was then manipulated by means of the statistical functions available on Excel and by using the STATISTICA software programme.

1.9. OUTLINE OF THE THESIS

Chapter 1 provides the context and framework for the thesis. The rationale, objectives and research questions that underpin the thesis are outlined. A brief definition of the main concepts and an overview of the research approach adopted are provided.

Chapter 2 provides an analysis and synthesis of the main issues derived from the relevant literature that pertain to the communication of information among basic and applied scientists. From this analysis variables are identified and incorporated in a reference framework that served as the basis for the empirical study.

In chapter 3 the research methodology adopted is outlined in greater detail. The analysis of the data and a discussion of the results are presented in chapters 4 to 5. The thesis concludes with a summary of the main issues, the conclusions reached and an outline of a proposed theoretical model of the communication process among a bounded population of basic and applied scientists in South Africa (chapters 6 and 7).

CHAPTER 2

COMMUNICATION OF INFORMATION IN SCIENCE

2.1. INTRODUCTION

In this chapter the researcher reviews the literature⁴ related to the communication of information in science. The purpose of this review was to identify and analyse the main conceptual issues that pertain to the field and to structure and utilise these as the reference framework for the research project.

It is an accepted fact that the development of science and its perpetuation is dependent on the body of knowledge that underlies all scientific endeavours. The communication and transfer of information is thus an essential component of scientific research (cf. also chapter 1.1. and chapter 1.5.) and Garvey in his well known analysis of the communication of information in science has argued very strongly that "communication is the essence of science" (1979:126). The aim of all scientists is to contribute to the body of knowledge in their field and their ability to contribute to the advancement of science depends to an extent upon the amount and quality of their interaction with fellow scientists (Blau, 1974:391; Gläser, 2003: 47; Eisend, 2002:307; Hertzum & Pejtersen, 2000: 762); Merton, 1973:6). Science, furthermore, is cumulative and each scientist builds on previously recorded knowledge, on the work of colleagues and predecessors. Several studies have, therefore, indicated that scientists spend a far larger proportion of their time on information communication activities than most other workers (Hagstrom, 1976; Lacy & Busch, 1983; Mick et al, 1980; Vickery, 1961).

Eisend (2002: 307-308) distinguishes between individual cognition and scientific cognition where the latter relates to the communicative interaction between scientists. Scientific cognition is the process whereby scientists communicate their knowledge to the scientific community where once it has been validated it becomes part of the body of scientifically proven knowledge. He further differentiates between the two dimensions of scientific communication where in the first dimension information or content is transmitted and the second is related to the social and interpersonal dimension of communication between scientists. Scientific research is essentially a corporate activity (see for example Kuhn; 1962; Ziman, 2002) and a distinctive feature and accepted social norm of the scientific community is the concept of a *communality* of ideas, i.e. a shared

⁴ Section headings are used as reference indicators for resources in electronic format that do not indicate page numbers.

commodity that belongs to everyone (Kronick, 1988:222). Gläser (2003:38) further argues that scientific communities constitute a “distinctive mode of collective production which is characterized by decentralized action coordination” which he refers to as *distributed* labour and based on this premise communication in science is thus not merely the exchange of previously produced knowledge, but “the transmission of material and components between producers”.

It would thus follow that in addition to dependence on the formal structure of knowledge, scientists would also rely strongly on informal communication networks. The important role of informal communication of information in basic and applied science has been highlighted by a number of researchers, ranging from the seminal work by Price (1963) on *invisible colleges* to the series of investigations conducted amongst others by Allen (1977), Crane (1969, 1972), Crawford (1971), Fry (2006), Garvey (1979), Garvey & Griffith (1968, 1971, 1972), Garvey and others for the American Psychological Association (1963-1969), Gaston (1972), Hertzum & Pejtersen (2000: 761); Shuchman (1981), Lacy and Busch, (1983), Raitt (1986), Pinelli and others (1989), and Salasin and Cedar (1985a & 1985b). Cronin has stated that informal communication did not evolve as a reaction to the shortcomings of the formal systems of communication but as a “device created by scientists for scientists to serve a particular set of functions” (1982:229). The popularity of interpersonal communication lies in the interactive nature of the exchange process and the stimulation that collegiate interaction provides. It provides an ideal forum where ideas can be debated and evaluated in their natural form amongst peer groups before formal publication is achieved (Poland, 1991:62). It further promotes the simultaneous satisfaction of a number of information needs at a single encounter, for example a scientist when interacting with a colleague could obtain feedback on his/her research, be kept up-to-date on new developments he/she is unaware of, and further also derive stimulation from the interaction (Von Seggern, 1995:99). Fry (2006; 300) refers to the complementary role of informal and formal communication in science as far as “the production of knowledge, dissemination of ideas, reputation building and growth of intellectual fields” and questions why so little research has been conducted on the impact of informal communication practices on formal communication and information seeking behaviour. Bathelt et al (2004:33) suggest that individuals (and even organisations) that manage to engage with a number of diverse information carrying channels of communication, both at the local level and globally, operate more effectively than those that only concentrate on certain channel interactions and that external sources of knowledge are often important triggers that stimulate innovation and growth within a specific environment.

It is clear that the system of scientific communication that has evolved over several centuries is now undergoing a transformation catalysed by a number of environmental, economic, and structural factors. The electronic environment that we live in has had a particularly pervasive impact and it is now possible to instantaneously transmit text, images, and data all over the world. Changes are therefore occurring in the communication system ranging from the effect on one-to-one communication between scientists to new publishing models that are emerging in the publishing industry. Walsh, et al. (2000:1295) find in their investigation of the effect of computer-mediated technologies (CMC) on scientific work that the Internet and electronic mail have probably had the greatest impact and considerably enhanced scientific collaboration and productivity.

A number of studies have indicated that there is a positive correlation between high levels of communication with colleagues and high performance levels and that performance increases if informal communication links are encouraged (Allen, 1977; Bouazza, 1989; Crawford, 1971; Cronin, 1982; Lacy & Busch, 1983; Pelz & Andrews, 1966; Tenopir & King, 2004). The study by Crane showed an exponential increase in publication output when high levels of inter-personal interaction were maintained compared with linear growth in publication output when low communication levels were maintained (1972:24-26). A number of indicators further suggest that scientists who belong to large informal networks are more actively engaged in collaborative research and publication collaboration, they have stronger citation links, their ideas are transmitted more effectively and they generally have more influence on research than their counterparts who do not belong to such informal networks (Crane, 1972:308-310; Crawford, 1970:48; Cronin, 1982:213-214).

Menzel (1966b:1000-1), in his seminal analysis of scientific communication, came to the conclusion that five characteristics could be isolated which adequately conceptualise the process, viz.:

1. The acts involved in scientific communication constitute a system which includes all the methods by means of which scientific messages are transmitted. The flow of scientific information is seen as a set of interactive processes in a social system which links users and generators and is influenced by the information-seeking actions of individuals, often involved in several work-related roles. Menzel therefore contends that scientists as generators and as users of information constitute interconnected publics.
2. The effective transmission of a message to the recipient often involves many channels of communication acting synergistically. Formal, informal, personal and impersonal channels interact, one or more persons frequently serving as relays between the source of the message

and its ultimate user.

3. Informal, unplanned communication plays an important role in the science communication system and there appears to be a regularity in the pattern of unplanned communication.
4. Scientists constitute publics who have a number of common interests and norms of behaviour which uniquely link them, viz.:
 - they are highly motivated to obtain information from the communication system;
 - the information they require is designed, as a rule, to promote certain professional activities; and
 - they have a well-developed and well-structured behaviour pattern relating to their professional communication.
5. Science-information communication systems serve multiple functions that can be related to the scope and permanence with which the information needed by a particular scientist can be described in advance. One can therefore distinguish the exhaustive search function, the reference function, the current-awareness function, the function to stimulate scientists to seek information outside their areas of specialisation and the function that enables them to familiarise themselves with an unknown area of research.

Walker and Hurt (1990:xiv) in turn suggest the encompassing function of "providing a cumulative record of knowledge in a field as it exists at any given time" for, as argued by Gläser (2003:39), "the only way that new knowledge can find its way to an unknown audience is by publication". Such a record of knowledge serves a normative function, it constitutes a reference point from which new theory is promulgated and to which new evidence may be added. A number of studies have further indicated that the underlying function of the formal communication system in science is for peer recognition and reward (Borgman & Furner, 2002, Garvey, 1979, Wouters, 1998), while informal communication and networking are important to ensure the diffusion of knowledge (cf. Price, 1963 Crane, 1972).

Various researchers have traced the communication of information during the stages of the research process, from the inception of the idea and the conceptualisation of the problem, through to the ultimate end-product of research. It was found that although the communication process follows diverse routes and information flows through various channels during the different stages of the research process, a recurrent and predictable pattern emerges. Both formal and informal channels of communication play an important role, are highly valued, and are utilised interchangeably during all stages of the research process. (See amongst others the studies by Bichteler & Ward [1989], Blau

[1974], Garvey & Griffith [1971], Garvey, et al [1974], Lacy & Busch [1983], and White [1975]).

The research process reaches its peak when with the research findings are published, an invention patented, or a physical entity produced. This final stage signals the transfer of the interaction with the communication system from the informal to the formal domain According to Borgman and Furner (2002:13), this final stage of creating public knowledge is essential as “research in all fields is incomplete until it is validated through review processes and shared with others”.

There appears to be a distinct difference in the way that applied fields of knowledge and the basic fields communicate and transfer information. Applied fields tend to transfer information vertically by exchanging information between researchers, practitioners, and others through several different levels of expertise. Basic fields, on the other hand, transfer information horizontally, by sharing information among peers who have the same levels of expertise (Salasin & Cedar, 1985b:103).

Furthermore, the publication of research findings is regarded by the basic science community to be the end-product of the research process. It underpins the communication process and its function is to add to the universal consensus of public knowledge in basic science. The end-product of applied science research, on the other hand, may in many instances never be published, and is often converted directly by industry into new procedures or products or into licences and patents for production purposes. The aim in applied science research is to provide the best solution to a problem.

2.2. COMMUNICATION PATTERNS IN BASIC SCIENCE

As mentioned above, the culmination of creative effort in basic science is reached when the research output is published and this transfer of knowledge into the public domain forms the basis and largely motivates the communication process in basic science. Both formal and informal communication of information feed into the system to create as output some or other refereed publication that then is assimilated into the body of recorded knowledge in the field (Hurd, 2000: 1279). The body of recorded knowledge so created underpins the advancement of scientific endeavour and forms an integral part of the scientific communication process (Osburn, 1989 279). Ziman, in turn, stated that the results of research in basic science become completely scientific only when they have been published (1969:318). By recording knowledge and making it public both the generator and the potential users of information are thus ensured of equal access to the body of knowledge in basic science (Line, 1992:201).

Ziman (1969:318-9) identified three fundamental characteristics of recorded knowledge in basic

science:

1. It is *fragmentary* in that each paper or contribution is not self-sufficient, but features merely a single element in the total store of knowledge in basic science;
2. It is *derivative (or cumulative)* as scientific papers depend to a large extent on previously recorded papers; and
3. It is *edited* as the research paper is subject to fairly rigid editing (or *refereeing* or even *censorship*). This can be done on an informal basis by means of peer judgement, and/or formally in the form of strict refereeing by a journal's editorial board before a paper is accepted for publication.

Price (1965:555-575) emphasised the point that the basis for all communication behaviour in basic science is its close-knit structure wherein new knowledge builds on old knowledge and all scientific endeavour is recorded and displayed in the literature. A further fundamental aspect of the communication behaviour of basic scientists is that they record their research results to enable replication and to provide the support to substantiate their arguments in areas that are not a part of accepted knowledge in the field. The system also exists to communicate information in such a way as to determine scientific priority and intellectual property rights (Gläser, 2003:39; Von Seggern, 1995:97). De Gooijer reports that publication output remains the most favoured performance indicator for all categories of scientific research (1993:122). The published output also forms the basis for acceptance by the peer community and enhancement of status in general. It is generally accepted that the individual scientist's drive for acceptance by his/her peer community is a strong influencing force of the basic science communication process, for it is through peer acceptance that the scientist achieves success and that knowledge advances. Peer review is thus seen to be the principal procedure for evaluating the validity, quality, relative significance and feasibility of research, as well as providing an invaluable feedback mechanism that enhances quality and advances research (Correia & Teixeira, 2005:353; Crawford, & Stucki, 1990:223; Gläser, 2003:39; McGarry, 1975:279; Welborn, 1991:55).

2.2.1. SCIENTIFIC ELITISM

Amick (1973:318; 322-327) was one of the first persons who attempted to prove the premise that there is a positive relationship between scientific elitism and the communication of information in basic science. It is presumed that scientific elites, or *sociometric stars* (as also described by Price (1971:74-75)), are intimately involved with (and often have control over) the scientific

communication system and that they tend to cluster at the *basic* end of the basic to applied science continuum.

The scientific elites comprise the eminent men of science who have been accorded recognition in their disciplines, they have achieved a standard of excellence in their work, they are highly productive in terms of publication, number of papers delivered, involvement with their professional societies and are generally highly visible in their professional community. They process more information and have more narrowly defined and less diffuse research interests than their 'non-elite' counterparts (Price, 1971:74-75).

Amick has suggested that a scientist's level of elitism may be measured in terms of one or more of the following (Amick, 1973:318):

editorial involvement with scientific journals, acting as a referee for scientific journals, the number of awards received, the number of office-bearer positions held in professional associations, the number of guest lectures presented, the number of patents registered, the number of papers and/or posters presented at meetings, conferences, etc., and the number of papers published in professional journals.

2.2.2. INFORMAL COMMUNICATION IN BASIC SCIENCE

The importance of formal communication in basic science is, as suggested in 2.2., beyond dispute, but as has been mentioned informal communication also plays a very important role in the total communication system of basic science. Cronin (1982:225), for example, has stated that "informal communication is the lifeblood of scientific progress" and it is suggested that the value of informal communication lies in its interactive and participative nature (cf. also chapter 2.1.). It allows participants to both disseminate and absorb new information, sound out theories with the experts in the field, and obtain feedback before the formal publication process begins. Many studies have thus shown that informal communication (ranging from inter-personal exchange, to informal pre-publication exchange of research results, to interaction at professional meetings) is very effective in meeting many of the information needs of basic scientists (Von Seggern, 1995:97).

Informal communication links in basic science occur horizontally by mean of well-developed person-to-person communication networks, frequently crossing organisation and discipline boundaries and usually among persons of equal levels of expertise (Salasin & Cedar, 1985b:104). It has further been established that informal links tend to be stronger and more frequently sought amongst basic scientists concentrated in countries with large basic science populations (Lacy & Busch,

1983:193-194). In part, this can be attributed to the greater opportunity for frequent contact with a critical mass of specialists in any particular research area.

According to Menzel (1967:421-424) the informal communication of information is particularly valued and utilised when basic scientists wish to obtain information on new principles and findings, new techniques, procedures and apparatus that would not easily be found in the published literature or which had not yet been published. Informal communication is further of importance when basic scientists wish to establish who the main researchers are in a field and when a new and unfamiliar field is first explored.

Fry (2006: 301] refers to ethnographic studies in the field of high energy physics that have established the importance of informal communication and social networks in the diffusion of ideas and obtaining peer recognition. It was found that significant communication within the research community takes place by means of casual interaction, including ordinary gossip and at gatherings such as conferences, lectures, etc. He thus suggests that the level of informal communication among researchers in a specific domain has an affect on their production and use of electronic media.

2.2.2.1. Invisible Colleges

It is reputed that Robert Boyle was the first person to use the concept *invisible college* in correspondence in the 1640's to describe scientific meetings held in England that later became the nucleus of the Royal Society (Correia & Teixeira, 2005:349; Walker & Hurt, 1990:xiii). Price (1961:99), however, was probably the first person to identify the *invisible college* phenomenon as an important vehicle of informal information communication. Price and a number of researchers have subsequently validated his original proposition empirically (cf. Crane, 1969, 1972; Crawford, 1971; Gaston, 1972; Griffith et al, 1971; Price, 1971; Zaltman & Kohler, 1972). The basic premise is that in each identifiable and circumscribable area of basic science specialisation there exists a group of people who claim to be reasonably in touch with everyone else. They are engaged in research along similar lines and communicate often and intensively with one another. Such a network almost acts as a social circle of scientists brought together by their common research interests. They are usually very productive and contribute materially to research in their subject, not merely on a national scale, but usually including all other countries in which the speciality is actively researched. These scientists meet at select conferences, commute from one centre where important research is conducted, to the next, circulate offprints and preprints to each other, collaborate in research, and often seek each other out to obtain information before searching the literature. They maintain contact

amongst themselves by actively communicating by mail, telephone or some electronic medium.

It has further been suggested that these networks are held together by the eminent leaders in the field and these *sociometric stars* or *elites* create a *gravitational force* that holds the field together and improves the communication of information within their *invisible college* (Crane, 1972:308-10; Crawford, 1970:47, 1971:309). Arndt and co-workers have established that the more senior and higher status scientists communicate actively with each other and that they then disseminate information to the more junior members in the system (Arndt et al, 1980: 444). Crawford (1971:309) refers to these eminent, highly productive and highly cited scientists who form the core of such *invisible colleges* as “nodal points for the dissemination of information” and she suggests that they are “the focus of a disproportionately large number of contacts”.

The membership of such networks is very fluid and changes constantly (Crane 1969:346-347) and although always voluntary, entry may not be easy for newcomers and the less eminent and junior members of a research field. The lifespan of *invisible colleges* would appear to be ten to fifteen years (Griffith and Mullins, 1972:962) and Price adopts the premise that the average number of persons in an *invisible college* rarely exceeds one hundred as larger numbers would inhibit easy communication (1971:74-75).

A number of disadvantages, however, also pertain to informal networks and Cronin (1982:224) lists such factors as their élitist and high status orientation, their fluid, unstructured and often short-lived nature, the expenses involved in maintaining them and the danger that irrelevant and often untested information may be disseminated. Most of these disadvantages, however, are generally offset by the positive factors that relate to the personalised, interactive, up-to-date and direct communication of information within groups that share common research interests which in turn results in immediate feedback, action, and establishment of priority in research. Such networks, further encourage the transmission of ideas across disciplines and across nations (Zaltman & Köhler, 1972:233). Doty (1992:24-38) further argues that the advent of worldwide electronic communication networks and their general use by all categories of scientists is rendering informal networks more accessible and more open to all levels of scientists.

The existence of the *invisible college* premise has not always gone uncontested and Bitz and co-workers (1975:9) have argued that their importance is overstated and that they have found very little evidence of such a social structure and dynamic operating amongst the scientists they had investigated, while Mullins (1968:790-795) has suggested a less cohesive and concrete social

structure. Cronin's (1982) overview of the field, however, strengthens the arguments in favour of the existence of such a phenomenon. It is thus proposed that the *invisible college* phenomenon is now becoming understood as a mechanism produced automatically by the basic science community. It is, furthermore, apparent that *invisible colleges* constitute highly effective informal communication systems, in which information pertaining to a specific field of study is exchanged among its members (See also Cronin, 1982; Price, 1971; Garvey & Griffith, 1972; Salasin & Cedar, 1985b).

2.3. COMMUNICATION PATTERNS IN APPLIED SCIENCE

Concurrent with basic science two related streams of activity, applied science (or more specifically technology) and the utilisation of science in commerce, industry, welfare and war, have developed and have functioned both as contributors to scientific development and as beneficiaries of scientific accomplishments.

The common conviction that basic science provides the basis upon which applied science is built has proved to have a limited historical basis. History has shown that the three activities of basic science (also referred to as pure science in the literature), applied science and their utilisation have followed largely independent paths through succeeding centuries to the present time. However, there have been intermittent links between the activities and there is an indication of closer interrelation now than in the past two centuries. (Marquis & Allen, 1966:1052; Pinelli, 1991:6; Price, 1986:240-241). It has further, been suggested that these fields of knowledge should represent points on an analytical continuum from basic to applied, rather than be rigidly and discretely classified (Amick, 1973:320-1; Menzel, 1966b:1000). Walker and Hurt, in turn, suggest that in some fields, such as biotechnology, basic and applied science have become so intertwined that the boundary between the two have become totally blurred (1990 xix).

Where links have been established between basic and applied science, the communication has been bilateral, direct and quite rapid. It has been established that the degree to which an applied science is coupled to its related basic science or advances independently to it, is extremely variable and that this is possibly based more on need than on progression. Some applied sciences would, therefore, be more closely coupled than others to their so-called underlying basic science (Allen, 1977:46-57). Price (1965:555), therefore, suggests that the research-front in applied science is not directly related to the research-front in basic science, but to sections that have been repackaged. From the above it is thus clear that although there would be many similarities in the communication patterns of basic and applied science, there would, however, be definite distinctions.

Although applied science also tends to develop cumulatively, with technical innovations and the literature building in most instances upon their predecessors, this phenomenon is not as strongly manifested as in the basic sciences (Price, 1986:155-179; Ziman, 1969:318-319). Publication, furthermore, generally also occupies a position of lesser importance in applied science and the published literature thus occupies a much less significant position than in basic science. An applied scientist is concerned, primarily, with producing a physical or practical end-product (e.g. a patent, license, new product, or process) which will provide the best solution to a particular problem, rather than with verbal encoding. "Whereas [basic] science both consumes and produces information in the form of human language, engineers transform information from this verbal format to a physically encoded form" by producing "physical hardware in the form of products or processes" (Allen, 1977:2) which, in turn, is information bearing. Verbally encoded information is usually only produced as a by-product to the main production process to further explicate the process or describe the product. These aspects, therefore, form the basis of the differentiated communication patterns between basic and applied science.

Although, as indicated above, published literature occupies a much less important position, it still plays a significant role in the communication of technical information (Tenopir & King, 2004). The literature of applied science, however, tends to be related specifically to the solution of particular problems as applied scientists are far less interested in theory than in reliable answers to specific questions, and they "tend to minimize loss rather than maximize gain when seeking information" (Pinelli, 1991:12). Applied scientists as readers become so accustomed to this form of output that they find it difficult to assimilate literature of a more theoretical nature within their field. The problem is compounded when they transcend the literature of basic science to solve specific problems encountered in the work situation.

The situation is further complicated by the differences in input and output formats of the applied science information processing system. Whereas in basic science there is an inherent compatibility between the verbally encoded inputs and outputs of the information processing system, in applied science the inputs are usually in verbally encoded formats, while the outputs are in physically encoded formats together with a usually somewhat incomplete verbal by-product. The latter information output is usually not adequate to serve as input to the next stage of the information cycle and applied scientists, if not acquainted with the development of the physical product, usually then require human intervention to supplement and interpret the information contained in such output documents (Allen, 1988:4).

The tendency for information to be transferred vertically in applied science (i.e. the passage through several levels of expertise) complicates the communication process and generally impedes the transfer of information in applied science (Salasin & Cedar, 1985b: 103-104). The difficulties of supplying applied research and practice with information have, therefore, resulted in the evolution of 'middlemen' that bridge organisational and disciplinary boundaries to transfer appropriate information to all levels of applied scientists in an organisation (Allen, 1977:41).

A further factor that differentiates the communication patterns of applied scientists from basic scientists is the fact that they usually work in different organisational environments. Applied scientists are generally employed by organisations that are profit motivated and this imposes certain restrictions on them, e.g.:

- the requirement that research is conducted only on problems which are of interest to the organisation and that they develop products that are market oriented;
- that they work within tight time constraints and follow fairly rigid schedules;
- that research results be contained within the organisation and not communicated to the profession at large.

These constraints generally further restrict the free flow of information and "impedes the formation, by technologists, of anything resembling an invisible college" (Allen, 1977:41). Pinelli (1991:12-13) identifies the following additional barriers to the effective communication of information in applied science :

management's general reluctance to place a high premium on information; the difficulty in finding appropriate information at the correct level of understanding; and the difficulties in assessing the quality of information.

In their extensive review of the literature relating to the communication patterns of engineers Tenopir and King (2004:1-2), however, come to the conclusion that the "new technologies such as the World Wide Web and electronic publishing, are having a profound effect on engineering communication patterns" and that the "the Internet has dramatically increased the potential for both informal and formal communication".

2.3.1. INFORMAL COMMUNICATION IN APPLIED SCIENCE

Allen and his co-researchers (Allen, 1966, 1968, 1977; Allen, et al, 1970; Marquis & Allen, 1966) have empirically proved that informal communication channels, particularly personal ones, are the preferred and most utilised mode of information transfer in applied science. It would appear,

furthermore, that the informal communication patterns of applied scientists differ from those of basic scientists. While basic scientists mostly communicate informally by means of invisible colleges which transcend institutional and even geographical boundaries, applied scientists, on the other hand, communicate informally by means of close association with co-workers in their own organisations. These differences, however, can largely be attributed to the difference between basic and applied scientists' work environment and the organisational structure of their employing organisations (Smith, 1981:325).

2.3.1.1. Technological Gatekeepers

From the preceding section it is apparent that, to a large extent, the communication of information in the applied science community is contained within the organisational structure and in order to survive, a technology based organisation would have to find means to effectively import new technical information.

Allen and his colleagues first identified the *technological gatekeeper* as the intermediary in an organisation who indirectly ensures the flow of outside information into the organisation and the subsequent dissemination of that information within the organisation (Allen, 1968:435-453). Thus *gatekeepers* accomplish the important function of coupling the organisation to outside activity and Bathelt et al. (2004: 44) have stated that "the role of internal gatekeepers and boundary spanners becomes crucial for translating externally produced knowledge into a form that can be internally understood within the organisation". Gatekeepers play a particularly significant role in closed environments (such as in industry) and also in situations where cognitive congruence is lacking among members of a group. While most studies have shown that *gatekeepers* have a very important function in information transfer in applied science, a study by Schuchman (1981) indicated that their significance is not always manifested equally strongly across disciplines in applied science and he has suggested that *gatekeepers* only account for a small proportion of the information communicated in engineering.

During the more than ten years that Allen and various co-workers spent observing the flow of information among researchers in various work settings in applied science they, however, verified the important role that *technological gatekeepers* play in the communication process of applied science. Among their findings Allen and his colleagues established that *technological gatekeepers* generally hold key positions in the communication network of an organisation. *Gatekeepers* are responsible for linking their colleagues with the outside world by means of their connections with both domestic and international networks. They are better acquainted with both formal and

informal sources of information than their other colleagues, and they assist in cutting through the communications barrier that separates researchers in industry from outside information sources. *Technological gatekeepers* also maintain contact among themselves, thereby increasing their effectiveness as linking agents between their information-inactive colleagues and appropriate information sources. In this way a two-step information flow process is created by means of which the average researcher is enabled to receive information on technological developments outside the organisation in which s/he works (Allen, 1977; Allen et al 1970). Such informal *importation* of information has proved to be very effective and probably explains the survival of the communication of information in applied science with its unique constraining features (Bathelt et al., 2004: 44).

In other disciplines opinion leaders serve a similar function. However, they do not have the same boundary-spanning role as they function without having to contend with the restraining organisational structure operative in the typical *technological gatekeeper* environment. Research in the health sciences and education has revealed similar role players who are community-based individuals who assist health care workers and educators in providing and transferring information to people in the community. They often act as *change agents* that encourage the adoption of new practices or procedures in their communities and they frequently created informal systems of networkers and advisors that help in putting research findings into practice (Metoyer-Duran, 1993:138-143).

Metoycr-Duran (1991) has proposed a model in which she defines six gatekeeper profiles that delineate a range of information seeking skills and orientations. The profiles of *impeder*, *affiliated*, *unaffiliated*, *broker*, *information professional*, and *leader/executive* suggest a graduated progression from gatekeepers that curb the flow of information (the *impeder*) to those that actively manipulate information to facilitate change to develop and implement strategy (the *leader/executive*).

2.4. CHANNELS AND MODES OF COMMUNICATING INFORMATION

Paisley (1980:122-123) has suggested that the way and medium in which information is communicated has a profound effect on the communication process. Information may be communicated by means of various combinations of mode and channel. The mode of communication is the physical state in which it is encoded such as oral, handwritten, printed and electronic encodings. The channel of communication is the medium or other arrangement by which

information is conveyed from sender to receiver, e.g. in the oral mode information can be conveyed by means of a casual conversation or formal speech, while in the written mode it can be conveyed by means of a printed book or handwritten letter. Over the years the forms of communication and the media used have changed considerably. Whereas early scientific exchange was primarily based on oral and handwritten communication the modern development of science was made possible first by the introduction of printing and later by electronic information processing. Eisend (2002: 308) refers to McLuhan's (1962) statement that we have reached the end of the *Gutenberg Galaxy* and have entered "a digital revolution or a new culture determined by computers" which because it provides scientists with a far greater array of communication options has the potential to enhance communication and scientific endeavour.

2.4.1. COMMUNICATION CHANNEL CATEGORIES

The range of channels an individual can use to acquire information is normally categorised either as formal channels (often also known as 'archival', as these mostly involve published modes of communication), or informal channels. Both formal and informal channels, in turn, can be further categorised as being either personal or impersonal. The former category involves personal communication between individuals and can be direct, from person to person, or indirect via a third person or a number of persons. The latter category refers to channels where the information is first recorded and then transferred by means of a medium such as a letter or book. A further distinction that may be made is between direct channels of communication which usually contain the information being sought, and indirect channels of communication which lead the user to the source or channel containing the information.

The following distinctions between formal and informal channels of communications have been derived from the categorisations provided by Garvey and Griffith (1971:350-359), Meadows (1974:93), and Menzel (1968:153-163):

Formal channels

- are public and thus have large potential audiences;
- contain information that is permanently recorded and stored and the information is thus usually retrievable;
- contain information that is relatively old;
- contain information that is generally complete in nature;
- are generally subjected to a fair amount of filtering;

- are primarily user selected, i.e. the user initiates the search process and seeks the formal channels that contain the appropriate information;
- contain information with a moderate amount of redundancy;
- provide little direct feedback to the originator and the communication channels are neither open-ended, nor interactive;
- contain information that may be ambiguous, but the information is authentic and reliable as it has been evaluated and monitored;
- enhance an author's prestige and priority if they, rather than informal channels, are used to present his/her work to the outside world.

Informal channels

- are private and thus have restricted audiences;
- contain information that is typically neither permanently recorded, nor stored and thus not easily retrievable;
- contain information that is up-to-date;
- contain information that is often unfinished in nature;
- are relatively free of filtering;
- are primarily source or disseminator selected, i.e. the flow is initiated and to some degree controlled by the generator;
- contain information where there is sometimes a large amount of redundancy;
- engender interactive and open-ended communication which may contribute considerable feedback to the originator;
- generally eliminate ambiguity, but the information contained may not always be authentic or reliable as it has not been evaluated, reviewed, etc.;
- do not enhance prestige nor can priority claims be made if this method of communication is used to present work to the outside world.

2.4.2. CHANNEL USE DETERMINANTS

There is evidence that scientists' preference for and frequency of use of a specific channel of communication is more likely to correspond to their estimate of the ease of using the channel, the accessibility and the physical proximity of the channel than to their estimate of the amount of information, or even quality of information expected from the channel (Hertzum & Pejtersen, 2000: 763; Gertsberger & Allen, 1968: 274; Pinelli, 1991:14). Thus communication channels are frequently "selected not to maximize gain in the information obtained but to minimize the cost in

terms of effort that must be expended to access the information” (Salasin & Cedar, 1985a: 95) and Rosenberg draws the conclusion that “the ease of use of an information-gathering method is more important than the amount of information expected” (1967:125). Von Seggern thus suggests that the reason why personal collections are so highly valued and frequently used is because of their accessibility and familiarity (1995:98). It has further been found that the *least effort* approach is particularly prevalent among applied scientists and that basic scientists generally exert more effort to obtain high quality channels as well as to publish in prestigious channels (Pinelli, 1991:13). Wilson (1981:9) in turn, has suggested that affective needs often have a greater effect on the choice of communication channels than cognitive needs, e.g. to attract attention a superior will be approached for information rather than a document.

However, scientists generally also acknowledge that while ease of use and accessibility determine the initial selection of channels, ideas are accepted and adopted in relation to the quality of the channel that conveys the idea and the utility level of the information. Information most useful to the work situation is generally found in high quality sources (cf. Gertsberger & Allen, 1968; Bouazza, 1989; Hertzum & Pejtersen, 2000; Pinelli, 1991). In general it may thus be stated that information sources are initially selected on the basis of their accessibility, then the users' familiarity with the source and ease of use, followed by quality considerations, utility factors, relevance, comprehensiveness, and finally expense.

The range of channels that various scientists employ has further been linked by a number of studies to the creative abilities of these scientists. There is evidence that scientists who are more creative tend to utilise a wider variety of communication channels and are less dependent on formal information sources and services than their less creative counterparts (Correia & Teixeira, 2005; Fry, 2006; Maizell, 1960; Palmer, 1991a; Stein, 1967).

Research projects that have, amongst other objectives, tried to determine under what circumstances channels of communication are used have revealed that:

- The need of specific information, such as for a simple fact, an explanation or a phenomenon and which, as a rule, is required urgently, is generally satisfied either by consulting an expert in the field, or by having recourse to the primary literature, especially journals, handbooks, and standard reference tools.
- The primary literature plays an important role in assisting users to familiarise themselves with a new or neglected field.
- A person's need to keep up to date is only partially satisfied by formal documentary sources. An

important source of current information is the wide range of informal channels of communication (e.g. personal conversations, attending conferences and visiting other institutions and colleagues).

- The need for exhaustive information occurs at irregular and infrequent intervals, generally at the start of new work or a new endeavour. Indirect sources of information that direct the user to the actual information are usually employed to satisfy a need of this kind.
- Informal communication channels are important sources of serendipitous information and personal informal communication often provides valuable leads to formal channels of communication.

(Bouazza, 1989; Hertzum & Pejtersen, 2000; Pinelli, 1991; Poland, 1991; Smith, 1981; Stevenson, 1980; Tenopir & King, 2004; Vagianos, 1971).

2.4.3. USE OF FORMAL CHANNELS OF COMMUNICATION

The findings from a number of studies suggest that peer-reviewed journals⁵ are the most frequently used information channel in basic and applied science (cf. Bouazza, 1989; Davis, 2004; Charton, 1992; Correia & Teixeira, 2005; Gläser, 2003; Hallmark, 2004; Lacy & Busch, 1983; Lawal, 2002; Pinelli, 1991; Smith, 1981; Tenopir et al., 2003; Tenopir & King, 2004; Vickery, 1961). When basic scientists and applied scientists are analysed as distinct groups it is found that basic scientists make relatively greater use of journals, review publications, monographs and secondary bibliographic sources, while applied scientists use research reports, standard and patent specifications, data compilations, technical handbooks, and textbooks to a greater extent. These studies further indicate that there are considerable differences in the amount that scientists read and whether they prefer print or electronic sources.

Engineers and applied scientists in industry rarely use the scholarly professional journals in their field as according to Allen (1977:73), "most professional engineering journals are utterly incomprehensible to the average engineer". The nature of an applied scientist's work often affects the source of information used, e.g. professionally orientated work usually results in the consultation of sources outside the organisation, while work that is operational in focus results in the use of internally generated and available sources. A further factor is that applied scientists interact more readily with information sources closely attuned to their work environment and publications that contain specific answers in a familiar and digestible format, i.e. those publications generated for or within the work environment (Pinelli, 1991:20-23). This would explain why the

⁵ It is generally believed that scientific journals started in the mid-seventeenth century with *Le Journal des Savants* and *Philosophical Transactions of the Royal Society of London* (Lawal, 2002: Introduction.).

unpublished report is the most important and heavily utilised recorded source of information in applied science, and "it is the principal written vehicle for transferring information in technology" (Allen, 1977:87).

Tenopir and her co-workers (2003:5-10) found in their longitudinal study that even after the general migration to an electronic environment libraries continued to be an important source of information, and not only as can be expected for older material. It was further found that while the proportion of readings from library collections increases moderately through the phases, the amount of readings per scientist increased appreciably.

According to Lawal (2002) preprints have, over time, become an important channel of communication as the number of articles produced by scientists has increased exponentially and the formal publishing process has become slower. Preprints, i.e. drafts of manuscripts, were originally circulated, first by mail and then by facsimile, to colleagues and peers for comment. Currently the use of the Internet and e-mail distribution has accelerated the process and in some instances increased the use of preprints (Hallmark, 2004). The formal process of providing preprints in digital format, or e-prints and e-print archives probably had their origin when Ginsparg (1994) created the ArXiv.com archive in high-energy physics at the Los Alamos National Laboratory in 1991. The high-energy physics domain has always had a particularly need to obtain rapid feedback on their research and have traditionally been active distributors of preprints to circumvent the slow turnaround time of the normal publishing process. The use of e-print servers, however, varies considerably across subject disciplines and while heavily used by fields such as high-energy physics (Hurd, 2000; 1281) it is against the policy of many publishers, particularly in the field of chemistry (Brown, 1999:933; Lawal, 2002: Results, Figure 1).

2.4.4. USE OF INFORMAL COMMUNICATION CHANNELS

According to Hertzum & Pejtersen (2000: 762) informal communication is of crucial importance particularly in a collaborative environment, and they and Brittain (1982: 145) state that several studies have provided evidence that researchers spend a considerable amount of their time communicating informally both as input to their work and as output to disseminate their results (these estimates range between Hertzum & Pejtersen's 40% - 66% and Brittain's 50% - 80%). Murphy (2003: Introduction and literature review) is of the opinion that there are "some overarching trends that characterize all research scientists ... scientists, in general, tend to rely on personal networks for information ... to gain perspective on how a problem can be solved".

Herner was one of the first researchers to investigate the comparative use of informal channels of communication between basic and applied scientists and he concluded that while all scientists valued informal interpersonal communication, applied scientists were more prone than basic scientists to utilise informal channels, particularly direct oral communication among colleagues within their own organisation, and basic scientists again made greater use of formal channels (1954:230-240). These conclusions were confirmed by a number of later studies (cf. Allen and co-workers, 1968 - 1988; Allen, 1977; Gerstberger & Allen, 1968; Grefsheim et al., 1991; Hertzum & Pejtersen, 2000; King, Casto, & Jones, 1994; Pinelli, 1991; Poland, 1991; Shuchman, 1981; Tenopir & King, 2004; and Zipperer, 1993). The major reasons for approaching colleagues within the organisation is that such colleagues are easily accessible, they have inside knowledge of the problem and can provide contextual insight (Hertzum & Pejtersen, 2000: 761, 774) and according to Zipperer (1993: 69-78), not only is instant feedback obtained from a trusted colleague, but the information provided is also the most appropriate in a given situation and referral is also often then provided to records available in the organisation. The study by Lacy and Busch (1983:196) of agricultural scientists, however, indicated that while the most frequent interpersonal interaction was between colleagues within the same division, the information obtained from colleagues outside their institute, even though less easily found, was more highly regarded.

While applied scientists tend to communicate actively within their organisations it has been found that basic scientists maintain more frequent contacts with colleagues outside their own organisation. Applied scientists generally rely on *gatekeepers* within their organisation to provide the outside contact, stimulation and information input (Allen, 1966, 1968, 1977). For example, the research conducted on information exchange in the petroleum industry of Nigeria found that the basic scientists depended to a large extent on discussions with colleagues at external universities, while engineers in the same industry showed preference for informal exchange of information with colleagues within the industry (Poland, 1991:67).

Studies that have compared the use of communication channels in different work settings have suggested that a preference for informal channels of communication is more related to a specific work environment and its concomitant organisational structure than to variation in discipline. It was, for example found that applied scientists engaged in production activities are even more prone to using informal channels of communication than their counterparts engaged in research and development in industry (Allen, 1977; Raitt, 1986; Wood, 1971).

Hertzum & Pejtersen (2000: 774) suggest that an important factor that underlies the preference for interpersonal (preferably face-to-face) as opposed to written information sources is that interaction with people provides additional contextual background and insight. They therefore deprecate the general lack of systems containing information on people with special skills, knowledge, etc., and they thus propose that such systems should more readily be developed to help identify experts (a very similar concept to the *blue pages* or expertise databases generally advocated in knowledge management).

2.4.5. USE OF INDIRECT CHANNELS OF COMMUNICATION

An important aspect of information seeking relates to the manner in which scientists become aware of and are led to the channel that contains the information they require (irrespective of whether this happens consciously or not). In most instances users are directed to the channels containing the information by means of an indirect source or channel of communication. The methods generally used to find relevant information are personal recommendations by colleagues; tracing references cited in the literature (thus utilising the interconnectedness of the literature in finding related works); asking a library or information centre to search for the information; regular scanning of current literature; personal searching of the Internet, other electronic databases and abstracting and indexing services; personal searching of publications and other secondary publications such as bibliographies; and also chance or serendipity. The relative use of these methods usually varies in accordance with the particular circumstances of the information need and the scientist's environment.

Tenopir and her co-workers (2003) found that there were three general ways that the scientists they studied learnt about the articles they read; they mostly browsed current journals to keep up with the literature, they conducted structured literature searches to address specific information needs, and they further discovered useful references through citations or being told about articles by someone. It was however found that over time the proportion of browsing had decreased considerably in favour of online searching. Hallmark (2003:Results) reports that 67% of the atmospheric scientists she had investigated became aware of the article that they had cited through reading the literature or by interaction with colleagues. They further also generally did not use electronic databases such as *Meteorological and Geostrophysical Abstracts*, as opposed to electronic journals in the discovery process. It was further found that most of the scientists obtained their article either through their library (both printed and electronic versions), the author, or a personal subscription.

Davis (2004:330) states that because of the extent of the chemistry literature and the volume of new publications each year, chemists have to use a number of methods to search the literature and keep up-to-date in their field. It is thus not surprising that he found that the chemists he had investigated extensively used bibliographic sources to identify and summarise the literature in the field. He further suggests that the relatively high number of referrals from generic Web searches and Web pages are an indication that the Internet is in many instances replacing traditional tools such as library catalogues and bibliographic databases. He argues that this could be because of the often more comprehensive search results obtained and the closer to one-step process if Web sources are used. Individuals will thus tend to “modify their strategies to maximise their rate of gathering valuable information” (Davis, (2004:330).

The results from many studies that compared the information seeking behaviour of basic and applied scientists have shown that basic scientists make slightly more use of abstracting and indexing publications and electronic databases than applied scientists. It was observed that basic scientists generally prefer to conduct their own literature searches, irrespective of whether on-line or manual, as they firmly believe that they are the only people who can select pertinent sources and librarians generally retrieve far too many irrelevant items. Applied scientists, on the other hand, tend to delegate literature searches, often requiring additional value-added services such as the evaluation of references, the extraction and summary of text (cf. Allen, 1977; Bouazza, 1989; Hertzum & Pejtersen, 2000; Murphy, 2003; Tenopir & King, 2004; Smith, 1981; Vickery, 1961).

A number of studies have revealed that a considerable proportion of leads to information sources are acquired by means of informal channels, such as a colleague's recommendation or prior knowledge (Hallmark, 2003; Meadows, 1974; Menzel, 1966a; Smith, 1981; Tenopir et al., 2003; Wood, 1971). Personal informal communication and serendipity often provide references to a number of relevant sources of information that would not come to light otherwise.

2.4.5.1. Current awareness channels

Bouazza (1989:148) refers to a study by Blaxter that found that for current awareness purposes basic scientists derived half of their current information by regularly scanning a small core of primary journals, a quarter from scanning secondary publications such as review and abstracting publications and the remaining quarter from secondary current awareness publications such as the *Current Contents* series, or from personal interaction with their colleagues. Informal communication channels received a relatively low rating as current awareness providers in basic

science. Von Seggern (1995:98), however, reports to the contrary and states that informal communication channels form an important current awareness vehicle in the basic sciences. Research results indicate that when applied scientists require information to keep up to date they most frequently turn to their colleagues, then consult their personal information collections, followed by trade catalogues and manufacturers' literature, then they read technical journals, external and internal technical reports (Jones et al, 1986:786-789).

2.5. THE ROLE OF CONFERENCES IN THE COMMUNICATION PROCESS

Conferences have ever since their inception in the seventeenth century (Walker & Hurt, 1990:7) been highly esteemed for the role that they play in not only providing a forum to transfer current *state of the art* information, but also for facilitating the informal transfer of information by means of the collegiate process and for stimulating the exchange of ideas and opinions amongst attendees.

Ziman (1976:111-112), although he identifies a number of negative aspects that attend to conferences, still comes to the conclusion that they play an important role in the communication process of basic and applied science. He refers specifically to the plight of scientists in developing countries and their need for the interaction provided by conferences. A study by Ehikhamenor of Nigerian scientists reinforces the importance of conferences to assist scientists in developing nations to stay abreast with the research fronts of science (1990:424-425).

Formal papers are presented at most conferences to disseminate new information and to serve as a basis for informed debate and discussion. Eminent persons may be invited to deliver papers on specific topics which are generally complemented by selected contributed papers. This may be supplemented with prepared discussions that respond to any of the above formal channels. However, much of what is of greatest interest and importance at a conference often occurs outside the scope of formal papers. Ad lib, unprepared debates and the interpersonal exchange of information, often during *corridor* conversations, is generally very highly rated by all attendants. Poster presentations, exhibits and displays constitute other less formal, but very effective, communication channels that promote focused discussions and immediate feedback with less time pressures than formal sessions (Grogan, 1982:164; Meadows, 1974:125; Smith, 1993:68-71; UNESCO Ad Hoc Sub-Committee, 1970:82).

A new development in conferences is electronic conferences and the use of bulletin boards to conduct a meeting. They range from totally unstructured, spontaneous contributions to formal invited and refereed contributions. All forms of participation, such as papers, discussions, and

criticisms, are conducted in the electronic medium.

The following is a resume of the most important reasons given by participants for attending conferences and the value they attribute to conferences:

- Information disseminated at conferences is valued for its timeliness and highlights the current awareness function of conferences. These early announcements represent the forefront of research and are invaluable for active researchers to keep abreast of research fronts. They further also furnish participants with the means to announce and publicise new research;
- Conferences engender interactive communication, peer evaluation and immediate feedback from the experts in a field. They, thus, provide the ideal forum to discuss and resolve problems that participants have encountered. The conference environment, furthermore, stimulates the generation of new ideas;
- They provide an ideal forum to establish contacts and nurture interaction among colleagues and fellow researchers across national boundaries and even across disciplines. Thereby networks of experts are created that regularly communicate to exchange ideas and information. Many individual researchers turn to small meetings, limited to a few selected specialists, as a means of informally keeping up-to- date and in touch with colleagues rather than try to cope with the rapid increase in published literature.

(Allen, 1991; Garvey, 1979; Grogan, 1982; Meadows, 1974; Smith, 1993; Unesco Ad Hoc Sub-Committee, 1970; Walker & Hurt. 1990:81-92)

2.6. ELECTRONIC MODES OF COMMUNICATION

Vannevar Bush, as far back as 1945 stated that

professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose ... But there are signs of a change as new powerful instrumentalities come into use ... The world has arrived at an age of cheap complex devices of great reliability: something is bound to come of it (Bush, 1945:101)

The vision of computers that would be used to send, receive, and store all kinds of communications has now come to fruition and the kinds of electronic media that were anticipated are currently widely used. Many recent studies have found that a growing number of basic and applied scientists are in some way or other interacting with the burgeoning number of electronic communication media and networks. It has become part of the modern way of interacting with

information communication systems and in many ways this is affecting the communication of information among basic and applied scientists with traditional communication methods often being overlapped and in part replaced by electronic communication modes. However, some disciplines are moving more rapidly than others towards using electronic communication modes with varying effects on the traditional communication structures.

Fry (2006: 301-304, 312) has suggested that factors such as the nature of a discipline and its level of inter- and multi-disciplinarity, the field's critical mass concentration, work organization and structure, engagement in collaboration, character and extent of personal networks, and physical proximity of personal networks to the locus of collaborative activities all have an effect both on the use of computer-mediated communication for both informal and formal interaction. Walsh & Bayma (1996: 689), in a similar vein, report that their study indicated that the size of a research field, market penetration, the place where critical information is found, degree of interdependence between research units, and technical limitations determined whether communities in science utilised computer-mediated networks.

It is, however, beyond dispute that the utilisation of electronic modes of communication within science communities is myriad. Eisend (2002: 308-310) has for example provided a useful categorisation of the various ways in which electronic media and systems (particularly the Internet) can be used in scientific communication:

- **For research purposes** they are used for inter-personal communication with colleagues (e-mail, chats); discussion with colleagues (newsgroups, mailing lists, chats); scientists create their own electronic databases to record and manipulate experimental data; this data can then be communicated to colleagues all over the world by means of electronic networks; it is also used to collect data from remote instruments, or conduct online surveys, or observe behaviour in newsgroups; scientist participate in electronic conferencing; they access centrally maintained bulletin boards; they can access remote bibliographic and other databases, and the Internet to search for of information; etc.;
- **For publication purposes** they are used to post advance research output such as preprints to newsgroups, mailing lists, personal homepages or to specialised preprint servers; reprints are sent out for discussion (newsgroups, mailing lists); articles are published in online journals where the normal peer review verification process is applied, or if the institutionalised scientific publication process is bypassed, documents are personally authored on the Internet.

Eisend has further suggested that different forms of communication have relevance for different purposes at different times and he refers to “theories of rational media choice” to distinguish between *rich and poor media* depending on the media’s ability to enhance understanding of the message and increase social interaction (Eisend, 2002:309). Taking these factors into consideration Eisend (2002:309) suggests that for inter-personal communication “face-to-face dialogue is the richest form followed by telephone, letters, faxes and finally e-mail” and that face-to-face is particularly relevant when there is a high degree of ambiguity in the content being discussed. Online communication, in turn, is the most appropriate when scientists need to rapidly search and exchange information and when they engage in factual discourse and simple forms of collaboration.

The escalating growth in the use of the Internet and the World Wide Web has far exceeded the original intentions of their creators and in scientific communication the Internet has assumed both a complementary and substitutional role in competition to other media and forms of communication. Eisend (2002:316) however states that whereas

*the Internet is able to break up traditional communication structures in the field of research ...
in the field of publication the Internet supplements the traditional and institutionalized forms of
scientific communications dominated by publishers.*

Electronic mail, in particular, has become an important vehicle in inter-personal communication and the growing collaborative nature of scientific research (Allen, 1991:33). It has substituted for written communication media such as letters, faxes, but according to Eisend (2002:315) not face-to-face interaction or the telephone. Davis (2004:330) again found in his transaction log analysis of chemists that e-mail was used extensively for referral purposes and as a major means of communicating within the research community, particularly when distance is a factor.

With the rapid expansion of the use of electronic communication modes the question arises to what extent this has affected information communication behaviour. Has it made an indelible impact as claimed by Allen (1991:32), or has it been absorbed into the scientific communication process as merely another mode in which information is communicated utilising essentially the same channels as before? Throughout the centuries humans have adapted their communication styles to fit new emerging media formats and Cronin (1982:228) is of the opinion that it is difficult to see in what sense the electronic communication of information would structurally, or substantively, affect existing practices and kinds of interactions. It has further been suggested that electronic communication of scientific and technical information may specifically affect the way informal information transfer takes place (Allen, 1991:32). Hurd (2000:1283), for example, suggests that the current *invisible*

college phenomena could evolve into *virtual invisible colleges* which could possibly broaden and democratise the membership base, a decided benefit for younger scientists and those from developing and often marginalised nations who often find it difficult to become integrated in *closed* interpersonal networks. Davis (2004:330) further also suggests that there are indications that electronic media have extended the concept of the *invisible college*. Talja et al. (2004: Introduction), however, are of the opinion that metaphors such as *virtual communities*, *cyberspace colleges*, and *voluntary networks* incorrectly imply that electronic communication forums are new kinds of *invisible colleges*. They are of the opinion that communication behaviour is not in fact affected by these enabling technologies, but rather by the inherent and fundamental “social and cultural contexts into which they are embedded”. It is suggested that although there is little dispute that developments in communications technology will to some extent affect the informal communication of information, it seems unlikely that electronic networks will entirely replace informal networks as they “have a functional (and psychological) reality which transcends the mode or mechanism by which they coalesce, and it is this (not the means of communication between members) which in the long run determines their validity” (Cronin, 1982:232). The real effect of electronic communication modes on the inter-personal communication behaviour of scientists therefore remains a point of debate.

It was found for example in the medical environment by Wulff and Nixon that while easier access to electronic journals in many instances increased use, the general pattern of journal use was the same in the electronic environment as in the print environment. Clinicians and researchers more frequently searched and used information produced in prestigious publications, irrespective of the mode of publication (Wulff & Nixon, 2004:321). Gläser (2003:47) in his discussion of whether electronic media and specifically the Internet have had an effect on the social structure and knowledge generation of scientists also comes to the overall conclusion that they have not had any substantive effect as “science communities are, and always have been knowledge producing and sharing communities”. He further contends that scientists have always used a variety of channels to communicate and share knowledge of which informal face-to-face communication is (and remains) one of the most important for their collaborative activities. O’Dell et al. have further suggested that only when scientists move away from cloning paper-based communication patterns in the electronic environment and go “beyond the limitations of a paper-publishing paradigm and exploit the possibilities offered by the digital age to the full ...[that]... the real scientific communication revolution will begin” (2004: 91). It would thus appear that there are contrasting views as to whether the communication process in science has fundamentally been

pervasive in the scientific communication process their assimilation and acceptance will take place incrementally and they will only be adopted if they “support and update traditional functions that endure because they are valued by a community of scientists”. She further states that the peer review system will remain a fundamental aspect of the communication process with quality control mechanisms adapted for effective use in the electronic environment.

Hurd (2000:1283) further suggests that new roles and synergies are evolving in the electronic environment and that these could have a fundamental effect on the communication process. She refers, for example, to scientists who author and publish on their personal Web sites; to universities that engage in publishing the research output of their academic staff; to subscription agencies (such as Blackwell, Dawson, and EBSCO) that offer aggregator services and have thus become gateway and service providers; and to professional societies that engage in archiving the primary information resources in their field. She further refers to cooperative ventures such as the SPARC (Scholarly Publishing and Academic Resources Coalition) initiative where scholarly associations, commercial publishers, university presses, research libraries, etc. all cooperate to cut electronic publishing costs. Gläser (2003:47) has also identified new functionalities in the communication process that he thinks could have a qualitative influence on work practices and knowledge production. He specifically suggests that features such as having online access to geographically remote data and the possibility to share data among geographically dispersed collaborators and colleagues, has the potential to enhance the science communication process.

It is thus clear that scientists' opinions toward electronic media and systems have evolved considerably from the early scepticism during the 1990's to recent enthusiasm. Initially high costs, usability problems, and questions around quality control of electronic journals were the main factors that prevented extensive use (Hallmark, 2003:Conclusions). Other factors related to problems with regard to accessing, downloading, and formatting, as well as not knowing about the availability of such services and how to use them (Folster, 1995:91). It is thus not surprising that a number of studies conducted in the 1990's indicated that the scientists investigated preferred manual systems and journal articles in print to those in electronic format (Bichteler and Ward, 1989; Brown, 1999; Folster, 1995; Hallmark, 2003, 2004). Von Seggern, however prophesied in 1995 that “as computer skills become more prevalent, systems more intelligent, and as physical access to such systems and other specialised information databases is improved, some aspects of information seeking may change, though at varying rates among disciplines” (1995:96). Mahe (2004:The dimension of uses) suggests (in contrast to other authors) that the virtual reproduction of print

communication channels into electronic modes has in fact helped ease the transformation process and made it more commonplace and thus acceptable.

Attitudes did in fact change remarkably quickly and by the turn of the century studies of scientists' information communication behaviour were indicating that they had adapted to electronic systems and media, integrating them into their information-seeking routine. The convenience of having immediate access to a wealth of information, rapid retrieval and seamless communication possibilities was particularly appreciated. Hallmark (2004: Introduction; Conclusion), when comparing the results of her 2004 study with similar unpublished data obtained in 1998, comes to the conclusion that there had been a rapid evolution and acceptance of electronic media and systems. While in 1998 the majority of chemists and geologists surveyed still preferred to use traditional (non-electronic) methods for access and retrieval of material, the later study showed that by 2002 not only was the Internet being used for rapid inter-personal communication, but also for immediate access and retrieval of information.

Bonthron et al. (2003) further suggest that for scholars to migrate from print to electronic journal modes there has to be a sufficient *critical mass* of electronic journals in any specific field. They found that although it was problematical to define an ideal critical mass in terms of explicit journal numbers, they could establish that such a critical point was between 60%-75% availability of electronic journals. These percentages however may vary according to the type of material that is available in specific disciplines, the accessibility of libraries serving users, and varying working environments. They further argue that usefulness however remains the primary criterion used by scholars to accept information and not the mode of communication of the channel containing the information.

The various problems created by the more traditional publication processes, such as high publication costs, problems caused by the full transfer of intellectual property rights from author to publisher, and the slow turnaround of traditional publishing, in combination with advances in information and communication technologies and the ubiquitous use of the Internet have made scientists realise that they should use alternative and more efficient ways to share results. New electronic publishing models, based on author self-archiving, have thus evolved and according to Correia & Teixeira (2005:349) have the potential to revolutionise scholarly communication by making it more efficient and effective. One of the most effective such initiatives is the development of electronic pre-print archives and particularly the arXiv.org e-print archive created in 1991 by Ginsparg at the Los Alamos National Laboratory to give access to pre-prints in the

domain of high-energy physics. The success of arXiv provided the impetus to develop a number of other e-print repositories in a variety of subject domains during the late 1990s (Fry, 2006:309-310). A related innovation has been the evolution of institutional repositories where open-access archives are established and managed by research organizations to house articles published by authors from their institutions. In December 2001, the Open Society Institute (OSI) convened a meeting in Budapest to establish a protocol to accelerate international efforts to make scientific and scholarly research results freely available on the Internet (Correia & Teixeira, 2005:353).

Lawal (2002) surveyed the use and non-use of e-print archives in different disciplines. The results indicated varied use across the disciplines, with the highest use among the physicists, followed by the astronomers and then researchers in the mathematical sciences. The lowest use rate was among the biological sciences, while the chemists did not use this channel of dissemination at all. It is the general policy among publishers in the chemistry domain to adhere to the *Ingelfinger Rule* which restricts and even prohibits such pre-publication of results. Scientists in physics have always had a well-developed structure of pre-print dissemination of new research outcomes and this has very effectively been upheld by the ArXiv e-print archives mentioned above. Lawal found that in addition to the disciplinary factors, the level of use of e-print archives related to the importance attributed to early and rapid dissemination of research results (particularly where the peer review process and regular publication takes very long), and the amount of visibility and exposure it provided for authors. Reasons for non- or low use included technology constraints and as mentioned publishers' restraining policies. Lawal further states that the inherent information communication behaviour and the nature of the literature in a field also affect levels of use of e-print archives.

Tenopir and her co-workers (2003: Background) have specifically identified three stages in the migration of scholarly literature from print to electronic formats and the effects this has had on the science communication process:

- The first or early phase (1990–1993) followed the introduction of electronic journals, both in online and CD-ROM format. At this stage, scientists as authors and readers were concerned about quality and sustainability of the new media and many publishers were also hesitant to commit to electronic journals. Libraries, however, were hoping that the emergence of electronic journals might provide the answer to spiralling print-media subscriptions and pressures of physical space. It was during this time that preprint archives were developed for physicists at the Los Alamos National Laboratory and the success of this innovation together

with developments in information communication technologies and the emergence of the World Wide Web all triggered widespread interest in electronic media;

- During the second or evolving phase (1994-2002) the majority of scientific journals became available in electronic format, new features were added to some journals, and some individual articles were made available through preprint archives, author web sites, etc. Most of the electronic journals were however merely replicas of traditional print journals (some only in electronic format, but most published in both formats). Libraries now began expanding their electronic journal collections in parallel or as replacement to print and academic libraries particularly began to rely on aggregator databases and/or negotiated licenses with publishers, library consortia or other vendors. Other electronic preprint services were also emerging together with author self-publishing initiatives, the development of institutional repositories, and the Open Archives Initiative (OAI);
- According to Tenopir et al. (2003) we have now reached the advanced phase in which sophisticated systems have evolved that provide searching capabilities, advanced features, such as deep links to raw data, individual articles, as well as full text core journals collections (often dating back to first volumes) integrated into one complete system. A good example of such an integrated system is the one developed by the American Astronomical Society (AAS) in conjunction with the University of Chicago Press and the Astrophysics Data System (ADS).

They further concluded from the three surveys they had conducted that while reading had increased over the period (from 0.3% during the evolving phase to 79.5% in the advanced phase), the usefulness and value attributed to the information read had however remained relatively stable across the phases (i.e. content had not changed) (Tenopir et al., 2003:Conclusion). A further unusual finding was that author web sites were not really visited as they accounted for less than one percent of readings.

Although the benefits of electronic communication are obvious, there are also inherent problems that attend on this mode of communication. Allen (1991:34) expresses the caveat that the “immediate benefits of new media often halo the opinion of the users of information, causing the potential hazards of the new technology to be overlooked or ignored”. Hallmark (2004:Access and use of data) suggests that discovery of useful articles through serendipity has decreased considerably and the chemists and geologists she surveyed expressed concern over the quality of journals and the possibility that the ease of electronic publication may result in the field being flooded with too many publication which further exacerbates the information overload. Mahe (2004:The

dimension of uses), again refers to the fact that many specialised journals are not as yet, and may never be, available in electronic format; referencing and citation practices are often irregular and confusing; and searching and retrieval can be impeded by the inflexibility of hypertext links and predefined files.

Hallmark (2003:Conclusion) found in her study of atmospheric scientists that while several of the scientists indicated that the Internet had revolutionised data access and transmission, others were less enthusiastic and enumerated various difficulties such as the cost of and slow access to certain data, incompatible data formats and media, and the lack of metadata. Libraries further also have to contend with ever increasing licensing and access costs (Hallmark, 2003: Introduction).

An area of particular concern that has frequently been mentioned is whether outdated electronic media would be readable in future if information technology sustains its rapid expansion and development. Mahe (2004:The dimension of uses) is particularly concerned about the general availability of journal back-files in the electronic environment, the slow access to some back-files, and whether publishers will maintain in perpetuity those back-files that do exist. According to Bonthron et al. (2003) technical problems can cause serious barriers to the use of electronic media and they, for example, found that the users they had investigated disliked reading from a screen. De Gooijer (1993:126), in turn, has stated that the growth in use of electronic media may create pressure to increase the speed of communication which could have the detrimental effect of reducing time for adequate reflection.

There is the further real danger that the expansion in use of electronic communication media will erode the fundamental principles on which scientific communication is based. As electronic media continue to overlap and replace traditional forms of communication there may be a marked reduction in permanent forms of documentation and the potential created for destroying important archival records required by future researchers. The structure of science depends to a large extent on the production of permanent records that reflect scientific endeavour which in turn underpin its cumulative base, its peer review system and its reward system. It is thus imperative that for electronic media to effectively replace print-based media and maintain their role in the scientific communication process that they adhere to the same scholarly control measures such as peer review for quality assurance and academic recognition; international availability; preservation for archival collections; inclusion in bibliographic services; and consistent convenient access (Allen, 1991:35-36).

Of major concern to the scientific community is the need for prudent use of instantaneous electronic

media for communicating scientific information when scientists do not adhere to the rules of peer review for validation of research methods and release information prematurely, the controversy that can erupt causes damage to the reputation of scientists and their discoveries. The enormous benefits of electronic media to scientists and publishers must not outweigh the concern for potential damage to the scholarly communication cycle (Allen, 1991:37).

Cronin is, however, of the opinion that even in the electronic era, the peer review system, the critical element of scientific communication will continue to be of paramount importance and that the “formal system will continue to serve as a post hoc presentation of research results, and a mechanism (an undeniably costly one) for dispensing recognition to the scientific establishment” (1982:228).

It has further been mooted that scientific communication will become less visible to the general public as more use is made of electronic communication networks. These networks often represent a closed environment with access granted *only* to privileged members (De Gooijer, 1993:125), and this in fact negates the argument that they have the potential to broaden the participative base of inter-personal communication. When electronic discussion lists first emerged there was the general expectation that they would increase communication and collaboration among scientists and that this would also result in increased productivity. It was anticipated that they would link information-seekers with the requisite information, that they would facilitate new links among scientists, facilitate discussion and knowledge sharing, facilitate the exchange of information and ideas, and cooperation among scientists, and extend the participatory base of inter-personal communication by bypassing exclusive collegiate networks (Talja et al., 2004: Earlier discussions on electronic mailing lists). Taubes (1993:1246-1247), for example prophesied in 1993 that bulletin boards would have a greater impact than the traditional refereed journal upon the dissemination of research outputs. Talja et al. (2004) are however of the opinion that very few of these expectations have come to fruition. In a similar way it was originally thought that electronic conferences would have many benefits and pave the way to increased worldwide participation (that is if the connectivity is there). It was soon seen, however, that although electronic conferences have on the one hand made conference participation more accessible, they have on the other hand removed personal interaction, one of the most important benefits of conference attendance. A further drawback is that as the proceedings of such conferences are generally not published, non-participants cannot access the published record of the proceedings and no permanent archival record is preserved for future use (Allen, 1991:37).

2.7. FACTORS THAT AFFECT THE COMMUNICATION OF INFORMATION

A fundamental prerequisite to understanding the communication of information among scientists would be to examine the variables that affect the communication process and information-seeking behaviour. A wide diversity of factors has been listed in the literature that might affect information communication behaviour, one of the most incisive being Paisley's 1968 analysis wherein he suggests that "the full array of information sources that are available; the uses to which information will be put; the background, motivation, professional orientation and other individual characteristics of the user; the social, political, economic and other systems that powerfully affect the user and his work; and the consequences of information use - e.g. productivity" could all in various ways be contributing factors (Paisley, 1968:2).

Wilson, in turn, suggests that a person's *life world* which he defines as "the totality of experiences centred upon the individual as an information user" underlies all information need that motivates and drives the communication process. Sub-worlds that have the greatest impact are the person's work environment, within which we find various reference groups with whom the user identifies such as fellow professionals, peer groups in the organisation, etc. Other sub-worlds will be the array of information systems (including their professional staff and technology) that a user is in contact with and which provide access to various "embodiments of knowledge" (Wilson, 1981:6).

Palmer's (1991a) study of the role of information in the daily lives of a population of research scientists provides valuable insight into how different categories of scientists interact with information and information communication systems. She studied researchers from three main disciplinary groups (entomology, biochemistry and statistics) that were attached to an agricultural research institute. Using a subjective and intuitive method that categorised the scientists' information communication behaviour according to cognitive style and personality she initially identified six categories of information seekers:

When she used cluster analysis techniques the various information communication behaviour patterns re-grouped into five distinct typologies that indicated that discipline, particularly the rate of change in the discipline, work role, organisational structure, and time spent in the subject field were important indicators of how each category of scientists interacted with information. Palmer's research clearly indicates that even within a single organisation individual scientists and, collectively, different sectors have distinct information requirements and manifest varying information communication behaviour patterns.

This researcher thus suggests that the variables that impact on scientists' information communication behaviour are an inter-meshed combination of factors that range from their basic human needs (cf. Maslow's hierarchy) to external environmental factors that include

- the scientists' innate personality traits (both affective and cognitive domains);
- their interpersonal relationships and demographic characteristics;
- factors that relate to their work situation (such as type of work, whether basic, applied, theoretical, or practical by nature; specific task attributes; professional and psychological characteristics required by work roles);
- their adherence to a discipline;
- exposure to information systems, both formal and informal, and cognitive;
- social aspects of information use.

Other factors that may affect communication behaviour relate to the scientists' interaction with information communication channels. This would include the perceived quality, availability, accessibility and ease of use of such channels as well as the users' interaction with the information systems that provide access to them.

2.7.1. THE SCIENTISTS' ENVIRONMENT

In his seminal information needs and uses review article Paisley, (1968:3-6) proposes that scientists and all persons for that matter operate within a series of many converging environments that influence and impact on their information needs and communication behaviour. He identifies ten such environmental systems, the scientist *within his own head* serving as a focal point for the other systems and denoting the cognitive function of an information user seeking, evaluating and utilising information. The other nine systems relate to and support this focal system which cognitively creates, motivates, and directs the need and search for information.

The next encompassing system relates to the group of people working directly with a person, e.g. on the same project. This environment is very important and influential as it is directly attuned to the person's work interests and information needs. The next system is the scientist within a formal organisation, usually his/her employing organisation, which tends either to block or to open channels of communication.

The political system, such as a nation, to which scientists belong, greatly affects their information requirements and the transfer of information to them; (all other systems discussed so far are contained in this system, and are consequently affected by it). For example a strong feeling of

nationalism can cause scientists to isolate themselves from communicating beyond national boundaries and for importing information. The political system may also restrict access to certain categories of information with consequent effect on the communication process. The largest system of direct relevance to the information communication process is the cultural system to which scientists belong. Such matters as prestige and professional prominence are unavoidably governed by the criteria of this system.

The membership group, which exists both within and beyond the previous two systems, is the professional group or discipline with which a person is primarily associated. Such a system is very influential, as in all likelihood it will control the official information channels in the scientists' discipline. Closely related to the previous category, but also extending beyond its boundaries, is membership of a reference group. A reference group coordinates people with related fields of specialisation, and is congruent with the scientists' area of interest. Contained within the reference group, and of which it forms a sub-system, is the *invisible college* to which the user might be affiliated (cf. also 2.2.2.1.). Such a *college* comprises a small peer group of people who may be dispersed all over the world, but who are all working in the same, very specific direction with strong communication links and who exchange information regularly on a personal level.

Each area of specialisation, profession, discipline, etc. that a scientist may be affiliated with has its own unique information communication patterns. An individual's affiliation to one or other of these groupings would thus directly influence information communication behaviour. A scientist's possible association with an *invisible college* further compound the complexities as such organisations are very influential as they collectively control most formal and many informal channels of communication in a membership group.

The two remaining systems are of a less personal nature than the preceding eight, and tend to cut across the others. The scientist within a legal/economic system is accountable to the prevailing system of copyright, industrial secrecy, competition, etc. which tend to act as barriers to the flow of information. On the whole, the economic system further determines the quality and quantity of information available. According to Wilson (1981:10) the economic climate and the differential stratification of resources may affect a person's information perceptions. For example certain communities might have better resources than others which may result in an 'information rich/poor' dichotomy. The final system that Paisley refers to is the formal information system, such as libraries and other information-disseminating centres to which a scientist has access. Wilson (1981:6), in turn, states that people interact with a variety of information systems which may

consist of human *mediators*, technology to facilitate information retrieval and access to "embodiments of knowledge" which may be both documents and people who have the required knowledge. Such systems have immense influence on perceptions of information need and the nature of information transfer.

2.7.1.1. Discipline and/or subject affiliation

It is readily assumed that information seeking and information use are professional requirements and, as a consequence, many studies have been conducted with the specific purpose of establishing whether or not affiliation to a discipline or profession has any marked influence on the information communication behaviour of scientists. Herner (1954:230-236) went so far as to suggest that the only significant factors that have an influence on information use are the discipline that scientists belong to and fields of work in which they are engaged. Palmer had originally thought it reasonable to attribute variation in information seeking behaviour among the scientists that she had investigated primarily to individual differences in user personality, but as was seen above the further analysis of her data indicated that although personal differences were important, discipline or subject area and particularly the rate of change in the discipline was of overriding importance. She further also found that work role, organisational structure, and time spent in the subject field were more important than cognitive style and personality as factors that influence information communication behaviour (Palmer, 1991b:273-275).

A number of researchers have addressed the impact of variation in discipline on information communication behaviour ((Bonthron et al, 2003; Davis, 2004; Hallmark, 2004; Hurd, 2000; Tenopir & King, 2002; Walsh and Bayma, 1996). Vakkari argues strongly that the relationship between individual information seekers and the communities in which they operate should not be ignored and that *situationality or contextuality* of information behaviour should be conceptualized as part of the wider "social milieu in which it occurs" (Vakkari, 1997:462). Talja and Maula (2003) relate differences in information communication behaviour to the paradigmatic nature of disciplines. The level of theory development has an impact on knowledge generation, the degree of scatter in a field, and field-specific relevance criteria which all in turn affect interaction with the information communication process.

Using Whitley's (2000) premise that the major differences between disciplines can be attributed to the degree of mutual dependence of scientists at the research front and the degree of task uncertainty when producing and evaluating knowledge claims in a field, Fry (2006) conducted a

domain-analytic study of the information behaviour of three scholarly communities. His findings indicated that research fields where scientists have a high level of “mutual dependence” together with a low level of “task uncertainty” are good at coordinating and controlling channels of communication and that they more readily integrate and utilise electronic communication media in their work environment. He thus argues that “patterns of coordination and control within scholarly communities” directly influence the information communication behaviour of each disciplinary field. In fields that have narrowly defined research areas, that are highly structured with standardised work procedures and which produce specific results it is found that the communication system is complex “with a highly formalised symbol structure that is used to coordinate research across geographical and social boundaries” (Fry, 2006:303).

Walsh and Bayma’s study of scientists’ use of computer networks found significant differences among the fields they investigated. They concluded that structural factors such as size of the research field, market penetration, the place where critical information is found, degree of interdependence between research units, and technical limitations determine usage of electronic networks for both informal and formal communication purposes (Walsh & Bayma, 1996: 689). Fields that are *market-buffered* like mathematics and physics make extensive use of electronic networks for informal communication purposes, while those that are *market-penetrated*, such as chemistry and experimental biology, mainly use electronic networks for formal communication. Walsh and Bayma (1996:693) further suggest that “each field of science is characterised by a particular work organization” and differences in both work organisation and the overall structure of a discipline affects the use of electronic media. Researchers in small fields are more likely to engage in interpersonal communication (and thus also electronic networks) as they know who can contribute relevant information in their field while in the large expansive fields information interaction is more prone to take place in the formal domain. In some fields critical information is found in the minds of colleagues, while in others it is located primarily in the laboratory, and in others in the published literature, etc. (Walsh and Bayma, 1996: 691).

Kling and McKim, in a very similar way to Walsh and Bayma suggest that four overlapping structural characteristics of disciplines influence the role that peer reviewing and formal publication plays in the discipline’s communication system. The differentiating factors that they identify are the cost of research projects, visibility of research in the field, level of industrial integration, and the way in which communication channels are concentrated (Kling and McKim, 2000:1317). They further indicate that trust is a pivotal differentiating factor when establishing

the use of electronic media across disciplines. Kling & McKim (2000: 1306) refute the assumption that emerging communication patterns such as the early-adopter behaviour found in high energy physics will be replicated in other specialities. They argue, instead, that there will continue to be diverse communication practises based on discipline-specific cultures and norms and thus varying levels of adoption and adaptation to new technological innovation.

Brown (1999: 929-937) further also found in her study that different disciplines showed different information usage. According to her while chemists have *continuous and on-demand* needs and rely heavily on current journals, mathematicians rely more on older material and monographs, and physicists particularly value pre-print archives (cf. references to ArXiv.org) as they need very up-to-date information. Tenopir and her co-workers (2003: Previous studies of journal use) argue that since physicists have always relied on preprints, it can be expected that they would currently make heavy use of e-print services. They further found in their longitudinal study that engineers, while reading fewer journal articles per year than scientists, spend more time reading each article they deem relevant. They further suggest that it may be the nature of the way research is conducted in specific scientific fields that cause higher reliance on electronic journals, e-print servers, or aggregated databases of articles.

Hurd suggests (2000: 1283) that the adoption and use of electronic innovations, would as in the past, vary from discipline to discipline and would relate to the unique culture of each area of specialisation, their value-systems and how the electronic environment would affect these values and these would largely be determined by

- (a) the existence of an active research front; (b) value placed on rapid dissemination of findings;*
- (c) presence of an active invisible college; (d) prevalence of large-scale collaborative projects;*
- (e) geographic dispersion of teams; (f) interdisciplinarity research collaborations use of large shared datasets; and (g) role of patents in protecting intellectual property.*

Fry's (2006:312) research corroborates other studies that have identified different patterns of informal and formal communication across fields and he further indicated that this aspect has an influence on the production and use of networked digital resources. He therefore suggests that

fields that are non-hierarchical, loosely organised, intellectually pluralistic, with local variation in work organisation, are particularly likely to rely heavily upon face-to-face informal communication for coordinating collaborative work, and will rely more heavily upon formal communication for community-wide dissemination of research and reputation building.

The fundamental differences between the social systems of basic and applied science, the difference in creative processes and creative products produced by the two social groups, and their divergent work settings all contribute to the varying communication patterns of the two main disciplinary groups. The following specific factors have been listed as contributing to the differentiated communication behaviour of basic and applied science (Pinelli, 1991:11-12):

- Basic scientists discover and explain nature; they search for theories and principles; they seek a result for its own ends; they contribute new and original knowledge; the reward system is based on peer recognition and approval; recognition is established through publication and priority claims of discovery; the communication system is based on unrestricted access to information; the social system in basic science enforces strong norms that ensure free and open communication of information; it is not considered proper to seek rewards outside the social system of basic science; a distinguishing feature of the social system of basic science is the utilisation of 'invisible colleges' to promote the informal exchange of information and peer recognition;
- Applied scientists exploit nature; they seek to develop and make things and use information for this purpose; they invent things and are engaged in solving problems within a practical operational situation; new and original knowledge is rarely required; the reward system is based on materialistic gain and serves as inducement to continue to contribute in some way to technical knowledge; they also tend to seek rewards outside the social system of applied science; the value of knowledge in applied science is related to its value as a commodity; communication networks in applied science are based on end products, not knowledge; strong impediments operate to prevent open access to information and the free exchange of information outside the immediate work environment; the social system of applied science is characterised by restrictions, security classification, and proprietary claims to knowledge.

2.7.1.2. Work environment: Employing organisation and work activity

It is further suggested that the immediate work environment of scientists has an important effect on their information communication behaviour. A scientist's work environment may comprise of a number of hierarchically related sub-systems and their influence on information communication behaviour may range from the direct and immediate impact of the specific work-team with whom a person narrowly associates to the overall employing organisation. Within any organisation it has been found that various organisational factors impact on the flow of information within, to and from the organisation and various status levels, roles, responsibilities, structures and policies tend to

influence employees' interaction with information and their need for information.

Cognisance of such factors features in a number of studies. Hall distinguishes between "public use [of information] versus proprietary use versus the academic urge to know" as a means to differentiate between the communication and use of information in various work environments (Hall, 1981:106). Communication of information in the public domain (usually government institutions) is categorised by a tendency to seek information only when a crisis arises, to seek information that denotes consensus opinion, to use information to control situations, to acquire information to achieve pre-stated goals, and to collect everything as widely as possible. These users infrequently process the information they acquire to produce new information. Proprietary use of information (usually in industry or business) may be distinguished by pre-emptive actions to acquire information that might be useful in future. Proprietary users set new targets constantly, and they retain only selected, prioritised information. Novel information is primarily used in their efforts to beat competitors and the emphasis is on the processing of information to produce unique marketable products. Only the most essential and critical internal reports are produced at as low a cost as possible. Academic communication of information is distinguished by an inherent *urge to know* and the need to research the chronological development of a topic. Academics are particularly interested in theory, there is constant informal exchange of information through the medium of invisible colleges, and all information on a specific subject is collected. Information is highly processed by academic users and the objective of information use is to produce and publish new information, to achieve peer group approval and to claim priority rights for new ideas.

Wilson has suggested that the various world views of different occupations generate divergent demands upon sources of knowledge (1984:200) and it is proposed that this in turn also affects information communication behaviour. Wilson proposes that persons working in bureaucracies have a distinctive cognitive style which may be distinguished by their general concern with orderliness and the legal basis of their establishment. This, in turn, results in an information seeking behaviour that tends to be utilitarian, introverted, constrained and overly preoccupied with their own organisation (Wilson, 1984:202).

Mahe (2004) found in her research that the importance given to scientific information was related to a scientist's work activity and where they were placed on the basic to applied science disciplinary continuum. Scientists whose research activities were more applied, confidential and contractual were marginal information users, the literature in their field was usually inadequate, and they frequently depended on other people to obtain and filter the basic scientific information

they required. Researchers working at the more basic end of the spectrum, in contrast, engaged heavily with the primary literature in their field, they were generally integrated into a large international scientific community that stimulated informal information exchange, and were prolific contributors to the information in their field (cf. also 2.2 and 2.3).

There is a whole body of research dealing with the interaction between organisational factors, information flow and performance (or productivity). T J Allen and his colleagues undertook in-depth and comprehensive research into the flow of information within the constraints of industrial organisations (Allen, 1966; 1968). Pelz, and a number of co-workers, in turn, extensively studied scientists conducting research in a number of diverse organisations with the objective, amongst others, to establish whether the organisational structure affected performance (Pelz, 1967; Pelz & Andrews, 1966).

From these studies it would appear that organisational structures and *climate* can have an important influence on a person's information seeking behaviour. The more open and transparent the structure and the more freedom granted and self-directed, or autonomous, employees are, the more effective and productive they are with an attendant increase in a need for and use of information. This further results in increased communication with colleagues within and beyond the organisation, a general decrease in isolation and an increase in stimulation.

A number of researchers have demonstrated that in general, information flows more freely in an academic and research environment than in industrial organisations. The latter type of organisation tends to inhibit the free flow of information as they are often organised along fairly bureaucratic lines and competition in industry, as well as the tendency to secrecy, frequently results in access to information being restricted. Further factors that affect information communication in industry are the general concern with deadlines and cost-effectiveness, and the fact that they are mission-orientated. Academics and research scientists, as a result of their less structured organisations and less restrictive work ethos, have fewer impediments to obstruct them when communicating and using information within and beyond the bounds of their organisation (cf Allen, 1977, Charton, 1992; Hanson, 1964; Marquis & Allen, 1966; Pinelli, 1991; Slater and Fisher, 1969; Stevenson, 1980; Talja, 2002).

From these studies it has further emerged that:

- researchers in industry require information more speedily than academics;
- factual (as distinct from theoretical) information is required more frequently by researchers in industry than by their academic counterparts;

- academic scientists have more specific, focused and defined information needs than industry researchers;
- academic scientists are far more unsophisticated in their use of information facilities (including libraries) than their industry counterparts;
- academics search for information themselves, while industry researchers tend to delegate this task more readily;
- researchers in industry have a wider range of information needs which are more difficult to foresee;
- academics tend to browse more to satisfy an unspecified or unknown need; and
- academics make less use of recent literature than their colleagues in the industry sector.

The type of work and a person's 'work role', (i.e. the activities, the responsibilities, etc. that a person is committed to as employee of some or other organisation) have further been identified as important determinants of information communication behaviour. Wilson has suggested that the performance of specific tasks, problem solving, decision-making, etc. will generate cognitive needs, while the personality of the individual and his/her ability to fit in with the organisational structure will create affective needs, and both these needs, in turn, motivate and initiate information communication behaviour (Wilson, 1981:9). Slater and Fisher (1969) investigated variation in work activity by comparing scientists who were primarily engaged in lecturing activities with scientific researchers with a minimal teaching load. They concluded that variation in work activity had a marked effect on information seeking and use behaviour.

2.7.2. AGE, EXPERIENCE AND STATUS

Age, experience, seniority and the status of an individual are often key factors in the information communication process in science. It is reported that older scientists derive inspiration from informal discussions, usually with their more senior (and thus also often older) colleagues in the same institution. It was further found that higher-ranked scientists tend to show greater information use rates than those in the lower echelons (Bouazza, 1989). Hallmark (2004) further reports that her study indicated that while the younger users preferred using e-journals, the older users rather referred to print journals. Talja et al. (2004: Earlier studies on scholarly mailing lists) in turn suggest that electronic mailing lists provide differentiated benefits for senior vs. junior and elite vs. non-elite scientists (it was found that the senior and more established scholars tend to find them less beneficial and then withdraw from the interaction).

One of the most marked effects of a scientist's status on the communication process is discernible in

the context of the informal communication network, where according to studies by Allen (1968:452), and Price and Beaver (1966:1017), such networks operate at a senior level. The more senior (and often also older) members of a profession communicate extensively on a personal basis at conferences, by letter, telephonically, electronically etc. The younger persons, in contrast, generally have fewer external personal contacts and they tend to rely more on the literature to interact with the leaders in their field by regularly reading their publications. Ford (1973:101) further also suggested that in a university environment, junior lecturers are more likely to use library facilities than professors, who usually form an integral part of some or other *invisible college* (often playing a key role). Accordingly, they obtain a large proportion of their information via their personal contacts, obviating the need, in many instances, to use formal channels through the medium of a library.

2.7.3. INFORMATION SYSTEMS

An individual scientist will generally interact with a variety of information systems, ranging from a number of formal systems either related to his/her work environment or social structure to the informal communication networks to which she/he may be linked. Studies have indicated that there is a clear interaction between an individual's information communication behaviour and the information systems that provide access to information. For example, the mere existence of a convenient and well-organised collection of information sources and formal information services or, on the other hand, the integration into an efficient informal information communication system may stimulate communication activities that would otherwise not have occurred. Conscious and unconscious needs for information may be activated by efficient facilities to meet them, while inadequate facilities tend to stifle information needs and communication behaviour. It is suggested that information users' perceptions of the information system serving them could be one of the primary determinants of successful or unsuccessful communication acts.

Many information users are uncertain and anxious when seeking information and communicating their information needs to information professionals. Mellon (1986:160) has found that states of anxiety and uncertainty are commonly experienced by users when first interacting with information services and those individual users perceive this to be due solely to their own inadequacy in handling the situation. These inhibitions negatively affect the interaction with information service providers and subsequently limit access to information and communication behaviour. Information systems have, however, traditionally ignored users' feelings of uncertainty, anxiety and confusion when they interact with the system and have rather adopted a systems approach based on order and certainty (Kuhlthau, 1991:361).

A number of researchers (Dervin, 1976:333; Nahl-Jacobovits & Jakobovits, 1992:13; Westbrook, 1993:546-547) have proposed that communication systems should rather concentrate on helping people to inform themselves by providing them with the requisite affective and cognitive skills necessary to cope with their information needs, rather than create sophisticated information retrieval facilities. Information users should be sensitised to the broader information systems and be made aware of the interconnections between the wider information systems and the services and resources of their immediate libraries.

2.7.4. INFORMATION USE

A comprehensive study conducted by Hall (1981:103-112) covering a cross-section of information users involved in research, information operations, and planning, indicated that the intended use of information plays a very important role in the information communication process. He suggests that the most important factor in judging the value of information is its intended use and he further states that this may change with time as roles and priorities are modified. This, in turn, may affect each person's value judgement as "a given individual operates from different inner centres at different times and ... the shape of his cognitive map shifts accordingly, in ways which can be linked to identifiable patterns of use" (Hall, 1981:107). Users judge the value of the information that they have received and take decisions on what they wish to retain and use based on a number of rational, objective as well as aesthetic, intuitive, and subjective principles. Information use thus goes through various levels as more energy and mental processing is employed to upgrade the information from the raw information acquired from external sources or personal resources to where it is selected, synthesised and analysed and finally used to take some or other action.

Information use is further inextricably interrelated to an individual's work roles, discipline affiliation and other environments that influence communication behaviour. As mentioned in 2.2 and 2.3 basic scientists generally utilise information to generate and publish new information (the production of scientific literature) while applied scientists use it to solve specific work-related problems and to develop and improve a product or process.

Research has revealed that applied scientists generally place more emphasis on facts and data of immediate practical use, and descriptions of objects, processes or methods. Basic scientists in turn place more emphasises on material for background reading and purposeful study, information to generate new ideas and to provide stimulation, and information on research methodology. (American Psychological Association, 1963-1969; Slater & Fisher, 1969).

Research by Harkins and Petty (1987:268) has revealed the *multiple source effect* where it was seen that individuals are more likely to use information that is available in more than one source, than when the same information is available in only one source. The authors argue that this is because users have the perception that information contained in multiple sources represents divergent and independent points of view and thus has greater validity.

2.8. PRESSURE ON THE COMMUNICATION SYSTEM IN SCIENCE

A number of authors have suggested that for the last few decades the science communication system has been experiencing severe pressure from the following impacting and constraining environmental factors (see for example: Andrews et al., 2005; Correia & Teixeira, 2005; Crawford & Stucki 1990; De Gooijer, 1993; Hurd, 2000; Shaughnessy, 1989; Von Seggern, 1995):

- The ever increasing cooperative and collaborative nature of research with long-term goals entailing many uncertainties.
- Increasing specialisation, growth in interdisciplinary fields and the rapid growth of many sub-fields.
- The factors mentioned above compound the exponential growth rate of the literature which is even further exacerbated by the ever increasing *publish or perish* syndrome.
- The severe information overload experienced by many scientists and the problem they experience to keep up with the plethora of publications which, in turn, results in reduced ability to keep track of new discoveries outside their own area of narrow specialisation.
- The emergence of novel publishing models for formal and informal communication among scientists, using information communication technologies that provide functionalities that far exceed those existing in the print world.
- The weakening in the peer review process caused by scientists bypassing the traditional channels of communication and publishing electronically.
- The closed environment of electronic networks can render scientific communication less public and less accountable in future.
- The different interfaces and architectures that the various multiple electronic resources have create major information communication barriers.
- The production of expensive highly focused journals, per-page fees, subvention grants and the overemphasis on return on investment.
- The erosion of traditional print-based revenue streams by electronic media has resulted in

pricing models for digitized products that only large consortium can afford.

- Rigidly controlled budgets, accelerating competition, and increased artificial rewards for discovery.
- Pressure on scientists to commercialise their research which militates against the fundamental assumption of open communication.

There is growing evidence that information technology is impacting on the communication process and changing the way in which basic scientists communicate information about their work, both to their peers and to the public in general. In the past, the journal held a pivotal role in scientific communication and this was largely based on its embedded peer evaluation system that ensured minimum standards and further that it provided a reputable vehicle for laying claim to discoveries. More and more scientists are now using electronic media to communicate their research findings with the result that their work is not always being evaluated and judged by the peer review system. A further problem that is coming to the fore is that replicability, one of the inherent features of science is becoming increasingly more difficult to maintain because of the tendency to work in large collaborative teams, the intensifying competition for funding, and priority in discovery.

2.9. CONCLUSION

It is evident that the system of scientific communication that has evolved over several centuries is now undergoing a transformation spurred by many factors, least of which is the electronic environment that we live in. Changes are therefore occurring in the communication system ranging from the effect on interpersonal communication between scientists to new publishing models, and the World Wide Web has further enabled new types of products and services to be developed that go beyond mere replication of print formats.

Not all technological innovations have necessarily produced positive results and assisted the communication process. Factors such as access problems, standardisation, transmission speed, bandwidth, etc. have impacted on the real potential of the new medium. Other, and probably even more important inhibitors, are the human and organisational behavioural factors that relate to acceptance of technological innovations. Electronic innovations in the communication process, albeit how effective, have to be adopted by the scientists whose activities they are intended to enrich. The value systems, reward structures, day-to-day work habits of scientists all have an influence on their willingness to accept and integrate new developments as part of their

information communication behaviour. Such value systems and reward structures are further also deeply embedded in the organizational cultures of individual disciplines, professional associations, work environments, etc. and it is generally accepted that change at organisational level is far slower than at the individual level. Also, all individuals have unique perceptions and value systems and what may appear as a good new visionary innovation to some may be dismissed outright by others.

From the above it is clear that a study of the communication and use of information is subject to many variables, all exercising a greater or lesser influence. The factors or variables that have hitherto received the most attention and which are considered to exert the greatest influence on communication behaviour are the profession the individual belongs to (e.g. engineer, etc.); the scientist's discipline and whether the nature is basic or applied; the stage of the project or task; the type of work environment and employing organisation (e.g. whether academic, research institute or government); job function; and finally the years of professional experience and status within the organization.

The review of the literature provided this researcher with clear indicators of the main issues that relate to and impact on the information communication process of science. The salient points derived from this review were further used to conceptualise a reference framework upon which the empirical component of this study was based. The variables outlined above were incorporated into the empirical study and formed the nucleus of the study. In the ensuing chapters the execution of the empirical study and its outcomes will be discussed.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

Research in library and information science has traditionally drawn very heavily on social science research techniques. This is a legitimate field to turn to since in these investigations we are concerned with the interaction between people and information, an acknowledged social system.

3.2. THE RESEARCH PROCESS

Before examining various aspects relating to research methodology in greater detail, the researcher will first outline the overall decisions taken during the research process. A number of authors have indicated that it is important to document the empirical process followed as carefully as possible to ensure later replication and verification. For this purpose a flowchart of the procedures and steps followed in this study will be presented. This by no means suggests that the iterative, interactive nature and the complexities of the research process can be reduced to a simplistic step-by-step procedure.

STEPS FOLLOWED IN THE EMPIRICAL RESEARCH PROCESS

CONCEPTUALISATION

Clarification and conceptualisation of the problem

Establishing the research parameters

Conducting the main literature review (this was continuously updated throughout the longitudinal study)

Concept clarification and generation of research questions

OPERATIONALISATION

Identification of the target population & definition of study population

Selection of research methodology and data collecting instruments

Development of an interview schedule

Pilot study

Development of a database containing population details

PHASE 1 (1990/1)

Arranging & conducting group and individual interviews

Capturing & analysis of data

PHASE 2 (2001/2)

Updating of literature review

Analysis of this data and integration with phase 1 data

Synthesis with conceptual component.

Conclusions, theoretical model & compilation of the final report

3.3. QUALITATIVE VS QUANTITATIVE RESEARCH APPROACHES

Qualitative research is humanistically oriented and attempts to provide an understanding of human activities. It provides a method to probe deeply into the inner world of persons and reconstruct their thought processes and lifestyles. Individuals and their cognitive sense-making worlds are the focal point of the research design. The emphasis is on the natural context of the environment within which an activity takes place, it is far more situation specific and provides contextualised descriptions of situations. Phenomena are thus studied in detail by means of less structured procedures in as natural a setting as possible by researchers who are immersed in the process. Concepts are defined and analysed to discern patterns and interdependence of concepts that have probably not been specified before. The research is thus not predetermined and structured by hypotheses explicitly stated at the outset of the project (although preliminary hypothesis may be outlined to guide the process). The goal is rather to generate new hypotheses and theories than to test hypotheses and both questions and answers evolve while the research is in progress (Bryman, 1992: 57; Grover & Glazier, 1985:247-253; Seldén, 2005: Introduction).

Quantitative research on the other hand tends to be more formalised and follows a positivist approach. The research is oriented towards description and explanation and the provision of universally explicable relations. Variables and categories of variables are isolated to explicate hypotheses which are stated explicitly and formulated beforehand. The researcher attempts to reduce ambiguity to a minimum and works with clearly defined concepts. The researcher tries to be as objective as possible and operates at a distance. The study is thus attuned to controlled measurement and data are collected under as controlled circumstances as possible (Brannen, 1992:4-10; Glazier, 1992b:6-7; Mouton & Marais, 1990:7-12).

Probably the most important difference between qualitative and quantitative research is the way in which each approach treats and collects data. The data collecting techniques may appear to be very similar, but the orientation differs considerably. Quantitative methods are oriented toward following a far more structured and unobtrusive approach and obtaining quantifiable data that may be analysed using sophisticated statistical methods. Qualitative data is usually collected from individuals or small groups, the researchers are involved with the instrument, and the information generated is often not numerically analysed or presented (Bogdan & Biklen, 1982:27-30). Analytical induction methods are used, i.e. they generalise by abstracting, rather than applying enumerative induction that abstracts by generalising (Brannen, 1992:7).

Both research approaches have their advantages and drawbacks and researchers should thus be aware of the most suitable approach to adopt for a specific study. Furthermore, although qualitative research originally evolved as an antithesis to the positivist approach of the more traditional quantitative designs, there is currently greater convergence and the two approaches are often used in combination to complement each other (Ferreira & Puth, 1988:164). Many authorities further believe that the two approaches are not necessarily mutually exclusive and that they rather lie on a continuum (Widdows et al., 1991:352). Many researchers thus suggest that the best attributes of each approach should be selected to arrive at a good mix of approaches with each enhancing the other. Thus, both modes could under certain circumstances be adopted in one study and used in a complementary way to obtain the clearest understanding of the phenomena and behaviour under investigation (cf. for example the views expressed by Babbie & Mouton, 2001; Brannen, 1992; Bryman, 1988; Ford, 1986; Rohde, 1986; and Streatfield, 1983).

Triangulation, or multiple operationism, or multi-strategy/multi-method research, are the terms used to refer to the situation where a number of research methods are used in a complementary way to study the same phenomena. The aim of such *across/between-method* triangulation is to compensate for the individual shortcomings of each method and to obtain more valid results. Such an approach ensures flexibility as well as systematisation, it serves as a validity check, and it affords the maximum utilisation and analysis of data (Brewer & Hunter, 1989:17-21; Glazier, 1992a:209; Layder, 1993:108,205-206).

It is generally thus considered that a triangulated approach enriches a study and improves validity. Several authors therefore recommend the combination of quantitative and qualitative methods in a single study to achieve convergence between the positive attributes of each approach (Bryman, 1988:95; Jick, 1983:135-136). Mouton and Marais (1990:92) specifically suggest that when combining techniques the researcher should try to combine more 'reactive' techniques with less reactive techniques (reactivity refers to the phenomenon where users are aware of the fact that they are being studied). It is therefore advocated that when selecting methods the researcher should try to provide an in-depth analysis of a situation as well as ensuring validity, reliability, replication and greater generalisability of results.

For the reasons outlined above and to obtain a true and in-depth picture of the complexities of information communication behaviour among the selected group of scientists in South Africa, the researcher decided to adopt a triangulated approach and to combine the best attributes from both the qualitative and quantitative research domains.

3.4. RESEARCH DESIGN

The literature on social science and library and information science research methodology indicates that there is general lack of consensus as to the absolute differentiation between research design and methodology and the techniques employed to collect the data required. An attempt will be made in the following sections to first clarify concepts used in this thesis, and then outline the overall research design, methodology and data collecting techniques applied in this study.

The researcher will adopt the views of Frankfort-Nachmias and Nachmias (1996:99) who suggest that a research design is the blueprint that assists the researcher to solve problems pertaining to the investigation. It consists of the "set of decisions regarding what topic is to be studied among what population with what research methods and for what purpose" (Babbie, 1995:104). Research methodology will be viewed as the conceptual processes pertaining to the conduct of the empirical study and will be distinguished from research method which will be taken to refer to the research tools or techniques used to collect the required data. This researcher specifically holds the view that the hypotheses or research questions are the core components that serve as the *blueprint* and framework for all aspects of the research project.

3.4.1. RESEARCH QUESTIONS

As stated in chapter 1 the purpose of this research project was to examine the constituent elements of the information communication process within the crystallographic research community in South Africa. The objective of the study was to establish useful predictive measures of communication behaviour and to infer appropriate assumptions about the role of various impacting factors on the communication process over the period from 1990/1 to 2001/2.

As this research project was partially embedded in a qualitative research paradigm, research questions rather than formal hypotheses were formulated to serve as the framework for the empirical study. In qualitative studies theories do not usually form the foundation and conceptual framework of the research project, but they evolve and develop out of the empirical investigation, i.e. they are grounded in the empirical data. Dey, however adopts the viewpoint that theories should serve as the organising framework for both qualitative and quantitative research and that even with qualitative research designs it is imperative that the study is conducted within a conceptual framework that maps the area to be explored, albeit a loosely defined one (1993:52).

The research questions that form the framework for this thesis evolved from the researcher's concern with the role of the communication of information on scientific endeavour in South Africa, together with problems identified when the literature in the field was studied (cf. chapter 2), and the general awareness of the impact of the rapid growth of information and information technologies and other structural and socio-political changes on the communication process in South Africa during the last decades.

Thus the primary research question that motivated this project related to

- **What constitutes the information communication process among a bounded community of basic and applied scientists in South Africa?**

and this was further amplified by the following subsidiary questions

- **What cognitive, behavioural and environmental factors drive the communication process in science in South Africa?**
- **What factors impact most on the communication process?**
- **What environmental and other changes have occurred during the intervening years of the longitudinal study that affected the communication process in South Africa?**
- **What is the role of informal communication of information in South Africa?**

3.4.2. RELIABILITY AND VALIDITY

Whether qualitative or quantitative research approaches are adopted, the researcher should ensure that the project satisfies the requirements of scientific credibility. The two criteria of reliability and validity are generally utilised to assess the quality and credibility of research. These two criteria are embedded in the concept of objectivity as it relates to research. Glazier (1992a:210) identify four aspects of objectivity that pertains to the discussion, viz.

(1) objectivity as a control in terms of methodological consistency, (2) objectivity as a control in terms of accuracy, (3) objectivity as related to new discoveries and anomalies, and (4) objectivity in the form of reflexivity as a means of being aware of the unintended and unanticipated effect the researcher has on the data as it is collected and analysed.

In quantitative research objectivity is used as a pointer to the degree of error or the level of bias introduced by the researcher in the collection and/or interpretation of the data. Glazier further contends that whereas in the quantitative paradigm, and particularly in the natural sciences, the acceptable percentage of a variable's variation should be contained in the .99 range, in qualitative research, particularly as applied in the social sciences, it is perfectly acceptable for the percentage

of variation to fall within the .50 range. "These differences do not necessarily reflect the rigor of the research in one area versus the other; rather it appears to be endemic to the nature of the phenomena being researched and the researcher's ability to control the variables impacting on those phenomena" (Glazier, 1992a:211).

For operational purposes objectivity may be categorised in terms of the concepts of reliability and validity. Reliability refers to the extent to which the repeated application of the same research methodology and instruments, under similar or constant conditions, will produce the same result, i.e. a measure of consistency. Qualitative research methodologies, by nature, are designed to be situation specific, and generally cannot be repeated under similar conditions. It is often the uniqueness of the situation that is highlighted in qualitative research. Thus the condition of reliability in the sense of the typical scientific paradigm is rarely attainable in qualitative research (Fidel, 1992:39).

Despite the inherent problems pertaining to these measures and qualitative research, the method should not be exempted from the need to test the reliability and validity to ensure the integrity of the research process. One way of overcoming the problems outlined above in terms of reliability is to conduct consistency checks by comparing the results obtained in the qualitative study with those reported in the literature (Glazier, 1992a:211). Another possibility is to apply triangulation and to utilise more than one method to collect essentially the same data and to compare the results. The methods used could all fall within the qualitative domain or constitute a mix between qualitative and quantitative domains.

Validity, in turn, relates to the degree to which the research methodology has in fact investigated or measured what it was supposed to investigate or measure, i.e. is the methodology appropriate for the type of data being investigated and how accurate has it been. Once again this might be more of a problematical issue in qualitative research than in quantitative research. In the former instance the researcher is generally immersed in the topic and interpretation of events is dependent on the subjective understanding of the researcher. This again relates to the question of reflexivity (Fidel, 1992:40).

Reflexivity refers to the researcher's awareness of his/her impact on the research process, i.e. that the researcher is aware that his/her subjective personal experiences and background may influence the way the data is interpreted, and that she/he is aware of the possible effect of his/her presence on the persons being investigated and on the outcome of the study (Henwood & Pidgeon,

1993:24-25). Researchers should therefore develop a sense of *reflexiveness* (i.e. reflective conscious self-consciousness) by being aware of personal values and beliefs. Reflexivity is, therefore, an essential attribute that every researcher, particularly those applying qualitative methodologies, should acquire to gauge and counter their impact on the research process. Henwood and Pidgeon, however, argue that in qualitative research the attainment of absolute neutrality is very difficult as "research activity *inevitably* shapes and constitutes the object of inquiry; the researcher and researched are characterised as interdependent in the social process of research" (1993:24).

Closely related to this aspect is the subject's *reactivity* to the research process. It is generally accepted that when humans participate in, or are the subjects in research and are aware that they are being studied, they may react to this fact and then act in an atypical fashion. They may then amongst others refuse to participate, supply incorrect information, or behave unnaturally to deliberately obstruct the research process or to create a good impression. This phenomenon is known as *reactivity* and it is one of the greatest threats to the validity of research findings. Data sources that directly involve humans tend to be more reactive than those where humans are only indirectly involved (Mouton & Marais, 1990:76, 78). With reference to these aspects Brewer and Hunter (1989:41) suggest that the following factors may induce reactivity: "the guinea pig effect, role selection, measurement induced changes, response sets, and interviewer effects".

Internal validity refers to the requirement that a study should generate accurate and valid findings that relate to the specific phenomena being investigated in that study. A research project is deemed to have satisfied the requirements of internal validity if the constructs have been measured in a valid manner (i.e. theoretical validity has been attained), the data has been accurately and reliably collected (i.e. measurement validity has been attained), if relevant analysis techniques have been applied (reliability achieved), and if the final conclusions are adequately based on the data collected (inferential validity achieved) (Mouton & Marais, 1990:118-119). To overcome the problem with internal validity, Fidel (1992:40) recommends that the researcher should implement controls by ensuring that each interpretation is based on several kinds of evidence and validation takes place by rechecking and comparing the different kinds of evidence, e.g. a number of observations of similar subjects engaged in similar activities in similar situations would be compared.

External validity is concerned with *generalisability* and refers to the extent to which results obtained can be generalised beyond the specific research project from which they were derived (Schofield, 1993:200). The results, thus have "greater validity than merely for the project in which they were

generated ... it would therefore be correct to regard external validity and generalizability as synonymous" (Mouton & Marais, 1988:51). A researcher who aims to achieve external validity should clearly circumscribe and define a target population of people or situations or periods, and then draw a representative sample that will be studied with the purpose that the conclusions and findings will be generalised to the defined population. It is thus clear that the greatest impact on external validity is the extent to which the sample is representative of the target population.

Schofield (1993:220-221) argues that although qualitative researchers have in the past played down the value of attaining external validity, the situation has changed and there is currently an increased awareness of the importance to design qualitative studies in such a way that they enhance "their implications for the understanding of other situations". Qualitative researchers have further moved towards a redefinition of the concept generalisability to one that provides a closer alignment to qualitative research and which relates it to the "fit between the situation studied and others to which one might be interested in applying the concepts and conclusions of that study" (Schofield, 1993:213).

To ensure the highest possible levels of quality and credibility the researcher tried to counteract as many of the threats to reliability and validity as outlined above. A reflexive consciousness was maintained and the possibility of *reactive* responses was guarded against throughout the project. A triangulated methodology was adopted to, amongst others, improve validity. By conducting an extensive literature study the researcher could ensure better comparison and the cross-validation of the interpretations. A further aspect that improved validity was that the entire study population was investigated in both studies in the longitudinal process.

3.4.3. VARIABLES

According to Mouton and Marais (1990:126) research problems are expressed in terms of a set of concepts or constructs and these are the categories according to which humans organise their unstructured empirical experiences. When we progress from the conceptual to the empirical level in research, concepts are converted to variables by "translating or mapping them into a set of values" (Frankfort-Nachmias & Nachmias, 1996:55). Variables are thus the specific concepts or theoretical constructs under investigation (Rubin & Babbie, 1993:120), or in other words the characteristics of the research object being investigated (Mouton & Marais, 1990:129).

A discrete or categorical variable classifies persons, objects or events according to the kind or quality of their attributes (Bohrnstedt & Knoke, 1994:20-21). Discrete variables can either be orderable, i.e. the categories can be meaningfully arranged into ascending or descending sequence, or they can be

non-orderable and their units, further, cannot be subdivided (Frankfort-Nachmias & Nachmias, 1996:58). Continuous variables can, in theory, assume all possible numerical values in a given interval and they can be stated in fractions of a unit. An accepted practice is to treat certain ordered discrete variables, such as those on a rating scale, as continuous variables in order to utilise the higher level of statistical manipulation permissible with such variables (Bohrstedt & Knoke, 1994:22). Variables that cannot be measured and expressed numerically are known as qualitative variables and have labels or names assigned to their categories, while those that can be measured and expressed numerically are known as quantitative variables (Bailey, 1994:62-63).

When studying the relationship between variables one should distinguish between dependent and independent variables. Generally speaking, the independent, experimental, explanatory, predictor or causal variable is the variable which, when varied, has an effect on the dependent or criterion variable. The latter is the variable the investigator wishes to explain. Thus the independent variable is the presumed cause and the dependent variable the presumed effect. When studying or measuring the relationship among variables, the researcher tries first to establish whether they vary in conjunction with others and, if so, an attempt is made to measure their degree of correlation.

The nature of the topic under investigation and the decision to utilise both qualitative and quantitative approaches predicated that the research purpose or orientation would be towards an in-depth descriptive study that further also investigated the factors that have the most impact on the communication of information among a specific group of scientists in South Africa. To follow Frankfort-Nachmias and Nachmias' categorisation, the emphasis was placed on investigating *property-disposition* relationships rather than *stimulus-response* relationships.

3.4.4. TIME DIMENSION

A further aspect to consider when deciding on a research design is the time dimension. Cross-sectional designs examine a phenomenon by taking a cross section of it and analysing that cross section within a particular time span. Longitudinal studies, in turn, are designed to collect data over a period of time to study the effects of change on the population being studied. A specific category of the latter is a cohort study which is used to study changes in a specific sub-population (cohort) over time (Rubin & Babbie, 1993:109-110).

As mentioned previously (cf. chapter 1.2.; 1.6; & 3.4.1.) the researcher not only wanted to investigate the constituent elements of the information communication process within a specific research community in basic and applied science, but also whether communication styles are changing as

a result of the advances in, and growth of, information communication technologies and systems, and further whether various political, structural and environmental changes have had an effect on the communication process in South Africa. The latter aspect motivated the adoption of a longitudinal, and more specifically a cohort, research design to examine the change in communication behaviour over the decade spanning the period from 1990/1 to 2001/2 (data were collected in 1990/1 and then again in 2001/2)⁶.

3.4.5. DEFINITION OF THE POPULATION AND THE UNITS OF ANALYSIS

Not only the temporal and spatial constraints, but also the study elements as well as the relevant characteristics of the group to be studied should be clearly specified and defined early in the project. A population is the theoretical aggregation of study elements (Frankfort-Nachmias & Nachmias, 1996:179) and usually a distinction is drawn between the target population and the population actually covered; the latter is generally referred to as the study population. The actual list of the elements composing the study population is known as a sampling frame and in practice, "existing sampling frames often define the study population rather than the other way round" (Rubin & Babbie, 1993:225). Such sampling frames are not always complete or up to date and the researcher may further decide to exclude certain elements and limit his/her study populations for specific reasons. Any such redefinition of the population should be clearly stipulated by the researcher.

The population is represented by the units of analysis (Bailey, 1994:83) that are the most elementary part of the phenomenon to be studied. They can be individuals, groups (which include formal social organisations and institutions), social artefacts (i.e. all products of human behaviour), social interactions (e.g. communication), and events whose characteristics the researcher wishes to observe, describe, and explain (Rubin & Babbie, 1993:111-114). The data collected in a study are employed to describe the individual units of analysis, or aspects thereof, and these data, in turn, are aggregated and processed to describe the population.

The researcher gathered from her survey of the literature that the communication of information is a complex and dynamic activity with various factors impacting on the process (cf. chapter 2.). The factors that were reported to have the greatest influence on the communication process were the scientists' discipline and subject orientation; work environment which included work activity and position; demographic factors such as age, position and qualifications; and each individual's various

⁶ The time lapse between the last data collecting exercise in 2002 and the finalisation of the thesis was due to the fact that the researcher had to undergo major surgery in 2004 and again in 2005.

cognitive, affective and psychological traits. As was mentioned in chapter 1 the researcher decided, after discussions with various well-known researchers in this field, to select a target population consisting of a clearly circumscribed and finite population of scientists who were subject to the influencing factors outlined above. A number of factors pointed to the selection of the community of scientists who were conducting research in crystallography in South Africa. Crystallography is studied from a number of viewpoints, ranging from the pure study of the field (usually by either chemists or physicists), to its utilisation as an analytical tool in a number of basic science subject areas (such as geology, microbiology and chemistry), to its application in applied science and technology (mostly by mineralogists, materials scientists, applied chemists and urologists). Further discussions with a number of crystallographers indicated that the entire group conducted research in one of three types of organisation: universities, research institutes and R & D facilities of large industries. This group of scientists clearly manifested the range of attributes and were subject to the variety of influences required for this study. The circumscribed units of analysis for this study were thus the individual scientists conducting research in crystallography in South Africa.

Most crystallographers in South Africa are listed in the *World directory of crystallographers* that is produced at regular intervals by the International Union of Crystallography (1986, 1997). This publication lists crystallographers by country as well as providing full contact and biographical details for each entry. This publication thus provided an appropriate sampling frame from which to select the study sample. On establishing at the time of the first study that only ninety eight crystallographers were listed under the South African entry and to ensure that all categories of crystallographers would be represented in the study a decision was taken not to sample, but to study the entire population. The researcher had also at this stage decided to adopt a triangulated research design utilising both qualitative and quantitative methodological approaches. The target population was thus considered to be sufficiently small to study the group in depth, but also large enough to be able to investigate the various factors that influence information communication behaviour that were reported in the literature.

During phase 1 (1990/1) of the study, the researcher contacted all the crystallographers listed in the then latest edition of the *Directory* (1986) and established that a number of the crystallographers had left the country, or had retired since being listed. It was further established from the South African Crystallographic Association that a few new members had joined the crystallographic fraternity in the interim period. From this information the researcher established that the crystallographic community in South Africa at the time of the 1990/1 empirical study contained 80 members and these crystallographers were thus constituted as the study population for the phase I empirical study.

The study elements for this study could now be re-defined to constitute all the individual crystallographers listed under the South African entry of the *World directory of crystallographers* (1986) who were in the country and actively engaged in research at the time of the study, supplemented by new members (not yet listed) in the same category. This process was repeated for the phase II study in 2001/2 and the 1997 edition of the *Directory* (the most current edition available at the time) was used to establish the initial list. Once again there were a few subtractions and additions of members who had left or new ones that had joined and the final study population for 2001/2 constituted 78 members. Of these crystallographers, 63% had also participated in the first study, indicating a very high level of commonality between the two studies.

3.5. RESEARCH METHODOLOGY

Having clarified the overall design decisions that should be taken, the researcher examined all possible research methodologies that would satisfy the parameters outlined above. The researcher eventually decided to concentrate on two possible approaches, viz. case studies which are orientated towards qualitative research approaches, and surveys, the most well known social science method in the more quantitative domain.

Case studies have often erroneously been categorised as belonging exclusively to the qualitative research domain. Yin, the eminent case study methodologist, while acknowledging the propensity of use of this method in qualitative designs, suggests that they may be used on either side of the quantitative/qualitative spectrum (1985:23) and Rubin and Babbie more recently refer to the trend toward using a case study approach that combines both qualitative and quantitative methods (1993:392). The distinguishing feature of case studies is that they focus on a single case, or a number of cases to investigate contemporary phenomena within their real-life context and that they utilise multiple sources of evidence (Yin, 1985:23). Its essential characteristic is the intensity with which each unit of analysis is studied (Fidel, 1992:37-38). Paris is of the opinion that this method is particularly suited to studying complex phenomena, to studying phenomena over an extended period of time and for descriptive studies (Paris, 1988:138). The rationale for applying this method is usually the availability of a special case that incorporates all the attributes the researcher wishes to investigate. It is ideally suited to studies that reflect the shift towards a more holistic, user-oriented approach and that require an in-depth investigation into information communication behaviour (Dervin & Nilan, 1986:19-20).

The more quantitatively oriented survey research method may be contrasted to case studies. While

the latter provides an intensive study of a few units of analysis, the former studies many units of analysis extensively. Generally speaking, surveys provide an overall perspective of a field and although they are usually concerned with populations or large groups, they may also be used to study small populations. This method provides a systematic approach to study the relative incidence, distribution and interrelations of a number of variables (Kerlinger, 1986:377).

Bailey, however, suggests that although surveys provide an effective method to examine the products of social activities, they are not the ideal method to use to examine the activities themselves and to attain a more qualitative approach, a case study would be more appropriate (1994:288). Other problems that pertain to survey research methods include the dependency and reliance on the respondent's veracity, understanding of the situation and recall capabilities as well as possible subjective bias that both the investigator and respondent might introduce. These problems, however, are encountered in most social science research methods, and the best means of resolving them are to be fully aware of their existence and to offset the adverse effects as soon as evidence of possible bias has been detected which may distort the integrity of the responses. Respondents should, furthermore, be encouraged to fully participate and to identify themselves with the integrity of the research project.

On the strength of the arguments put forward above a decision was taken to combine the best attributes of case studies with surveys and to conduct a small-scale survey that would approximate the depth attributes of a case study. In this way both qualitative and quantifiable data on the communication behaviour of scientists in South Africa and factors affecting the process could be obtained. This would further satisfy the requirements of a triangulated research design as indicated in 3.3.

3.6. COLLECTING THE DATA

The next step in the research process is to collect the data in order to try and answer the research questions posed. Data collecting techniques may be categorised in a number of ways depending on whether the data being collected is new, or whether existing data will be used; the nature of the source of the data, i.e. whether the data is obtained directly or indirectly from individuals, or from recorded or other physical manifestations of human behaviour, or whether simulated data is used; how aware the subjects are of the research process, i.e. the level of obtrusiveness of the technique; the level of control over the situation and the level of structure embedded in the data collecting procedure. Data collecting techniques can further be placed on a continuum from quantitative to qualitative if they are classified according to the nature of the data obtained (cf. also the reference to this in 3.3.).

Obtrusiveness in data collection refers to the degree to which participants are aware of being studied. The more natural the setting of the research project, the less obtrusive the data collecting technique and the lower the reactivity level but the lower the validity of the results (Mouton & Marais, 1990:78-79). The researcher thus constantly has to weigh up the advantages of control and validity against the risk of reactivity and the decision as to which aspect should be favoured will depend on the aims of the research project. Each of the main data collection methods may operate on a spectrum that at the one end incorporates highly structured procedures and on the other end utilises a totally unstructured approach. (Mouton & Marais, 1990:78-79). Qualitative methods generally utilise data collecting techniques with the least structure and control and are often highly obtrusive, while quantitative designs derive data in a far more structured, controlled and unobtrusive way.

There are essentially only two main sources of data that are generally utilised in information and library science research, viz. data obtained directly or indirectly from the respondents themselves, and all forms of recorded information found in archival sources. Each of these main categories of data source is in turn associated with a specific data collecting technique. Observational and questioning techniques are generally employed to obtain essentially new data directly from respondents, whereas archival sources can be examined and analysed to obtain already existing data. It is generally accepted that if more than one source is exploited, it is possible to obtain a more comprehensive and detailed perspective of the situation (cf. the reference to triangulation in 3.3.).

3.6.1. QUESTIONING DATA COLLECTING TECHNIQUES

Questioning data collecting procedures have tended to dominate the field of library and information science research (Hewins, 1990:146) and it is generally regarded to be the most effective technique to use to obtain both objective and subjective information and to ascertain a subject's opinions or attitudes on given matters. However, the researcher should be aware that verbal responses may not always provide objective data as many persons tend to report only what they perceive to be socially acceptable attitudes; and respondents tend to answer questions in terms of their own insights.

This data collecting technique divides essentially into self-administered questioning methods (such as mailed and e-mail questionnaires) and interview techniques. Each category, in turn, can utilise questioning schedules that range from the highly structured to the totally unstructured situation. Interviews can be conducted with individuals or with groups and may be in person or by means of communications media such as the telephone, or some electronic medium (Babbie & Mouton,

2001:249-253).

Self-administered questionnaires may be distributed either by mail or e-mail or by personal delivery. Self-administered questionnaires are recommended for research situations where a large population is investigated; where the respondents are geographically scattered; where sufficient knowledge of the topic warrants the maximum use of structured questions and standardised responses; where costs are a factor; where interviewer bias may play a role; where time limitations are a constraint; where anonymity is a factor; and where the researcher is confident the respondents will be able to understand and answer the questions (Bailey, 1994:148-149; Rubin & Babbie, 1993:355). The main disadvantages of self-administered questionnaires pertain to the low response rates; the restriction on the complexity of questions that can be asked; the inability to probe for further information or clarification of ambiguities; the lack of control over who answers the questions; the inability to observe and record non-verbal behaviour and to record spontaneous answers; and the general lack of flexibility (Babbie, 1995:149-151; Frankfort-Nachmias & Nachmias, 1996: 226). Interviews are, therefore, the better technique to use to ensure the veracity and validity of responses and where complex situations and phenomena are being investigated in detail (Frankfort-Nachmias & Nachmias, 1996:237-238; Rubin & Babbie, 1993:342-342).

The main advantage of interviews is that the researcher or interviewer is present and this generally helps to establish rapport and create a dialogue situation, which generally results in greater and more accurate detail being obtained. However, this may also have a negative affect as the interviewer may introduce bias to the situation (*reflexivity* effect) or evoke distorted responses or the presence of the interviewer may intimidate the respondent or prompt the respondent to act differently (*reactivity* effect). Further deficiencies that relate to this method are that it is a very time-consuming method and costly, it is difficult to execute if the respondents are geographically dispersed, and only relatively small numbers of people can be interviewed. (Bailey, 1994:175; Babbie & Mouton 2001:250-256). Many of the problematical features may however be avoided by being aware of them and by consciously counteracting them. Interviews, thus, have a clear advantage over self-administered techniques, as data collected in a face-to-face situation are of a high order, yielding rich and spontaneous information.

3.6.2. INTERVIEWS

Interviews may range from the more formal, less flexible, structured techniques to the informal, highly flexible and unstructured situation. The structured approach generally generates quantifiable and

comparable data (Frankfort-Nachmias & Nachmias, 1996:233-234). The unstructured approach in contrast is far more *open* and flexible. The interviewer has the freedom to adapt the proceedings to fit the needs of the specific situation, to delve deeply and obtain data that truly reflect the respondents' feelings and opinions about a topic. Such unstructured interviews, however, are in no ways conducted in an unplanned and haphazard manner and as much thought and careful planning precedes them as with structured interviews.

Between these two ends of the spectrum lie focused interviews that are "malleable enough to follow emergent leads and standardised enough to register strong patterns" (Oliker in Frankfort-Nachmias & Nachmias, 1996:234). The respondents in such studies should all be in a position to contribute to a discussion of the phenomena that form the focus of the study and the interviews should also focus on these phenomena. An interview guide is thus usually employed to direct the process and to keep it focused on the main issues under investigation.

It is often advocated that a triangulated approach should be adopted where structured, non-structured and semi-structured elements are all be combined in a single interview to obtain all the data required (Frankfort-Nachmias & Nachmias, 1996:237). For example factual information may be elicited by means of structured questions while the less directive format may be used to obtain opinions and attitudes.

The medium in which the interviews are conducted further differentiates between interview techniques. The most common method is the personal interview where one or more interviewers personally conduct the interviews. Other lesser used variations are telephone interviews, and interviews using electronic networks (Bailey, 1994:213; Babbie & Mouton, 2001:262). Interviews may further be conducted in either a one-to-one situation between interviewer and respondent, or a small group situation.

Individual interviews provide a face-to-face interpersonal role situation and may operate on a continuum from the more structured to the less structured approach. Individual interviews are usually conducted in circumstances where highly individualised, in-depth information and perceptive commentary is required, the topic is of a sensitive nature, respondents would not convey their opinions within a group situation, and detailed explanations and answers are required. Individual interviews are thus the ideal method to use to obtain deeper insights, to establish rapport with the respondents, and where it is important to obtain a specific person's responses (Shuter, 1987:31). The greatest disadvantages of individual interviews (that is in comparison to group interviews) include the problem

of establishing rapport with the respondent; the greater obtrusiveness of the method; the overload of data obtained; the intensity of the method; and the limited number of respondents that can be interviewed due to time and cost constraints (Schurink, 1988:138). However, most of the negative factors mentioned above may be counteracted by being aware of them (cf. the reference to reflexivity and reactivity in 3.5.2.), by handling the situation with sensitivity, and by consciously trying to avoid them.

Focus group interviews relate to group interviews that focus on specific issues and involve participants that can contribute to these issues. An interviewer conducts interactive interviews with a small group of people by introducing a topic which is then freely discussed amongst the respondents. The discussion is 'focused' on a specific topic and the interviewer elicits the required information by means of subtle probing (Ward, et al, 1991:267). This interview technique provides the ideal environment to analyse complex situations and the group situation engenders synergism, veracity, frankness and often more detailed responses than in a one-to-one situation. Group dynamics generally stimulate recall, the generation of new ideas, and the interaction that comes into play amongst group members can produce very valuable insights. This method further incurs less direct costs than individual interviews and it is less time consuming. (Ferreira & Puth, 1988:168; Ward, et al, 1991:269; Widdows, et al., 1991:352).

This technique, although providing valuable data and insight, does also suffer from a number of drawbacks. It shares the problem of obtrusiveness with all questioning methods and the flexibility of the situation and group interaction can lead to unpredictable and inconclusive outcomes. Individual respondents may be influenced and inhibited by the other members in the group or be threatened by the group situation or if tension builds up between group members. The length of focus group meetings (often up to three hours) may restrict participation, and the logistics to gather together the members of group at a mutually suitable time and period may be problematical. (Bailey, 1994:192-193; Drabentstott, 1992:89; Merton, et al., 1990:147-153). However, if the interviewer is aware of these possible negative outcomes many of these pitfalls can be avoided. The interviewer should control the interview sufficiently to keep it focused on the topic and also encourage all members to participate as well as preventing any one person from dominating the proceedings.

An important factor to consider with this technique is the ideal composition of the groups. The literature produces a range of recommendations which ranges from the incorporation of homogeneous to contrasting respondents to total random selection (Drabentstott, 1992:90; Ferreira

& Puth, 1988:71; Ward, et al., 1991:267). Although the ideal number of participants in focus groups would appear to range between four and ten persons (Drabenstott, 1992:85), it is suggested that the nature of the research project and the specific situation will dictate the ideal number of respondents. The time allocated to the interview is largely determined by the complexity of the topic and time limitations set by the respondents and generally varies from a minimum of one hour to a maximum of three hours (Widdows et al., 1991:352).

Telephone interviews represent a semi-personal method of collecting data that has become a popular and acceptable method to use (Frankfort-Nachmias & Nachmias, 1996:242). The method, while viewed with scepticism and distrust in the past has gained in popularity (Babbie, 1995:269) and if effectively used has produced valid, reliable and quality results (Rubin & Babbie, 1993:348). Powell is of the opinion that this method combines the advantages and disadvantages of personal interviews and mailed questionnaires (1997:108). Factors that have made this method popular are that telephone costs are considerably less than that of personal interviews; technological advances have made telephone interviewing easier and more accurate to execute; it is far less time-consuming than personal interviews; and interviewer bias is less of a factor (Bailey, 1994: 196; Huysamen, 1994:147-148). The abuse of this method for sales campaigns has, however, made the general public inherently reluctant to participate in telephone interviews and it is very easy for a respondent to terminate an interview before all the questions have been asked. Telephone interviews, by nature, also produce more perfunctory information (Bailey, 1994:198); the researcher cannot record non-verbal responses and user characteristics; nor can the environment be contextualised (Huysamen, 1994:148). Frankfort-Nachmias and Nachmias (1996:243-244) thus suggest that although in certain circumstances telephone interviews could replace personal interviews, they would rather recommend that they be combined with personal interviews to complement the latter.

Having investigated and evaluated the various data collecting methods outlined above, the researcher decided that although she would utilise more than one method concurrently, she would concentrate on personal interview techniques as the most appropriate primary method for this study. During both the first and second stages of the study individual interviews, focus group interviews, and telephone interviews were conducted. The latter were mostly used to follow-up and clarify certain ambiguities that came to the fore during the data analysis stage. In 2001 e-mail questionnaires were also used in the instances where interviews could not be arranged. Throughout the two stages this data was supplemented with appropriate data obtained from documentary and electronic resources.

Once a decision was taken on the data-collecting instruments to use for the study, the researcher made a concerted effort to counter as many of the weaknesses as possible of the techniques selected. As the researcher conducted all the face-to-face interviews personally she was acutely aware of the possibility of both interviewer and respondent bias arising from the complexities of person-to-person interactions, and she was aware of the need to prevent such factors from distorting the results.

3.7. INTERVIEW SCHEDULE CONSTRUCTION

As stated in 3.6.2. interviews can range from the highly structured to the totally unstructured situation, or a combination of techniques may be applied in a single interview. This, in turn, affects the nature of the interview schedule utilised in a study. This can range from the situation where no schedule is used during an informal conversational type of interview, to a more structured interview guide approach, to the situation where interview schedules are used that contain standardised open- and closed-ended questions that have been carefully constructed and sequenced to ensure maximum consistency with minimum intrusion from interviewer effects and biases (Patton, 1990:280-285; Rubin & Babbie, 1993:161). In the event that a more structured approach or mix of approaches is used, the guidelines that have been outlined in the literature that relate to questionnaire construction would apply equally to the construction of an interview schedule. However, more flexibility would be allowed in the design of interview schedules than with questionnaires as far as legibility, presentation, simplicity, and ambiguity are concerned.

The researcher decided to utilise a semi-structured interview approach (cf. Appendix B and C) for all the categories of interviews. The second interview schedule (Appendix C) was also used as the basis for the e-mail questionnaires that were administered. These schedules served as a guide during the interviews and the questions varied from totally unstructured prompts to structured rating scales. The researcher primarily referred to Babbie (1995), Babbie and Mouton (2001), Bailey (1994), Berdie and Anderson (1974), Duncan and Steinbeck (1988), Frankfort-Nachmias and Nachmias (1996), Moser and Kalton (1972), Oppenheim, (1966), and Rubin and Babbie (1993), for guidelines and assistance in designing the interview schedules for this study.

As with most aspects in a research project, the development of the interview schedule is closely related and integrated with the overall objectives and design of the research project. The interview schedule should thus address the specific problem under investigation and only questions that have direct pertinence to the stated purpose of the research project should be included. A further

point that should be noted is that all potential sources of error that could be attributed to the interview schedule should be anticipated and counteracted whenever possible, e.g. inaccurate question wording, incorrect structuring of response categories, asking non-ambiguous and easy to answer questions, etc.

The establishment of rapport is not only related to the interview situation, the personalities involved, and the interview technique followed, but also to the type, structure, sequence and wording of the questions asked. The respondents' motivation to answer the questions in the first instance and to provide accurate and honest answers may all be affected by these factors. To ensure maximum co-operation the interview schedule should be designed in such a way as to create a positive attitude towards the investigation. Bailey (1994:115, 143-144), Frankfort-Nachmias and Nachmias, (1996:260-263) and Rubin and Babbie (1993:186-188, 190) have amongst others provided useful guidelines that can be adopted when constructing an interview schedule. These include phrasing questions carefully, factors such as clarity, brevity, correct language and terminology, the sequence of the questions, keeping the schedule as short as possible, and pre-testing to obviate deficiencies.

Most questions usually relate either to facts (or what are believed to be facts) or opinions (or attitudes). Factual questions are essentially concerned with the respondent's background and demographic characteristics and facts relating to the subject of enquiry. Questions relating to demographic facts (also categorised as classification questions) are often used to distinguish the main groups of respondents for analysis purposes.

Opinion questions that relate to subjective attitudes are, generally speaking, far more difficult to phrase and construct than are factual questions. A number of specific problems have been enumerated in the literature and include the difficulty of obtaining meaningful answers, assessing the intensity of respondents' opinions, the multifaceted nature of responses to opinion questions, and extraneous factors influencing responses (Bailey, 1994:115-113; Frankfort-Nachmias & Nachmias, 1996:252-253; Moser & Kalton, 1972:317-318). These problems should be carefully considered and circumvented when designing an interview schedule.

Broadly speaking all question formats employed in research projects may be categorised as being either of the 'open' or 'closed' format. In open-ended, or free-response questions the respondents are asked to provide their own answers to the questions. Closed or pre-coded questions, on the other hand,

offer the respondents a choice of alternative replies.

Pre-coded questions are generally quicker and easier to answer, more questions can be answered in a given time, they are pitched at the level of precision required by the researcher, they produce standardised responses, and quantification and analysis is straightforward (Bailey, 1994:118-119). The chief advantage of open-ended questions are the freedom they give the respondents to express their own ideas spontaneously, in their own language, in the detail they wish and to qualify any answer. They can generate *rich* data that conveys an in-depth picture of the respondents' perspectives and views (Bryman, 1992:70). Open-ended questions, however, create problems with coding and data analysis, the amount of irrelevant data produced, and the time required to complete them.

The interview schedules for this study were developed in accordance with the guidelines outlined in the previous paragraphs and the final products are attached as Appendices B and C. The only difference between the two interview schedules related to the effect of various changes over the study period and specifically that of electronic modes of communication that were addressed in the second (2001/2) schedule. Both factual and opinion questions were included in each interview schedule. The various response formats adopted are indicated in the outline of the main sections of the interview schedules as follows:

- Section A: This section contained classificatory questions that were used to verify the biographical and demographic information obtained from the *World directory of crystallographers* that was used as the primary source of biographical information at the time of each data-collecting exercise. These included details regarding the respondents' affiliation to their organisation and details regarding the specific department they worked in (if it was established when making the appointments that the person had relocated), his/her current position, highest qualification (and details pertaining to it), and current research interests. An *aide-memoir* was also included to remind the researcher to ask for all the biographical details of the crystallographers who were not listed in the *Directory* and who had been added to the population.
- Section B: Provided an outline and *aide-memoire* of the points that had to be discussed during both the individual and the focus group interviews. These non-directive, unstructured questions related to the communication of information in general, communication of information within the respondents' organisations, between them and other persons within South Africa, and between them and persons outside the borders of South Africa. They were further asked to

discuss any factors that related to the communication of information as it affected their work environment and their profession in general. They were further requested to name the persons with whom they regularly communicated to obtain information on a professional basis. In the second study respondents were also specifically asked to highlight major changes that had occurred in the communication process in the last ten years.

- Section C: This section included a mix of factual questions and opinion questions to obtain specific details regarding the information communication process and the use of various communication channels. The questions were formatted both as open-ended unstructured questions and closed-ended questions formats. Multiple-choice questions that included checklists, rating scales, and ranking techniques were also incorporated as measuring instruments. The various categories were judiciously interposed to arrive at a satisfactory sequence and arrangement of questions. The following aspects or themes were addressed in this section: General aspects pertaining information communication and the use of channels and modes; the communication of information on an interpersonal basis; the use of print-based modes; the impact of electronic media and modes – in the second study far more detail and specific questions relating to this aspect were asked (cf. Appendix C, question 7); the role of conferences on the communication process; the information gathering process and the role of channels of communication; and finally the interaction with libraries.
- Section D: This section reverted back to only asking open-ended questions pertaining to the crystallographers' professional activities and research output. They were also specifically asked to provide a list of their publications, reports produced, etc.
- Section E: This final section asked for general comments relating to the communication process that had not been covered in the previous sections (i.e. an open-ended question format was used).

In preparing the interview schedules for this study and when formulating free-style questions in the field, the investigator attempted to word questions in such a way as to obtain optimally reliable and meaningful data. Her own science background, long years of service as science librarian, the pilot study and pre-tests helped considerably to achieve this. Care was taken to simplify wording and sentence structure, to state questions precisely and concisely, to avoid leading and ambiguous questions, and to generally avoid or eliminate all factors that could potentially affect bias or affect responses (cf. reference to these aspects in the sections above). The researcher further endeavoured to sequence and group the questions as logically and effectively as possible. The researcher also

attempted to produce interview schedules that had a neat and uncluttered appearance and which were easy to read and follow during the interviews. The e-mail questionnaire that was sent to the crystallographers who could not be interviewed during the second study was an exact replication of the interview schedule. The telephone interviews were conducted on an ad-lib basis as they were used in the follow-up process to clarify ambiguities, or to obtain missing elements and greater detail.

The researcher further subjected the interview schedules (and thus the e-mail questionnaire) to a number of pre-tests involving a sample of the intended population, experts in the field and information science, and two experienced research methodologists.

3.8. PILOT STUDY

There is general agreement that a pilot study is an essential prerequisite to any empirical investigation. Pilot studies are small-scale advance studies, covering most of the ground of the full-scale study, and they help to clarify the finer details of the research design to be followed. Pre-tests, generally speaking, are directed at testing specific components of the research project, such as the reliability, validity, and effectiveness of the interview schedule. Both categories provide the researcher with advanced knowledge of the factors to be encountered and of the findings that may be obtained. Such prior knowledge assists the researcher to further familiarise himself/herself with the topic of enquiry, the study population, the reaction that the questions will evoke, the duration of the interviews, and the suitability of the data collecting technique. It is generally recommended that a pilot study should where possible also be based on a representative sample of the target population and that the size should be large enough to fulfil its function, but small enough not to deplete the main study population, particularly in the case where the population is of limited size (Bailey, 1994: 143-145; Huysamen, 1994: 197-198).

During the course of this research project various pre-tests on isolated problems of the design were conducted while the formal pilot study consisted of five interviews that the researcher conducted with crystallographers who represented a cross-section of the study population. They covered various work environments, fields of research, crystallography application and position categories.

All these preliminary investigations jointly provided information on the research design to follow, the target population for the study, the most suitable data collecting method to use, the probable duration of the of the interviews, the adequacy of the interview schedule and other useful input.

3.9. EXECUTING THE EMPIRICAL STUDY

Before embarking on phase 1 of the empirical study the researcher contacted all prospective respondents that were listed in the South African entry of the *World directory of crystallographers* explaining the purpose of the study and requesting an interview. The researcher approached all 98 crystallographers listed under the South African entry and found that a number of the listed crystallographers had either retired, or were on protracted leave within South Africa and abroad and further that new members had joined the crystallographic fraternity since publication of the 7th edition of the *Directory* in 1987. The final population of crystallographers that were present in South Africa at the time of the study was eventually fixed at 80 members. Once the final sampling frame had been established, the researcher telephoned all the potential respondents to arrange convenient times for the interviews. It should be stated that at the outset that the researcher was never refused an interview and that she was warmly received by all participants in the study.

The respondents were concentrated mainly in five geographical areas in South Africa, which ranged from the Western Cape in the south west, to the Free State in the centre, to Kwa-Zulu/Natal in the east, and South and North Gauteng in the north of South Africa. The considerable distances in South Africa entailed extensive travelling to conduct the interviews and extended the time-span of each study. The interviews were thus conducted intermittently from the end of October 1990 to September 1991.

At each regional site the researcher scheduled 4 to 5 individual interviews per day and attempted to restrict each interview to about one to two hours. The focus group interviews were restricted to two to three per day and generally lasted two hours. The researcher manually transcribed all responses as she was of the opinion that a tape-recorder would be too inhibiting and distracting. She reproduced answer sheets for each interview and these consisted of the interview questions together with extensive blank spaces to record the responses. This ensured logical progression and assisted with the later synthesis and analysis of the data.

The process followed in the first phase during 1990/1 was generally repeated in the phase 2 study conducted in 2001/2. The crystallographers listed in the 1995 *Directory* were contacted, non-active members taken off and new members added to the sampling frame. The number of active crystallographers had diminished over the ten year period to 87, and of these only 78 were available to participate in the study. As mentioned in 3.4. sixty three percent of the crystallographers in the second study had also participated in the first study. The researcher conducted personal interviews

with as many of the 78 crystallographers in the sampling frame as were available during the period July, 2001 to April 2002. All members of the study population who were not available during the interview study were contacted and asked to respond to an e-mail questionnaire during May 2002 and as the response rate was low this was repeated again in June/July 2002. In a number of instances the researcher further made telephonic contact with respondents to clarify ambiguous responses and to probe certain issues in greater depth.

3.10. ANALYSIS OF THE DATA

According to Babbie (1995:2-3), research is concerned primarily with measurement and interpretation. Measurement refers to data collection (or as he terms it observation) that is deliberately and rigorously executed and it may range from that which is numerically or quantitatively orientated to that which is qualitative. Interpretation, or data analysis, is where logic and/or statistics are used to analyse the data collected to establish whether meaningful patterns emerge and to make inferences. Such patterns can range from simple description, to providing verbatim quotes from the responses, to describing the objects of investigation in terms of the variables that characterise them and their relationships, to an understanding of why variables are related. Data analysis further transforms raw data into a useful format and it assists the researcher in making sense of and communicating the results of an empirical study in an intelligible format (Shuter, 1987:35).

There are two main approaches on which data analysis is based, the inductive approach which begins with concrete, specific data collection and aims at identifying some general principles governing what is being observed; and the deductive approach which begins with general principles or theory and then turns to data collection as a way of testing the validity of the theory. The well known philosopher, Kaplan (1968:347), in a similar way, posited the “deductive model” (i.e. deducing reason from known facts) and the “pattern model” (i.e. establishing patterns in the data to explain the factors being investigated) as the two main methods of explanation in research. While inductive logic and the “pattern model” generally form the basis of qualitative data analysis, deductive logic, in turn, has traditionally underpinned quantitative data analysis.

A number of researchers suggest that these two approaches are not mutually exclusive but complementary. They suggest that in practice a combination of these strategies can be used where researchers alternate between the inductive and deductive, moving from the one to the other and back as observations result in theoretical explanations which suggest other patterns that may be present

which may be tested by means of further data collection and where the results may lead to the modification of the original theory (Babbie, 1995:2-4; Dey, 1993:3; Mouton & Marais, 1990:103). Dey (1993:3) thus suggests that, although qualitative data deals with meanings that are analysed through conceptualisation and quantitative data deals with numbers that are analysed through statistics, the two forms are interrelated and mutually dependent as "in social science, number depends on meaning, and meaning is informed by number". The relationship between the qualitative/quantitative data dichotomy shifts with the level of measurement that is applied which ranges from the situation where meaning is predominant and the role of numbers is negligible (nominal/ordinal levels of measurement), to the situation where numbers assume a more important role than meaning (ratio/interval levels of measurement).

3.10.1. ANALYSIS OF QUANTITATIVE DATA

In quantitative data analysis a general distinction is made between parametric and non-parametric statistics. The latter refers to the analysis of discrete, or nominal and ordinal variables, while the former refers to the processing of continuous or, interval or ratio variables (Bailey, 1994:389). If the variable is nominal or ordinal (i.e. more qualitative), percentages and proportions are calculated and non-parametric techniques applied. If, on the other hand, the variable is interval or ratio by nature, measures of central tendency or dispersion are calculated and parametric techniques may be employed (Rubin & Babbie, 1993:456-457). Rubin and Babbie (1993:457), however, further state that in practice there are many 'grey areas', such as when rating scales have been used with an ordinal variable and the mean rating given to that variable or its categories by the sample or population is calculated.

Descriptive statistics merely indicate the properties of a sample of observations and do not reveal very much about the population from which the sample was drawn (Bohrstedt & Knoke, 1994:22). Inferential statistics, however, apply the mathematical theory of probability to make inferences about the likelihood that properties observed in the sample can be generalised to the entire population from which the sample was drawn (Bailey, 1994:389). If a random sample, which is representative of the population, is drawn, the researcher may with a degree of confidence make inferences about the parent population and statistical significance tests can be applied to establish at what level of error, or confidence, results obtained about a particular sample may be inferred or generalised to the population.

If data have been gathered from an entire population, the question arises whether statistical significance tests are necessary. Rubin and Babbie (1993:529-530) indicate that this is a matter about

which statisticians are not in general agreement. There are those who contend that significance tests need only be conducted when sampling has occurred and where inferences are made from sample data about the parent population. If the entire population is investigated, any observation made or relationship detected should be significant as there is no sampling error and it constitutes a true reflection of the population's attributes. Others, however, argue that the above statement only applies to descriptive statistics, and that if the researcher wishes to infer that an independent variable really causes changes in some or other dependent variable, and that such variation is not merely a function of random processes and due to covariation by chance, significance tests should always be applied to establish the plausibility that relationships observed reflect true causal processes.

Many researchers further also utilise significance tests to establish whether a relationship exists between two variables and to test hypotheses. This, however, is inadvisable as significance tests merely indicate the probability whether a relationship was caused by chance (i.e. sampling error) and whether that relationship can be inferred to exist in a theoretical sense or in a broader population (Bohrnstedt & Knoke, 1994:23; Rubin & Babbie, 1993:489). Therefore, if a relationship is found to exist, the researcher should rather utilise a statistical measure of association to establish the strength and direction of the relationship (Bailey, 1994:378). One should however be aware that a negative or low outcome, particularly when working with smaller samples, does not necessarily disprove the existence of a relationship, and that it may merely indicate that the chances that it exists due to sampling errors is greater.

Explanatory statistical analysis is the method used to analyse a perceived relationship between two or more variables (Bailey, 1994: 378). Bivariate analysis examines the relationship between two variables and multivariate analysis the simultaneous relationships among several variables (Rubin & Babbie, 1993: 460, 465-466). In bivariate cross-tables two variables are placed together in a single table in such a way that their interrelations can be examined. The strength of the relationship is measured in terms of the degree of correspondence between the variation in scores of one variable and the variation of scores in the other variable (Bailey, 1994:395). Both parametric/non-parametric and descriptive/inferential statistics may be used in cross-tabulations. Once a relationship is detected the researcher should first apply a significance test to establish whether the pattern observed in the sample data is likely to reflect covariation in the population from which the sample was drawn. To assess the size, direction and strengths of relations among variables, one or other of the various statistical measures of association should then be calculated. The type of significance test and association measure applied will depend on the level of measurement used and the type of variable, (Bohrnstedt & Knoke, 1994:155).

A significance test, as mentioned above, merely indicates that a relationship exists between variables, but not how strong the relationship is. Measures of association or correlation coefficients are generally used to assess the strength of such a relationship by measuring the covariance between the variables. They generally range between scores of 1 for a perfect correlation, and zero for no relationship and can also show the direction of the relationship by means of a '-' for an inverse relationship and a '+' for a positive relation. (Bailey, 1994:396). The question now arises what would represent a sufficiently large correlation coefficient. In the first instance this would be indicated by the significance level associated with the coefficient. Secondly it has been suggested by Bohrnstedt and Knoke (1999:146) that correlation coefficients as low as 0.25 are sufficiently substantive to explain the variance in a dependent variable for a single independent variable in social science (this would however not necessary apply to other disciplines).

3.10.2. ANALYSIS OF QUALITATIVE DATA

Whereas in quantitative research concepts and categories are predetermined and defined operationally, in qualitative research the interaction between empirical data and the concepts that are grounded in the data generally informs theory construction. The qualitative analyst is supposed to unearth problems, identify indicators and formulate hypotheses as the end-product of research, rather than investigating predetermined problems within an established theoretical framework. To the qualitative researcher the formulation of theoretical propositions, the observation of empirical events, and the evaluation of data and theory are typically all part of the same ongoing process (Denzin & Lincoln, 1994:212). The researcher develops theories, or generalised understandings, over the course of the data collection and analysis process. Each new set of empirical observations are related to general principles and their impact is evaluated. The tentative theories and conclusions, so arrived at, then provide the conceptual framework for further data collection. In the course of data collection and coding the researcher will establish the interaction between variables and emergent patterns. It is thus clear that data collection and analysis are interwoven processes in qualitative research.

Maykut and Morehouse (1994:122) refer to three main approaches in qualitative data analysis that they derived from Strauss and Corbin's (1990) work. These approaches are positioned on a continuum that ranges from low to high levels of interpretation and abstraction which then culminate in theory building. The first merely presents the data without any significant analysis or interpretation, while

the second approach, known as “interpretative-descriptive”, provides a descriptive and realistic reconstruction of the data. The outcome of the third approach is theory building and requires the highest level of interpretation and abstraction. This is akin to the *grounded theory* approach as developed by Glaser and Strauss (1967) and which many researchers see as forming the foundation for all qualitative data analysis. This approach adopts the premise that theories cannot be divorced from the processes that generated them and that they should be inductively derived from the data. Thus hypotheses and concepts are not only derived from the data, but are "systematically worked out in relation to the data during the course of the research" (Glaser & Strauss, 1967:6).

The grounded theory approach, however, is not without its critics and Seldén (2005:114) is of the opinion that qualitative research should not be conducted without a framework that maps the area to be explored and that researchers should thus adopt theories (even if loosely defined) as the organising framework within which to connect the various concepts used in the analysis process. Theory should thus have a role to play in providing a conceptual framework for a research project. Despite these divergent opinions and even when considering and accepting greater convergence between qualitative and quantitative approaches, it is however clear that the logic of qualitative data analysis differs considerably from that in quantitative data analysis and that each approach would adopt different data analysis techniques.

From the previous paragraphs it would be obvious that a major concern in qualitative data analysis relates to the generation and classification of concepts (used interchangeably with “categories” and “constructs” in the literature). During this process the researcher is endeavouring to extract from the empirical data the distinguishing concepts that can be generalised into theories and Lazarsfeld (1972:226) warns that the process of "switching back and forth" between concrete categories embedded in the empirical data and general categories that relate to other fields of experience until "both concrete applicability and generality are obtained" is a time consuming process. Dey (1993:30), however, suggests that despite various opinions relating to the conduct of qualitative data analysis, a common thread can be discerned that can be used to categorise data and make connections between categories. He thus proposes that the researcher should at the outset arrive at a thorough and comprehensive description of the phenomena being studied. This *thorough* process is often also referred to as *thick* description and this is in contrast to *thin* descriptions which merely state facts (Dey, 1993:31-32).

The constant comparative method is frequently referred to in the literature as a useful tool to analyse qualitative data. It combines inductive category coding with the simultaneous comparison of

all the units of meaning established during the 'unitizing' process (Maykut & Morehouse, 1994:134). Units of meaning are categorised and coded and as each new unit is identified it is grouped with similar units of meaning. If there are no similar units of meaning, a new category is formed. This results in a continuous process of refinement, initial categories can be changed, omitted, or recombined, while new ones can be formed and new relationships identified. It is important that the researcher devises rules that define the dimensions of the categories, their properties, their limits, and their relationship to other categories to assist in inclusion/exclusion decisions, as well as "to provide a basis for later tests of replicability; and to render the category internally consistent" (Lincoln & Guba, 1985:347).

The key to this process is classification and the categories that are used to sort or organise the data according to relevant characteristics. Categorising the data assists the researcher in more easily making comparisons and retrieving it in a variety of ways according to different characteristics. Classifying the data therefore provides the basis for making new connections between different bits of data and identifying relationships between variables. Classification both breaks data up into bits and reassembles these bits into classes or categories and it provides the conceptual foundation for analysis. It is at this stage that the researcher can establish whether the categories can be further refined, or sub-categorised, whether boundaries between categories can be finalised and the first comparisons can be made. This process of re-organising the data according to a designated category set is also known as *recontextualisation* and once data have been categorised they can be counted, and such enumerated data can be statistically analysed, albeit at a simple level (Dey, 1993:40, 129).

Categories should be sufficiently grounded conceptually and empirically to form the required analysis framework and to arrive at an adequate categorisation of the data it has been suggested that

- the data should always be considered in context;
- categories should reflect the purpose of the research;
- categories should include all conceptual definitions;
- categories should be exhaustive, mutually exclusive and independent, and they should derive from a single classification scheme;
- the researcher should be flexible and open to constant modification of the categories;

(Dey, 1993: 105, 112; Holsti, 1969:94-100).

Once the data has been classified the researcher can examine it for regularities, variations and singularities and so establish whether there is a pattern in the data. By studying such correlation

between different categories or variables, the researcher can identify connections between them (Maykut & Morehouse, 1994:139-145). Not only regularities are identified, but variations and exceptions may also be distinguished and by delving deeper the researcher may establish why such variations have occurred. Only once a logical reason and meaning for the association has been identified does the correlation between different variables acquire significance and the researcher should thus constantly return to the data to see whether such a connection can reasonably be inferred. According to Dey, (1993:49) cause in qualitative analysis is not only external and contingent, but it is also related to the "inherent capabilities and liabilities of social actors, and how these interact to produce particular effects".

Dey (1993:131) further suggests that the next step in the analysis process involves the combined processes of *splitting and splicing*. The former refers to the further sub-categorisation of the data to achieve greater resolution, detail, scope, a more intelligible and coherent analysis, while "splicing" refers to re-combining categories to provide a more integrated conceptualisation. The rationalisation for further subdivision depends on similar factors that determined the decision to arrive at the initial set of categories.

Linking data involves recognising substantive rather than formal relations between things. Formal relations refer to how similar or dissimilar things are, while substantive relations refer to how things interact (Sayer, 1992:88). Sayer (1992: 89) further distinguishes between relations that are "internal or necessary" and relations that are "external or contingent". To ensure consistency and enhance clarity the researcher should list and label the links which have been used to associate or relate bits of data. Links may be derived from the underlying theoretical concerns that underpin the research, or they can be inferred from the data.

Threats to the reliability and validity in the qualitative analysis process are generally attributed to the subjectivity of the process, selective perception, evidence being fabricated, discounted or misinterpreted, and lack of generalisability of such studies (Dey, 1993:222; Lincoln & Guba, 1985: 289). One of the checks against such errors in the quantitative domain is the ability to replicate the study. In qualitative studies this is notoriously difficult to achieve as the main aim is to be sensitive to spatial and time contexts which is usually impossible to replicate exactly. A number of methodologists, therefore, suggest that the researcher should institute *internal* replication procedures of his/her research by means of an *audit trail*, or detailed research records which will ensure that the procedures that were followed are clearly stated and outlined so that they can be inspected and scrutinised by other researchers (Dey, 1993:222; Lincoln & Guba, 1985:318; Maykut

& Morehouse, 1994:146).

However, the greatest problem in qualitative research is the unwitting misinterpretation of data as it is only human for most researchers to be influenced by their personal presumptions and biases when they start the analysis process: "We may tend to make more of the evidence that confirms our beliefs, and pay less attention to any evidence that contradicts them" (Dey, 1993:222). It is thus proposed that to minimise and prevent such errors the researcher should produce sufficient corroborating evidence to support impressions, provide opposing interpretations of the data, delay coming to conclusions too soon in the analysis process, and not only accept one interpretation as the correct one (Dey, 1993:228). Rubin & Babbie (1993:297) also advise that qualitative observations should be augmented with quantitative ones as even rough quantification might provide safeguards against selective perception and misinterpretation.

3.10.3. DATA ANALYSIS METHOD ADOPTED FOR THIS STUDY

The analysis of the data for this study was conducted following the guidelines provided and within the parameters outlined in sections 3.10.1 and 3.10.2. above. All responses, both qualitative and quantitative, from the two studies (Phase I and II) were initially captured using the dBASE™ database management software and Microsoft's Excel spreadsheet software. A record structure was created that accommodated the various fields ranging from the respondents' structured responses to their unstructured qualitative responses. The quantitative data was then manipulated by means of the statistical functions available on Excel and by using the STATISTICA software programme. Where relevant and according to the data category, level of measurement, and purpose of analysis, percentages, means, significance measures and correlation statistics were calculated and represented in tables. To further explicate and clarify the analysis process certain analyses were graphically depicted as charts.

The more detailed analyses of the data involved cross tabulating the various sub-categories of the population (the independent variables) with the various categories of the dependent variables. ANOVA or chi-square statistics were further calculated for each data set to establish which cross tabulations were significant at a significance level = .05. This initial analysis provided the overall effect of the independent variables on the dependent variables. The Wilks' lambda statistic, the F ratio and phi values were also calculated and used to establish the strength of correlations.

The constant comparative method was used to analyse the qualitative data that was generated.

Inductive category coding was combined with the simultaneous comparison of all the units of meaning that were uniquely identified. The phenomena being investigated were described, classified and categorised. Categories were refined and re-combined as required. Once the data had been classified the researcher examined it for regularities, variations and singularities and also whether any patterns and correlations were evident in the data. Not only regularities were identified, but variations and exceptions were also distinguished and the researcher tried to explicate the reason why such variations occurred.

In the ensuing two chapters the results of the data analysis exercise, both qualitative and quantitative, have been reported in an integrated way to obtain a synthesised view of the results.

CHAPTER 4

INFORMATION COMMUNICATION PATTERNS AND NETWORKS WITHIN THE CRYSTALLOGRAPHIC COMMUNITY

4.1. INTRODUCTION

This chapter is based primarily on the qualitative data obtained from the unstructured questions asked during the individual and focus group interviews in 1990/1991 and again in 2001/2002 and was further supplemented with that obtained by means of the structured questions put during the two sets of data collection (cf. Appendix B & C, Section B, Questions 1-3) as well as follow-up telephone interviews. The respondents were asked to discuss the communication of information in their immediate research and work environment and then to expand it to the wider crystallographic and general science community, first in South Africa and then globally. Specific attention was paid to the factors they thought had had the most significant impact on the information communication process between the 1st and the 2nd study. This chapter provides an overview of the information communication process and interpersonal communication networks that an analysis of the data revealed. The next chapter will address the specifics of channel and mode preference and discuss the factors that impacted on the information communication process in greater detail. In each of these chapters the overall situation that applied to both studies will be outlined followed by changes (if any) that were noted in the intervening eleven years. The demographic profile of the respondents is outlined in Appendix D and this data was obtained from Section A, questions i. – vi., Appendix B and C.

4.2. COMMUNICATION OF INFORMATION WITHIN THE ORGANISATIONAL SETTING

From an analysis of both the qualitative and quantitative data it clearly emerged that the respondents' work environment and work structure largely determined communication patterns and the interaction with information. (This is in agreement with the findings of a number of studies as reported in 2.7.1.2.) The organisational ethos that prevailed in each of the three work

environments (industry, the research institutes and the academic institutions) generally determined specific work structures which in turn impacted in varying ways on the communication of and interaction with information. These ranged from the most structured approach that prevailed in industry, to the less rigidly structured research institutes to the academic institutions where a far more flexible approach was adopted.

The communication of information was closely integrated with and related to the research activities of these respondents, the underlying reason for conducting research, and the information needs engendered by these activities. The communication process was thus driven on the one hand by a need for information to start up a new research project, to test a theory, to solve a problem, design a system, product, process, etc. and on the other to keep up to date with new developments in their field. Another very important driving force was to impart the end result of the research effort to management, the wider organisation, clients, colleagues, and in many instances to the science community in general. These interactions with the information communication process were conducted either on a direct interpersonal level (mostly using informal communication channels), and/or on an indirect impersonal level (mostly using formal communication channels).

4.2.1. COMMUNICATION WITHIN THE INDUSTRY SECTOR

All the respondents in industry worked in the research and development (R&D) divisions of one of five industrial concerns in South African. Four of the five divisions were, by South African standards, large units with professional staff complements that ranged from 300 to 400 persons. The fifth unit was much smaller with 50 scientists conducting applied research. Two of these companies were affiliated to large international conglomerates, while the other three had no formal international affiliations.

All of these crystallographers were engaged in applied research that was in one of the following fields: applied chemistry, mineralogy, or material science. The majority of these respondents worked in South Gauteng (i.e. in the environs of Johannesburg), while the other smaller contingents worked either in North Gauteng (mainly Pretoria) or Sasolburg in the Free State. The vast majority of the industry respondents had doctorate degrees that were almost equally distributed between those obtained in South Africa and abroad. It was found that most of these respondents held senior posts and were in the 36 to 50 age category. This group of

crystallographers constituted 16% of the 1990/1 and 14% of the 2001/2 population. There was only a marginal change in the profile of the respondents when the two studies were compared and this related primarily to a slight increase in the age profile and slight drop in numbers of the industry respondents in the 2001/2 study.

The organisational structure within the research and development section in each company was generally very similar. Researchers were grouped into divisions that were engaged in cognate research areas and these were further divided into smaller more homogeneous research units, or groups, each addressing a specific research project of interest to the company. The groups and divisions were respectively managed by group and division leaders, with a research manager and often also a deputy research manager providing overall leadership and co-ordination of all research projects. The R&D division of the smaller company mentioned above, although following the overall pattern, had a less structured and more flexible approach than the larger R&D divisions.

The overall flow and communication of information within the five companies thus followed very similar patterns with minor differences evident between those companies with international affiliations and those without such affiliations and also between the larger and smaller R&D divisions. It was further observed that the flow of information was largely determined by the ability of the group and division leaders to stimulate and encourage the communication process and by the level of confidentiality of the research they were engaged in.

The research emphasis in these R&D divisions was obviously not on basic research, but on providing solutions to problems that were related to the operation of the company. They were, thus, involved in developing and implementing new products or techniques, in providing technical and product support for the company's production facilities, and in *troubleshooting* and problem solving for the production and management divisions of the company. This implied that they were very dependent on bilateral interaction with all company divisions and other outside clients that required their services to receive input and feedback to direct their research activities. There was, thus, constant interaction between them and the production side of the company, with general management and to a lesser extent with the sales divisions.

Although most respondents commented on the inherent problems attendant on communicating effectively in the work situation, there was consensus that this problem was generally resolved by the good, workable communication structure that prevailed within all the R&D sections of these

companies. This operated at two parallel, but also intersecting, levels where both formal and informal modes and channels of communication were utilised. On the formal level this was driven by the project management structure within which most of the industry crystallographers operated and which enforced regularised reporting and communication of information.

Researchers working on specific projects reported on their progress on a regular basis to their project managers, group or division leaders who then met at fairly formal, weekly to bi-weekly meetings to consider the progress made on the most important projects and to focus on short term problems. The more junior researchers also participated in these meetings if the topic related to their work. These meetings were generally chaired by a member of the senior management team of the R&D section, typically the research co-ordinator. In addition to these meetings, less frequent, but still regular, project review meetings were held to review all ongoing projects and these were generally chaired by the research managers. Representatives from the production or other units for whom research was being conducted also attended and provided input at these meetings. The outcomes of all these meetings were regular progress reports to the top management of the company, who then provided feedback and comment which was disseminated back to individual researchers by their managers. Other information of general interest was also filtered up and down the hierarchy to ensure that all persons were kept informed.

Formal links were further also maintained between all major divisions in the companies by convening formal but less frequent (monthly to bi-monthly) meetings that involved all sections, including the R&D division to discuss general company policy and to exchange information in general. Senior management from each division generally represented their sections at these meetings and relevant information pertaining to the research and development operation was then disseminated back to the laboratory researchers. The research managers were also included in the decision-making process that involved only the top echelon of the company. Once again it was incumbent on them to ensure the effective flow of decision-making information up and down the hierarchy.

In addition to the formal communication structures that were in place all respondents that were interviewed emphasised the importance of informal, person-to-person, exchange of information. It was evident that the informal exchange of information was in fact actively encouraged and was the major method of communication when information was required to solve specific problems encountered in the work situation. This was particularly prevalent at the research team level

where project teams worked in close-knit units, communicating interactively. When a specific problem arose the researchers concerned would first consult amongst themselves and if they could not provide the information to resolve the problem they would approach their group leaders. If the problem persisted the relevant group leader would then consult the research co-ordinator or research manager or some expert from another research group. This could eventually result in an ad-hoc meeting being convened among all relevant people who could possibly assist with the problem and provide a solution. If still not solved, the research co-ordinator, or group leader would then either request the technical library to conduct a literature search, or more likely approach experts within South Africa or abroad for the appropriate information to solve the problem.

Such informal communication operated not only at the research team level, but also among the more senior members of the R&D divisions. Group leaders generally held regular informal discussions amongst each other and with the top structure of the R&D division to discuss problems encountered as well as progress made. Such ad-hoc informal communication was also extended to their 'clients' in the production and other units of the organisation for whom they were conducting the research, or offering a service. Face-face communication was the preferred mode of interaction, but the telephone and e-mail were also used extensively.

It was specifically observed that informal, interpersonal communication was the most active and effective when it operated at the same hierarchical level. As soon as information was communicated outside the peer group more formal channels, such as meetings, seminars, reports, technical notes etc., were generally utilised to ensure the effective exchange of information up and down the hierarchies.

From the interviews it clearly emerged that the key person in the R&D communication network was the person in charge of the researchers working in research teams (this generally varied between six to fifteen persons working together). Such group leaders were in direct contact with the researchers in the laboratory, with each other and by means of project meetings with top management. The group leaders generally acted as *gatekeepers* for the group, and ensured a two-way communication pathway to and from their groups to the wider company and even wider to the overall research community. They were often also members of wider research groups in the same broad fields that extended beyond the specific company and incorporated all subsidiary and affiliated companies. A feature of the larger multi-affiliated companies was that inter-company

meetings were regularly convened to discuss mutual problems and to exchange ideas. Such *panel discussion groups* transcended rigid subject boundaries resulting in a cross pollination of ideas. In the instances where the companies were part of international conglomerates, these meetings then resulted in the local researchers meeting up with experts from all over the world within the same family of companies. This aspect was considered to be an important countermeasure against the isolation from the cutting-edge of international research that was enforced by the confidential nature of their work and the geographical distance of South Africa from the major international researcher centres.

Although the majority of the researchers were of the opinion that the lines of communication were very good within their companies they all agreed that communication could always be improved. At the time of the 1990/1 study it was suggested that greater use should be made of facsimile transmission and electronic methods to improve inter- and intra-company communication and that regular inter-company symposia covering pertinent technical/scientific topics should be held to gather together all interested parties, particularly the more junior researchers, and improve the flow of information in the companies.

When these aspects were addressed in the second study it emerged that the use of electronic media have had a considerable impact on the communication process and are heavily used in most of the work environments. E-mail, online databases and the Internet are used routinely and outside the immediate work environment the use of e-mail is very extensive, particularly for international communication. E-media have facilitated group interaction and this has made it feasible to obtain information on particular aspects of their work or advice from an expert within hours from anywhere in the world, and to quote one respondent "the global village has in fact become a reality".

However, while it was generally considered that electronic media had improved the ease, speed and accuracy of information communication (especially when transferring files), all the respondents still held strong views that person-to-person information exchange was the preferred mode of communication and remained the best method to obtain information for problem solving. To quote two of the respondents:

E-mails are useful, but no substitute for one-to-one discussions with colleagues and experts in the field and Although electronic communication is fine for exchange of information we still need face to face communication in order to maintain relationships.

Electronic mailing lists and electronic conferences were regarded in a very similar way – they were considered to have some use, particularly for idea generation and interim discussion, but the consensus was that they did not fully emulate the interactive nature of face-to-face communication that traditional conferences, for example, promoted.

A specific problem that was raised with the use of electronic media was the danger that security could be breached and confidential information accessed. At the one R&D facility the possibility of industrial espionage was taken very seriously and the open use of e-mail and the Internet was strictly controlled. They could only use their own secure tie-lines amongst all subsidiary companies world-wide to communicate and transfer files. Another problem that all the respondents referred to was that the poor bandwidth in South Africa had a detrimental effect on effective communication.

In addition to the information communication structures outlined above these researchers also interacted with other layers of formal and informal information communication channels and networks. This related to information networks they maintained with colleagues and other experts outside the immediate work-related environment in South Africa and abroad and their interaction with the published or recorded literature in both printed and electronic modes. These communication interactions were important as they ensured that external information was imported into the work environment and that their knowledge was transferred to wider audiences, and if published also to the public domain. The interaction with colleagues outside the immediate work circle will be further discussed in 4.3.

Most of the industry respondents held very strong views about the importance of engaging with the published or other recorded literature. They all believed in conducting extensive literature searches before embarking on any new research project. The comment recorded below provides a good overview of the respondents' general views on these aspects:

When searching for information on new topics I use the Internet and CD-ROMs to get pointers and then follow these up by searching the printed literature and communicating with people. I then follow this up by looking for references found in journal articles, etc. It is important that one should always conduct a thorough literature review of all sources before embarking on a new project - it is expensive to replicate work already done. I search the printed literature, databases and patent databases extensively. I don't often use the Internet for detailed information as it produces far too much junk, but when I have to I generally ask the library to do the search.

The interviews clearly indicated that the final encoded research output was a formal report, or series of reports which was circulated within the company, and if applicable, to other subsidiary and/or affiliated companies in South Africa and abroad. In addition patents were promulgated and to a far lesser extent conference papers, journal articles and other published material were produced. All final reports were lodged with the respective company libraries where they were indexed and incorporated in the library's database. A copy was also sent to affiliated companies for wider dissemination. These reports were all classified according to their level of confidentiality and concomitantly the level of access was restricted.

All respondents were in agreement that report writing is of vital importance and a fundamental component of the communication process in industry. Reports not only contain invaluable information, they also prevent *the reinvention of the wheel* by encoding the outcomes of the research process for future reference. However, it was observed that the free flow of information in applied science is generally impeded by the fact that reports are not distributed beyond the boundaries of a company.

Patents were the other important form of research output in industry and they played a considerable role in the communication process of applied science by ensuring that industrial research entered the public domain. Although research reports and patents constituted the primary written end-product of the research effort in industry, many of the researchers that were interviewed stated that they did try to publish in international journals as well as deliver papers at conferences. There was, however, usually a problem with confidentiality in industry which prevented them from publicising information that could be detrimental to the company, but as this was largely related to the sensitive nature of specific research projects, the embargo on publication was often lifted in the instances where they were of a less strategic nature. Further factors that inhibited the general publication of research findings was that the driving force that is inherent in basic science to ensure that new knowledge is made public does not apply in industry as their primary objective is to produce a product and/or to provide the best solution to a problem.

The only significant change, other than the far greater utilisation of electronic media, between the two studies, was that it was apparent that far more research was being contracted out to universities and research institutes and this in turn caused a far more complex communication structure. This meant creating good, working inter-organisation communication channels and

extending both trust and confidentiality restrictions beyond the immediate company boundaries. The R&D facilities were, as a result, either downsized or their research efforts were redirected towards troubleshooting and problem-solving, while the more fundamental, developmental research was outsourced.

4.2.2. COMMUNICATION WITHIN THE RESEARCH INSTITUTES

The crystallographers working at research institutes constituted 23% of the 1990/1 and 22% of the 2001 study population and were attached to one of the following three organisations in South Africa: the Council for Scientific and Industrial Research (CSIR), the Council for Mineral Technology (MINTEK), and the Atomic Energy Corporation of South Africa (AEC)⁷. The professional, managerial, and technical staffing complements of these institutes ranged from approximately 450 to 1 000 members and these research institutes all maintained very similar organisational structures. The organisational and management structure, as in the industry sector, to a large extent dictated the formal information communication networks that were in place. All researchers in these institutes were grouped into one or other division under the direction of a director, often assisted by a deputy director and/or a project manager. The divisions were established according to broad subject, or mission orientated categories and each division was generally further grouped into project teams of approximately 8 to 15 researchers working on specific programmes under the direction of a group leader. It was found that there was a greater tendency in the research institutes than in industry to delegate responsibility and devolve power, resulting in a fairly-flat organisational structure and a more delegated working environment.

All the respondents from the three research institutes were predominantly engaged in applied research and were working in the fields of either materials science, mineralogy or applied chemistry. The majority of this group worked in Pretoria, North Gauteng, while a smaller proportion was situated in Johannesburg, South Gauteng. More than two thirds of this group held PhD qualifications that were mostly obtained in South Africa. These respondents were fairly equally distributed amongst the three age categories of 20 – 35, 36 – 50, and 51 – 70, and approximately half held more senior research positions. There was no significant change from the first to the second study in the research institute respondents' profiles.

⁷ Now known as the Nuclear Energy Corporation of South Africa (NECSA).

The majority of the research institute respondents adhered to very similar communication patterns which were largely determined by work structures and the prevalent business model that operated at the time. A feature of their work environment was that a large proportion of the research was conducted under contract for some or other external client (either in the private sector or for some government department) and they, in turn, often further contracted their research out to various universities when they lacked the expertise or facilities to conduct the research, or they collaborated with academics on research projects. The divisional structures outlined above formed the basis for information communication in the research institutes. Although considerable differences were discerned among the three research institutes and the various divisions followed fairly differentiated work models, a generalised information communication pattern did emerge. The preponderance of contract work dictated that the communication process was, despite the fairly open culture and flat hierarchical structure that prevailed, still fairly formalised and structured. Intellectual property and confidentiality issues also impinged on the process.

Formal information communication in the divisions was established by means of regular structured meetings between the directors and the group leaders, who in turn, passed the information up and down the hierarchy. The directors, in addition, held meetings with all the researchers in their divisions at least once a month. The directors were, in turn, part of the top management structure that held regular strategic planning or so-called *summit* meetings. Internal project management meetings, which ranged from the totally informal to a formal structured situation, were held regularly to discuss problems and to exchange relevant information relating to current work. In addition, inter-programme seminars were held where the divisional directors and project leaders communicated across program boundaries. This encouraged cross pollination of ideas and helped to resolve problems that could not be answered within the unit itself. In addition to all this, ad hoc informal meetings were convened to discuss specific problems that arose from time to time. For each project that they were engaged in, progress or interim reports and finally formal concluding reports were issued. All reports were disseminated to the senior levels for evaluation and feedback and then finally to the appropriate clients. Reports were archived both in printed form and electronically.

Work that was sponsored by outside organisations and contract work further also required regular reporting to the sponsor, or client. Communication was firstly personal, then by means of workshops, progress meetings, meetings of the management committee, and finally by reports (this sequence was indicated as being representative of the order of importance and

effectiveness). Progress meetings and regular workshops were specifically held with their industry partners to help to keep them in touch with progress and the outcomes of the research, to explore problem areas requiring investigation, and to clarify any ambiguities. Such contracts often ran for a number of years and the resultant interaction and communication between the researchers and their clients was fairly extensive.

There was continuous informal interaction amongst the members of research groups and the researchers involved in day-to-day empirical research tended to communicate on an informal, unstructured basis amongst themselves rather than by means of structured meetings. The overall communication process was generally facilitated and mediated by the group leaders who ensured the effective vertical and horizontal communication of information in the work place. This they achieved by means of informal interpersonal discussions, seminars at various levels of formality, reports that disseminated the research output and the literature disseminated by the library.

As in the industry environment, informal, interpersonal interaction and exchange of information was highly valued, actively encouraged and it occurred on a daily basis. The view was expressed by most of the researchers interviewed that they valued direct personal interaction and would thus rather exchange information on a person-to-person basis or by telephone, than engage in written communication with their colleagues or find the information in the literature. In their opinion informal tearoom discussions with colleagues often sparked off ideas and solved problems and were thus one of the most effective methods of communication. This view was succinctly summarised by one of the respondents as follows:

Personal interaction provides in-depth information as well as a bigger picture of what people are doing. In an hour you can be briefed in the direction that the group is taking and you can be advised of new techniques, new philosophies that are not as yet or never will be in print. The information is generally less formal and very informative. The literature on the other hand is more accurate and detailed.

An added dimension that was provided to the communication process at one of the research institutes was the fellowship structure. The fellows are scientists who are accredited by this institute for their excellence, and who are acknowledged international experts in their field and recognised nationally and internationally for their contributions to science. Although they are ranked as the most senior members of the staff and participate in strategy planning and decision making, they remain in active research. They meet and communicate actively among themselves

and their knowledge is regularly sought, for technological strategy development, planning and foresighting, amongst other reasons.

The research institutes also engaged extensively in multi-dimensional collaborative research projects that often involved themselves, universities, industry and the public sector. A good example of such a multi-faceted collaborative research project that created fairly complex information communication structures was the deep mining research project where the one research institute instigated a collaborative research effort to solve deep level mining problems for the entire mining industry. This project constituted a large research team (over 250 researchers) where approximately half of the participants came from two of the research institutes, and the remainder were derived from a number of universities, and representatives from the mining industry and government. The one research institute acted as the lead organisation that co-ordinated the project. It required extensive networking skills, research leadership and direction to ensure that the various researchers from all the collaborating organisations worked effectively together and met the targets set. Persons who were normally in competition with each other now had to work together and this often caused personality, professional and organisational problems that required good mediating skills. The information networking was at task level with regular progress reviews that culminated in quarterly reports.

The research institute researchers, in much the same way as their industry counterparts, also interacted with other layers of formal and informal information communication channels and networks. Their interactions with colleagues and other experts outside the immediate work-related environment in South Africa and abroad will be discussed in 4.3. Their formal interaction with the published and other recorded literature was achieved either by means of their own efforts to find appropriate information by personally searching electronic databases and the Internet, and browsing through current journals and other sources; or by means of their interaction with the library. The latter related to the various services offered by their libraries such as SDI services and online searching conducted by their libraries for them. A number of these respondents mentioned that the most important service offered by their libraries was the systematic routing of relevant journals. The library's involvement with information exchange was thus viewed to be an integral and very important aspect of the communication process.

As in industry, project reports represented the main formal written research output in the research institute environment, and, thus, the information input into the communication cycle. Research

reports, furthermore, were seen to be an important method of communicating with outside clients and sponsors with whom they had contract research agreements. Progress and final reports were produced and distributed internally to all interested parties, while contract clients and sponsors received copies of relevant reports. All reports were permanently stored, usually in the library, to maintain records of previous research and development and for information retrieval purposes.

The publication of journal articles and the presentation of conference papers, although playing a secondary role, was far more heavily utilised to disseminate research findings than in the industry environment. This was partly because not all research was confidential and partly because of the prevailing ethos of sharing information with the wider research community. Patents were another form of encoded research output within this environment.

Although the basic information communication model outlined above remained fairly constant from the 1990/1 to the 2001/2 study, certain significant changes did surface during the second study. The variation was predominantly caused by changes in the work environment in the institutes and the impact of electronic information communication media in the intervening period. The change in the work environment was primarily caused by changes in their funding structure. These organisations changed from institutions that received very large and liberal grants from the government to a situation where state subsidies were reduced considerably and they were forced to operate as self sufficient business units. The intervening years thus saw a shift from a purely research-based ethos and environment where they were free to conduct research on any applied or basic science aspect thought to be of use to the country, to one where the driving factor was the motive to make a profit. This has resulted in the need to engage almost exclusively in remunerative contract work, which in turn brought about the enforcement of confidentiality restrictions by their clients (usually in industry) and intellectual property rights issues.

This awareness of intellectual property and the need for secrecy has made people less open, and the flow of information more restricted. Whereas previously a collegiate environment prevailed with all new knowledge that was generated being freely shared, there was now a dramatic move away from transferring their research outputs into the public domain (e.g. by means of publications, conference presentations, etc.), to patenting innovations and producing profit-driven products (usually in partnership with or for clients). The number of publications thus dropped considerably and to quote one director,

where previously our division produced over a hundred scientific publications a year, it has now dropped to one to two due to commercialisation, intellectual property rights and confidentiality.

This contract driven environment, with its attendant time restrictions and almost exclusive focus on final outcomes, has had a considerable impact on the information communication process and as one respondent stated:

The collegiate ambience that used to exist and was fostered at our institute has changed because of the profit drive. The emphasis in our institute has moved from our annual publication output to what income we have generated - the days of huge funding for basic research have disappeared and we are now part of the global village and its competition.

Informal interpersonal interaction has also been affected by the new environment and, because they have become less fundamental-knowledge oriented, conferences that had previously played a very important role, have become less relevant. While they still exchange knowledge, the focus has shifted and peer groups are not so much interest groups based on sharing technical knowledge but more focussed and oriented towards the exchange of information that is market oriented and imbued with restrictions dictated by the confidentiality imposed by their clients. In the process informal networks of people struggle to exist mainly because budgets that are geared towards selling man-hours penalise time *wasted on chat groups*.

The researcher, however, detected glimmerings of yet another change in the organisational structure and research environment of the research institutes. This was the reference made by a number of respondents that there was a growing appreciation in their institutions of the possibilities and value that a *knowledge management* approach and knowledge sharing could have in the work environment. The largest research institution was in fact actively investigating the feasibility of introducing knowledge management principles and practices. There was thus once again a drive to acknowledge and appreciate the importance of collegiate interaction, knowledge networking and tapping into tacit knowledge and realising the benefits this has for knowledge generation. The implication was that the focus would once again shift to an environment of collegiate interaction and learning. A few respondents even mentioned that once again greater emphasis was being placed on the importance of transferring knowledge outputs into the public domain. Such a new drive towards a knowledge intensive and sharing culture could however create tension with the still prevailing profit oriented culture and the attendant emphasis on confidentiality.

With reference to the impact of information technology and the electronic information

environment it was noted that electronic communication modes were important, heavily used and have significantly impacted on the information communication process in the research institute environment. Electronic media have changed the mode of communication, it is now feasible to communicate in dispersed mode, it has speeded up the process and far wider communication networks are more easily maintained. For example, electronic current awareness services such as e-newsletters were mentioned as being an important and convenient new innovation that provides very up-to-date alerting possibilities. E-mail, however is the mode that has had the most significant impact on their information communication process. According to these respondents it is easy to use, convenient and has revolutionised networking and collaboration. It has facilitated the sharing of information, the writing of joint proposals, the requesting of information and it has made managerial information communication very effective by reducing the number of typed letters and internal circulars that are disseminated.

Not all electronic modes and media were however equally heavily used. It was found, for example, that electronic mailing lists were generally not used amongst these respondents, but then those who did engage with them stated that they have assisted them to establish far more robust communication networks than in the past and have helped to increase the frequency of interaction with colleagues. The main reason given for not using electronic conferences was that they did not afford the all important platform to interact face-to-face with other people. It was further stated that there were too few journals in the electronic format that they could access in their field to make a substantive difference to their use of this journal mode.

A number of disadvantages to this mode were also noted and a recurrent theme was that because it is an easy medium to use, it generates endless amounts of irrelevant information and junk mail. Another problem of e-mail that was highlighted is that it often generalises the communication interaction and does away with the finer nuances of one-to-one relationships between people with different communication styles. The general view was that e-mail is adequate for communicating unambiguous and clear information, but that it cannot supplant personal interaction, or even the telephone, which provides the possibility for immediate response, dialogue and the clarification of ambiguities, and as one respondent stated

after the first e-mail contact there should be personal follow-up and interaction to ensure effective communication.

A further issue that surfaced was the tension between the ease of use and effectiveness of

electronic communication modes and its dehumanising aspects. It was felt that personal one-to-one communication and the human factor gets lost when electronic modes are used to communicate information. Another theme that was often referred to, was the importance of fostering collegiate communication and informal unstructured interaction as this engenders a culture of lateral and innovative thinking. The scientists at the research institutes were concerned that these important aspects were not currently being sufficiently addressed and the following quote is fairly representative of these views:

In the previous environment - i.e., where less emphasis was placed on information technology and of course where there was a more open, less profit motivated ambience - we scientists talked and communicated with each other – sometimes by means of formal seminars and sometimes during informal group discussions. Typically, the tea room was used to discuss problems and this interaction resulted in idea generation, synergism and problem solving.

Only three respondents in the first study and one in the second study deviated from the information communication pattern outlined above. These respondents were working on their own on specialised research projects and were not involved in the normal reporting and communication structures. This was an exceptional situation and did not normally prevail in the institutes. In all the instances, the researchers were utilised in this way because they had specialised knowledge and the field of enquiry was at an exploratory stage and would, if found to be a feasible project, be expanded into a group research project. They all still maintained informal information exchange links with their colleagues in their divisions, attended all divisional meetings and seminars and interacted vigorously with their divisional directors. They also maintained extensive contacts with outside people. They, further, communicated by means of their reports that were circulated internally and to outside clients.

4.2.3. COMMUNICATION WITHIN THE UNIVERSITIES

The crystallographers that were attached to the twelve academic institutions at the time of the interviews constituted the largest group of respondents (61% in 1990/1 and 64% in 2001/2). The majority of the academic crystallographers were situated in Gauteng where they were almost equally distributed between Pretoria (North Gauteng) and Johannesburg (South Gauteng). The other academic respondents were attached to academic institutions in the Western Cape, the Free State, and Natal in almost equal proportions. The academic staff complements of these universities ranged from the smallest with 311 full time equivalent (f.t.e.) academic staff to the largest with 1270 f.t.e. staff (at the time of the 2nd study in 2001/2).

All of the academic crystallographers were basic scientists and within this category two distinct groups were identified, (a) those academics that engaged in crystallography as a primary discipline (they will be designated as *pure crystallographers*) and (b) those academics that utilised crystallography as an analytical method in their main fields of research (these crystallographers generally referred to themselves as 'tool' crystallographers). The distribution between the 'pure' and 'tool' crystallographers was almost equal and their subject fields ranged from Chemistry (by far the largest proportion), to the smaller groupings in Physics, Geology, Materials Science and Biochemistry (Physics and Biochemistry were grouped together with Applied Chemistry under the *Other* category).

In the second study the age distribution was fairly equitably distributed among the three age categories, while in the first study almost half the academic respondents were in the 36 to 50 age category. The majority of the academic respondents held a doctorate degree, generally obtained in South Africa. Half of these respondents were in more senior positions and the remainder were equally divided between those at senior lecturer and junior lecturer level.

It was observed that the formal research team structure that constituted the norm in industry and only slightly less so in the research institutes was far less strictly adhered to within the academic environment. However, a natural evolution towards group forming and collaborative research occurred amongst a large proportion of the academic respondents. Three distinct working styles were thus discerned:

1. Those academics that worked together in well-organised, cohesive research units, or groups and maintained fairly strong, interactive and structured communication links amongst themselves and for the purposes of this study have been designated: *the structured groups*;
2. Researchers that worked together, but within a totally unstructured framework and designated: *the unstructured groups*; and
3. The academics that worked entirely on their own and designated: *the loners*.

From these working styles three clear communication patterns developed that were based on the degree of group forming and collaborative research undertaken by the academic respondents. The communication of information that pertained to the academics will thus be discussed according to whether they predominantly conducted research in a structured or unstructured group, or operated on their own.

The structured groups

The largest proportion of the respondents that belonged to structured research units were *pure crystallographers* and worked in the field of chemistry. For example, the four single crystal diffractometer facilities at South African universities were all operated by units in the chemistry departments that were involved in pure crystallographic research. Membership of the groups was however not restricted only to members of the crystallographic fraternity and even in the groups that concentrated on pure crystallographic research, academics and postgraduate students from outside the field of crystallography were incorporated. The group sizes ranged from ten to thirty members, with a median of 16.

The groups all consisted of a leader who was often also the head of the department; one to four fairly senior academics at professorial, or senior lecturer level (who generally spent half of their research time on their own special interests and the other half on the group's work); a number of researchers (often engaged on a contract basis) and other junior lecturing staff who concentrated their research efforts on the groups' activities; post-graduate students working in the same field and under supervision of senior members of the group (they often constituted half the numbers in the group); and finally technicians and other support staff.

It was very clear that the members of these groups all shared common research goals, that a strong bond existed amongst them and that they were very directed and focussed. Although the members of the team collaborated with each other and other scientists all over the world, each person in the team was encouraged to make their own unique contribution. A distinctive feature of these research teams was the strong communication links that were maintained and which ranged from daily, informal, contact during which everyday problems and new innovations were discussed, through to ad hoc, but more formal, brainstorming sessions to resolve urgent issues, to formal meetings that were held on a regular basis (weekly to monthly). At these meetings the group's research progress was reviewed, problems were discussed and post-graduate students reported on progress made. Although all members participated, the group leader was generally the driving force and these meetings often served as a forum for the leader and other members who interacted most frequently with the external environment and information media to report on conferences attended, research contacts made abroad, discussions held with outside colleagues, the latest literature in the field (both printed and electronic), etc. Information was thus freely exchanged within the group and each member

contributed by alerting others in the group of new developments in the field that might be of interest to them.

The success of the group dynamic largely depended on strong leadership. This was found to be an important factor with all the groups in all three work environments that were encountered in the study. Strong leadership resulted in the development of a good team spirit and active inter- and intra-group communication of information. It was thus also found that in all instances the group leader, or one or more of the more senior members of the group, played a very important and active role in maintaining the strongest links with the external environment. They exchanged information with colleagues outside the group, they filtered and disseminated the most relevant information into and out of the group; i.e. a typical *gatekeeper* role was adopted.

The more junior members were far more dependent on the leader of the group, or some other senior member, to disseminate information obtained from their contacts with the exterior environment than the more senior members, who had generally built up their own network of contacts and were thus less dependent on the leader to mediate in this way. The more junior members, in turn, maintained a far stronger link with the institutional library and the published/recorded literature (both printed and electronic) than their more senior counterparts. They often provided the physical link with the library and kept the group informed of the latest literature in the field. All members, however, generally endeavoured to keep up-to-date by regularly scanning the latest journals in the field. The cross fertilisation of ideas and new knowledge was further actively encouraged by regularly inviting other scientists from within the country and abroad to address these groups. Such groups thus maintained strong links with both the formal and informal information communication channels in their field. (This aspect will be discussed in greater detail in 4.3)

A feature of these groups was that they frequently provided a service to other researchers, often external to their university and in diverse research areas that ranged from crystallography to totally disparate research areas where crystallographic data or assistance with the structural analysis of substances were required (this was particularly applicable to the four units that operated single crystal diffractometers). Such activities resulted in expanding their communication networks far beyond the field of crystallography. The operator of the

diffractometer within such a group and the group leader were the persons most frequently contacted in these instances.

Even within these fairly close-knit groups it was observed that collaborative research and group forming in the academic environment was less structured than in industry and in the research institutes where research was far more mission oriented. The university environment cultivated and encouraged individuality and unrestricted interaction. Group forming was thus a voluntary process which depended largely on the motivation of strong individuals within the departments and a sufficient critical mass of people conducting research in the same broad field.

The unstructured groups

In this category the academic respondents were usually members of the same department that collaborated, but who did not form as close-knit a research unit as the previous category. Although, as in the previous category, most of the crystallographers were chemists there was a far more equitable distribution among the disciplines represented in the study, particularly as far as geology and physics was concerned. Another distinguishing feature was that the majority in this category were not *pure* crystallographers but rather utilised crystallographic techniques as an analytical tool. The unstructured group sizes typically varied between three to fifteen academics that collaborated with each other and regularly communicated. The nature of the interaction, however, was far less structured and formalised.

When they interacted and met they generally addressed very similar issues as the structured groups and discussed problems encountered, new ideas and information found, new material found in the library, conferences attended, new contacts made, or any matter of general interest. They also actively communicated with their post-graduate students and other researchers and colleagues on and off the campus who were working in cognate fields, or requiring information from them. Although, as in the previous category, it was found that the more senior members communicated more actively with the external environment than the more junior members, and the latter tended to rely more heavily on the literature and the library for their information than their more senior counterparts, this differentiation was not as marked. There was a general tendency for all members in this sub-category to engage more heavily with formal channels of communication (e.g. published/recorded literature and the

library) than those that operated in a more formal group structure and individual members were less dependent on the group leader to interact with the external environment and to drive the process. Individuals were thus far more independent and actively involved in the communication process and there was far less cohesion and evidence of a group dynamic.

The loners:

The last category consisted of the academics who worked independently and in virtual isolation. These lone workers primarily used crystallography as an analytical tool and their specific subject fields were fairly equally distributed amongst chemistry, physics, geology and biochemistry. These *loners*, although working outside a group structure, did maintain informal, unstructured communication links with colleagues in their departments, in other cognate fields and outside the university environment. They usually communicated extensively with the main crystallographic group at their university, basically to draw on their technical crystallographic expertise, or to use the diffractometer (if available). The interaction was mostly with the leader of such a group and the operator of the diffractometer. They also undertook collaborative research, but to a lesser extent than their counterparts in the other two categories. They all regarded the library as an important link in the communication chain in their work environment.

The driving and motivating force for all the academic researchers was to make their research known to as wide a scientific community as possible and a major end-product of their research was thus some or other publication. In this way they received peer acknowledgement for their research endeavours and they could also contribute to the body of knowledge in their field.

The changes that were observed between the two studies in the information communication patterns for this work environment pertained mostly to the impact of certain structural changes in their organisations and the escalating electronic information environment. The structural changes related to the fact that government funding of universities had increasingly been reduced over the period and funding for research was not as freely available as it had been eleven years ago. Competition for NRF⁸ (National Research Foundation) funding was thus intense within and between universities. This had led to the universities moving into the realm of profit-based contract research which they undertook for government and/or industry. This competition for

⁸ The NRF had been established in the intervening years as the main national research funding parastatal organization that channels research funding allocated to it by government and other organizations to the universities and research institutes.

funding and the need to secure contract work has increased the level of tension in the universities and two opposing views surfaced with regard to the effect this has had on the academic environment. The majority of the academic respondents were of the opinion that it countered open learning, the free and vigorous flow of information and that it had a detrimental effect on collegiate interaction. This view is succinctly summarised by two of the respondents as follows:

there is now a greater level of aggression and the old collegiate interaction is not as prevalent as before and

this competition, because of decreased funding, is not healthy and this has caused considerable friction in the Department

The opposing view that was held by a much smaller proportion of the respondents was that competition is good and that it stimulates research, increases output and has further enforced a shift away from a very theoretical research basis to a more applied approach which has considerable beneficial outcomes for the country.

As far as electronic modes of communication were concerned, the general consensus was that the impact of has been extensive and to quote one respondent this

has particularly helped international communication by speeding it up and has increased the possibilities of exchanging data very easily and speedily all over the world. I use e-mail extensively for this purpose.

The use of electronic modes of communication has made both national and international collaboration far more feasible and helped to considerably increase the propensity of such collaboration. The problems that were encountered in South Africa because of inadequate bandwidth and the detrimental effect this has on communication were, however, also raised by the respondents.

The general opinion with regard to the attributes of electronic journals was that the mode in which the information appeared was not of particular importance and although they were "nice to have and have many advantages" it was more important to have access to quality information and not all the main crystallographic journals were available in electronic format at their institutions. The university respondents' view on publishing in the electronic format was that the medium was irrelevant other than their concern that there might be problems with archiving. Their main concern was that the journal they selected for publication purposes should have a prestigious standing in the scholarly scientific community. A further very positive impact of the electronic environment was that university libraries had extensively embraced the enhanced service

opportunities provided by electronic media and were amongst others offering electronic alerting and searching services which were highly valued by the respondents.

Almost all the respondents, however, held negative views with regard to electronic conferences as they did not provide the opportunities for personal interaction and because of their "lack of social dimension". In their view the most important aspect of conferences was not the presentations, but the value of interpersonal exchange of information and the possibilities provided to initiate and maintain contacts. The university respondents were further also not very enthusiastic about the value and quality of the information they found on the Internet.

It is clear that although the impact of the growing electronic environment has been considerable in the university environment it was still not as wide spread as what had been expected. This is in line with Tenopir et al.'s (2003) reference to the evolving or pre-advanced stage (1994-2002) of electronic media adoption (cf. also Hallmark, 2003, 2004 and chapter 2.6.) A further aspect to note was that once again there was the recurrent theme that personal contact is very important and that electronic modes of communication had not supplanted the need for personal interaction in the information communication process.

4.3. COMMUNICATION OF INFORMATION OUTSIDE THE IMMEDIATE WORK ENVIRONMENT IN SOUTH AFRICA AND ABROAD

Two factors had a considerable effect on the communication of information among the wider community of researchers involved with crystallography in South Africa and abroad. The first relates to the professional organisation of this community in South Africa and world-wide. The international crystallographic community is very well organised by means of the International Union of Crystallographers (IUCr) which was established soon after the end of World War II. Since 1948 they have been publishing the *World directory of crystallographers* and the *Acta crystallographica* series (Sections A – D), which is one of the most prestigious serial publications in the field. They further also publish the *Journal of applied crystallography* and the *Journal of synchrotron radiation*. Their *Newsletter* and *Minutes* of the Union's meetings are further also distributed to all member crystallographers on a regular basis. In addition to the print versions of these publications, electronic formats are distributed as *Crystallography journals online*. The IUCr was in fact one of the first scientific organisations to embrace electronic information communication modes when it launched its online programme in 1999. According to John

Helliwell, Chairman of the IUCr Commission on Journals, the “WWW has provided rapid and efficient communication between the IUCr staff and its Editors, streamlined peer-review procedures and permitted the development of additional author and reader services culminating in *Crystallography Journals Online*” (2000:5). This online publication provides full text versions of all the IUCr journals in both HTML and PDF formats, and all supporting data are made available through the IUCr electronic archive. Other services such as e-mail alerting, tables of contents and details of forthcoming events are also made available online. Links are further provided from *Crystallography journals online* to relevant bibliographic and structural databases (such as Medline) and other primary publications that are available on the Worldwide Web. One of the leading crystallographers in South Africa in fact administers and maintains one of the three international IUCr Web mirror servers.

In addition to their formal publication efforts they also ensure further interaction by means of specialist conferences and their general tri-annual congress to which each country sends a delegation to attend the Assembly. The Union has further established a network of *Commissions* that cover a number of areas and which provide a body of experts who can be consulted on issues that range from new apparatus, to publishing and research, to various specialised fields. The respondents were generally of the opinion that the IUCr provides the ideal forum that facilitates co-operation, interaction and exchange of information among the members of the international crystallographic community.

A major impact on communication among the crystallographic fraternity in South Africa was the establishment of the South African Crystallographic Association in 1984. It was specifically founded to facilitate the communication of information related to crystallographic research in South Africa and this Association maintains close links with the International Union of Crystallographers and the central body of scientific unions in South Africa. The latter has, as one of its functions, acted as a clearinghouse for scientific information in South Africa and it also maintains close ties with international bodies of a similar nature. Communication within the Association is fairly active, and is mainly driven by the regular symposia that are held in the field in South Africa. These symposia further stimulate the informal communication among the members.

The second major factor that affected communication was related to the researchers' access to and interaction with sophisticated crystal analysis equipment and crystal structure databases. Without

such access crystallographic research would be severely curtailed. Access is specifically required to analytical equipment such as single crystal diffractometers, and if possible powder and neutron diffractometry facilities. In South Africa only five institutions have the capacity to acquire and run single crystal diffractometers and all researchers in the field are thus heavily dependent on the analysis services that these five institutions offer to the crystallographic research community in general. South African researchers further rely on the Cambridge Crystallographic Unit (CCU) at Cambridge University in Great Britain; the Joint Commission for Powder Diffraction (JCPD) in the United States of America; the facility at Grenoble in France where a number of countries cooperate to run a large neutron diffractometer facility; and the facilities at the Brookhaven and Rutherford Laboratories for powder diffractometry and other more sophisticated crystal analysis.

Institutions in South Africa could never afford such large and sophisticated facilities and local crystallographers therefore rely heavily on data obtained from such units, and the possibility to use the sophisticated equipment maintained at the research laboratories when the need arises. A few institutions in South Africa have subscriptions to the electronic crystal structure databases produced by the CCU and the JCPD and they in turn provide access to this data to the local crystallographic community in general. All of the respondents, however, specifically mentioned that international and local cooperation was excellent and this resulted in the open and often free exchange of information, data and computer programmes in the field (this even applied to the years when South Africa was politically ostracised by the international community).

From the above it is clear that members of the local and international crystallographic fraternity are closely linked to each other either by their need to access sophisticated equipment or their willingness and ability to provide a service to outside researchers. The result is that there is constant communication (both person-person as well as by indirect means) between crystallographers within the country and the international community.

Access to such facilities formed the basis for much of the networking in the field in South Africa. Originally the CSIR was the only institution in South Africa that had a diffractometer and they provided a structure analysis service to all researchers in South Africa. As everyone was dependent on that facility close links were maintained between the crystallographic community and the crystallographers at the CSIR. However, since 1983 four other institutions acquired diffractometers which has resulted in a more dispersed information communication network. The crystallographers who have their own diffractometer communicate regularly with each other

concerning technical and operational problems regarding equipment. In addition, crystallographers who do not have their own diffractometers interact regularly with the institutes that do have the facility.

In the following sections a more detailed outline will be given of the local and international information communication structures that prevailed among the researchers in the three work environments.

4.3.1. COMMUNICATING WITH THE EXTERNAL ENVIRONMENT: INDUSTRY

The main impediment to the free exchange of information and inter-personal communication outside the immediate work environment in industry was the competitive environment and the confidentiality and secrecy of their research. The researchers in industry, however, were very conscious of being isolated from new innovations and research and were thus aware of the necessity to constantly import new information and technological developments. They, therefore, made a point of maintaining very active communication links with researchers in cognate and relevant fields at the research institutes and the various universities in South Africa and abroad. They, for example, regularly invited academics and other researchers to visit their R&D facilities, or visited them at their institutes.

They maintained particularly strong links with the universities where their more senior researchers obtained their postgraduate degrees, or where they had done post-doctoral research. In one instance, where most of the senior research staff was of British origin, it was found that the communication links were mostly with British universities. Senior researchers in industry often served on various committees at the universities they maintained alliances with and in this way a clearly defined network of contacts both within South Africa and overseas has been built up over many years.

A feature of this interaction was that while the researchers in industry generally initiated interaction with outside researchers, particularly in the academic community, the converse did not always apply. However, there was general consensus among industry respondents that there was a growing tendency towards greater interaction between academics and applied researchers. It was suggested that each draws from the others strengths and expertise. Industry provided the actual problems and funding for research, while the universities and research institutes contributed the

required research expertise and advanced theoretical knowledge and frequently conducted sponsored research for them. The second study in fact indicated that most of the R&D divisions were downsizing their research activities and were contracting out a considerable portion of their research to universities and the research institutes. Interactive communication links were, therefore, maintained with the project leaders at the universities and research institutes with whom they had contracts, or where they sponsored research projects. A fairly complex relationship has thus evolved between industry on the one hand and the universities and research institutes on the other.

It was interesting to note that notwithstanding the constraints of corporate security restrictions, the researchers in industry often maintained information communication links with the R&D departments in cognate industries (often their main business rivals). It was thus not surprising to observe that vigorous communication and information exchange took place among parent, subsidiary and affiliated companies, both within South Africa and abroad. In the one instance a formal agreement existed between the international group of affiliated companies to exchange information systematically. Another group of international companies maintained a central research centre in the United Kingdom that served all the affiliated companies that contributed to the funding of the centre. This research centre conducted fundamental long-term research and new technology development was transferred to all the contributing companies who then adopted, adapted and applied the results to local needs. This research centre often contracted academics to conduct research for them and further encouraged all affiliated companies to second their own researchers to work at the centre for extended periods. Individual companies could also bid to do contract research for the centre and in turn they could contract these projects out to local universities. Two such contracts were in operation at the time of the interviews at a South African university. The respondents were of the opinion that such world-wide co-operation and participation resulted in cost effective research, cross fertilisation of ideas and effective exchange of information. It was, however, emphasised that they firmly believed in the maintenance of their own local R&D facilities as South African operational conditions are often unique.

The respondents at companies with no international affiliations were particularly aware of the necessity to interact with international experts and to import new knowledge, innovation, information and technology. This aspect was emphasised by one of the respondents when he stated that

while academics tend to collaborate on research which leads to mutual interaction, researchers in industry have to consider confidentiality factors and this means that we work in isolation within our companies - we then have to seek contacts in other ways as cross fertilisation of ideas is very important, particularly with experts from overseas as we share very few research interests with persons in South Africa.

They were generally actively supported by their top management in their efforts to maintain regular links with colleagues and experts overseas, many of whom were scientists listed in the *World directory of crystallographers*. All of the industry respondents went abroad very frequently, the more senior of them going a few times a year. The main purpose of these visits, other than for business reasons, was to specifically obtain new ideas and information by interacting with international experts they had contact with, visiting research institutes (such as the Cambridge Crystallographic Unit) and international R&D facilities, contacting equipment suppliers, and attending relevant international conferences.

It was, however, noted that although conferences in general were valued they did not play the same role in the information communication process in industry as they did in the other two environments. The confidentiality of their research generally prevented the industry researchers from making presentations and they, in turn, derived very little direct benefit from the formal presentations as they were deemed to be far too theoretical and of very little relevance to their applied needs. The few conferences that were of a more applied and practical nature were appreciated and all conferences were valued for the opportunity they provided to make contacts and to strengthen interpersonal networks.

Another important platform of interaction was provided by the links between the R&D divisions and their outside suppliers and manufacturers of materials and equipment. These informal networks that operated with their suppliers, often from abroad, were very important as many of the suppliers could impart unique and very practical knowledge and up-to-date, useful information.

It clearly emerged that external contacts were initially made by means of indirect methods such as via third party referrals, or because of knowledge gained during doctoral/post-doctoral research, or attending specialist conferences, or the literature and then followed up by means of some or other mode of correspondence and finally personal contact. The preferred method of communication was by means of personal visits, but in the interim periods extensive use was

made of telephone contact, e-mail, and faxes. The more senior respondents had more extensive external connections than the more junior respondents and they went abroad far more frequently to initiate and maintain communication links. The more junior members were kept informed of external developments by their senior counterparts who always held debriefing meetings on return from these visits.

It became clear that a few key persons, often only one to two, in the R&D divisions played a particularly important gatekeeper role in the communication process (cf. also reference to this in 4.2.1.). They provided the motivation and stimulation that encouraged the exchange and importation of new information, they maintained direct contact with the other researchers in their divisions, they kept themselves informed of the information needs of their colleagues, and they maintained the closest and most active links with the outside world. They actively sought information which was then disseminated to all concerned.

4.3.2. COMMUNICATING WITH THE EXTERNAL ENVIRONMENT: THE RESEARCH INSTITUTES

All the respondents at research institutes were very aware of the importance of maintaining contact with international research in their field and it was obvious that they were encouraged by top management to interact vigorously with scientists abroad. There was further also a feeling that there was not a sufficiently large critical mass of local experts in most of the scientific fields in South Africa and that this militated against meaningful interpersonal exchange of information. Most of the respondents in the research institutes therefore went abroad as frequently as possible and maintained contact with scientists overseas. Such contacts usually stemmed either from doctoral studies abroad, contacts made by presenting papers at and attending international conferences, membership of committees of international associations, post-doctoral or sabbatical research abroad, and correspondence with persons identified through the literature.

On their visits abroad they attended as many international conferences in their field as possible, visited research facilities and leading academic departments, used advanced facilities such as the Grenoble neutron diffractometer, and visited suppliers of equipment and materials. Such visits were then followed up by correspondence by e-mail, or in the past by letter and fax. They also used these opportunities to find people to invite to South Africa. The one research institute was particularly proactive in inviting overseas scientists to their institute for fairly extensive visits to

share ideas, to broaden local perspectives, to assist in the cross fertilisation of ideas and also to solve specific problems. They generally also invited the wider South African research community to share in this experience. They felt strongly that this provided an effective and affordable way of exposing as many researchers as possible to international expertise and to help to overcome the geographical isolation that all researchers in South Africa were subjected to.

The research institutes generally maintained close contact with similar research institutes abroad and often instituted various reciprocal agreements. The one research institute also maintained very close ties with an international organisation that co-ordinated research in their field. This made them an active partner in this international research environment and its global information network. Another research institute received considerable sponsorship from abroad and they were involved in extensive contract research for international concerns which they in turn had partially subcontracted out to a number of universities and private research laboratories. There was thus intensive interaction with both their overseas principals, sponsors and the academics who were doing the contract work for them.

As the research institute respondents undertook a significant amount of contract work, very close communication links were consequently forged with the various companies and government agencies who sponsored them and for whom they did the research. There was thus regular and active exchange of information which included formal meetings involving the clients and the project teams and informal meetings where mutual problems encountered were discussed. As this research was often confidential, communication on these matters was thus restricted to their own group within the institute and the sponsor/client for whom the research was being conducted.

A further area of regular communication was with academic institutions. As was observed with the respondents in industry, it was found that particularly strong links were maintained with their current or previous supervisors. They contracted work out to them and consulted them on a regular basis to assist in problem solving. A researcher who actively communicated with colleagues at universities stated that he had more interaction with departments engaged in applied research (e.g. engineering, materials science and metallurgy) and with departments that could provide information on analytical and related crystallographic techniques than with academics engaged in basic research as "my work is very applied and often remote from that done at universities". In contrast, two other active communicators again stated that they valued contact

with basic scientists as they provided them with insights into the latest theoretical research in the field as "in this way I can focus on what is coming out of the mill".

As in the industry environment, it was found that suppliers and manufacturers of equipment provided valuable information to the research institute respondents. Scientific meetings and conferences in South Africa and abroad provided another forum at which information was regularly exchanged, both formally and on an inter-personal basis. In many instances, however, the confidential nature of their research prevented them from presenting their research at these conferences. This aspect generally impacted on the free exchange of such information outside their immediate research circle.

It was further observed that the work structure had an effect on the level of personal communication with the external environment. Researchers who worked in structured project teams depended to a large extent on their team or group leaders to handle external communication links. The group leaders thus generally facilitated the flow of information to and from the research institutes. This *gatekeeper* role, however, was less marked than in the case of industry and individual researchers interacted far more actively with the outside world on a personal level.

4.3.3. COMMUNICATING WITH THE EXTERNAL ENVIRONMENT: THE UNIVERSITIES

The factors that played an important role in the academic respondents' external communication of information related mostly to whether they participated in collaborative research, how structured such cooperation was, whether they conducted *pure crystallographic* research or used crystallography as a *tool*, and their level of seniority. It was generally found that the leaders of structured groups conducting pure crystallographic research were the most active communicators and they maintained close communication links with all the leading *pure* crystallographers at the other universities throughout the country. They also maintained contacts with academics in other cognate areas, and with researchers at research institutes. Such communication related to the exchange of information with the researchers with whom they were collaborating on a research project, as well as with other scientists who required their expertise in solving problems, or information they, in turn, required from other experts to solve problems they had encountered. They also communicated with researchers in industry and in this instance the link was often unilateral and usually initiated by the R&D researchers. In many instances they conducted

contract work for various companies and research institutes and once such a link was established they maintained close relationships with their principals.

The leaders of structured groups who used crystallography as a tool followed very similar patterns to their peers in *pure* crystallography, except that they communicated more with scientists in their primary research area than with crystallographers. The leaders of unstructured groups, while following very similar patterns, generally communicated less frequently than their counterparts in structured groups. The senior academics who worked on their own, i.e. the *loners*, also followed a similar pattern, except that they were even less active than their peers who worked in unstructured and structured groups.

It was found that the more junior the academic respondent was, the less active he or she was in communicating with other scientists. It was further evident that the more structured the work environment, the more the junior members relied on the more senior members and particularly the group leaders to interact with the outside world on their behalf. The more senior members of structured groups, particularly the group leaders, thus played the most active and important role in the communication process and in the crystallographic community in general. The converse applied in that the less structured and greater the level of solitariness in which they worked, the more the less senior academic respondents relied on their own devices to interact with the external environment and acquire the information they required. This interaction, however, still remained at a much lower level than that of the *group leaders*.

A special category of communication took place between the crystallographers from the five institutions that had their own diffractometers. They communicated actively with each other on technical and operational matters and in this instance the group leaders and operators of the diffractometers maintained particularly close ties with the crystallographer who used to operate the first diffractometer in South Africa. A further form of communication was with the researchers who did not have their own diffractometers and who approached them for assistance and a crystal structure analysis service.

It was very clear that a close relationship existed between the academic respondents and their former students. Such students either moved into industry and then they approached their alma mater to do contract research for them, or they conducted research at other universities or

research institutes from where they maintained close communication links with their former supervisors to obtain or provide information, to solve problems, and/or to collaborate on projects.

University respondents rated conference attendance as a very important factor in the communication process. It was evident that most of the academic respondents tried to attend as many relevant conferences that were held in South Africa and abroad as possible. In their view such conferences provide a valuable forum to discover and discuss new developments, research fronts and innovations, to publicise their own research findings, and probably the most important of all, they provide the environment to meet new people in the field and to foster old contacts.

Although the university crystallographers also expressed a need to interact with the international research community, they did not manifest the same level of international activity on a one-to-one basis as their counterparts in industry and the research institutes. Their main form of interpersonal interaction at this level was by means of collaborative research. There was further far greater emphasis on the role of formal channels of communication in the international arena and in making their work known amongst their peers abroad. There was thus a greater urgency to communicate internationally by publishing their work in international publications, to present their work at international conferences and to read the latest literature in the field, than to personally obtain the latest information from some or other expert abroad. It was also clear that funds to travel abroad were not as forthcoming as amongst the respondents from the other two work communities.

However, they did try and go abroad as frequently as they could. The more prominent and senior university researchers maintained the most active links with scientists abroad and they generally tried to go overseas every year to two years to attend conferences and visit their foreign contacts. The *pure crystallographers* maintained far more contacts more frequently with other *pure crystallographers* abroad than the university crystallographers who used crystallography as a tool. These links were very positively stimulated by the activities of the International Union of Crystallographers and interaction with the Cambridge Crystallographic Unit and other such international research facilities.

As mentioned, although interpersonal contact was primarily maintained with scientists abroad with whom they wished to collaborate, the university respondents also did interact with scientists from other countries with whom they wished to exchange ideas and information. All forms of

interaction was generally initially established at either the time of doctoral degree studies abroad, and/or post-doctoral and sabbatical research overseas, and/or contacts made at international conferences, and/or persons they identified through the literature with whom they made contact, and/or international scientists who contacted them because of their publications, and/or visitors to South Africa, and/or contacts made through colleagues in South Africa.

4.3.4 EXTERNAL COMMUNICATION: DEVIATION BETWEEN THE TWO STUDIES

The major differences that were observed between the external communication patterns of the two studies related to changes imposed by decreased funding, the effect of electronic modes of communication, a greater drive towards collaborative research, and the changed political dispensation in South Africa.

Budgetary constraints affected all three environments, but was the most marked in the university and research institute environments where the respondents reported that because of ever decreasing budgets over the intervening years, they were forced to more actively solicit contract work to generate funds. This then inevitably resulted in a greater shift from basic to applied research and confidentiality restrictions. This in turn affected the open exchange of information. The latter impinged mostly on the transfer of information into the public domain. The one major positive aspect of this change was that the university and research institute respondents now maintained much closer links with outside organisations both in the public and private sector and engaged in research that had very practical outcomes and a greater utility factor. This profit-driven business model was in greater evidence in the research institutes than in the universities. Although the industry respondents were far less affected by budgetary cuts, it was still very clear that in the intervening period the R&D facilities had been downsized considerably and that they were expected to contract out more of their research to the research institutes and to the universities.

Electronic modes of communication played a very important role in external communication of information and particularly assisted interpersonal communication. The vast distances in South Africa and the country's remoteness from the epicentres of international scientific research rendered electronic media even more appropriate and useful. Although face-to-face communication was still preferred, the use of electronic modes was often more feasible and could easily be used to interact with colleagues all over the world in near real-time and at reasonable

cost. It also meant that persons engaged in collaborative research could not only readily interact, but also exchange files and data very easily. Electronic modes not only effected interpersonal communication, but also in many instances widened the scope, the ease and the speed with which researchers could interact with the recorded literature in the field. Electronic modes of communication made a particularly great impact on external communication in the universities and research institutes, while the industry environment was more cautious to embrace the new mode as they were concerned about the possibility of security breaches.

The worldwide drive towards increased collaborative research has also had an impact in South Africa, and particularly in the university environment. Not only did the respondents report on this tendency, but a perusal of their publication output saw a marked increase in the number of joint publications. This meant that there was a greater need to interact with colleagues outside their immediate work environment and this was further assisted by the greater ease with which they could communicate electronically.

The change to a democratically elected government in 1994 further assisted interaction with the international scientific research community. The embargoes that had been placed on South Africa and South Africans in the past were now lifted and travel, collaboration and interaction with the international research arena were far more feasible.

4.4. INTERPERSONAL INFORMATION COMMUNICATION CONTACTS

In this section the dynamics of interpersonal and informal communication of information outside the immediate work environment will be examined in greater depth. In many studies the important role of informal information exchange has often been neglected. This is despite the early indications and empirical proof obtained by well known researchers⁹ that often the most frequently used and important channel of communication is direct informal oral communication.

To try and obtain a clearer picture of the dynamics of direct personal communication among the members of the South African crystallographic community, the respondents were specifically questioned on the personal contacts that they maintained with respect to their research and/or work situation and they were requested to provide the names of all the persons (and their

⁹ cf. the early work of Price, Gerstberger & Allen, Crane, Crawford and others; and more recently Fry, Hertzum & Pejtersen, Murphy, Poland, Salasin & Cedar, Von Seggern, Zipperer, etc.

affiliation) with whom they exchanged information on a regular basis within and without South Africa (cf. Appendix B & C, Section B., Question 2.). From this data a matrix was created for each data set (1990/1 & 2001/2) to analyse the interpersonal communication networks that the respondents maintained. The contacts to crystallographers listed in the *World directory of crystallographers* were identified and a distinction was drawn between South African and foreign contacts. The total number of contacts as well as the average number of contacts was calculated for each interaction in South Africa (in general and to listed crystallographers), and with contacts abroad (in general and with listed crystallographers). It was further possible to establish which of the respondents were regularly approached by the other respondents and the number of contacts received could be calculated. This data is represented in Table 4.4. below⁹.

TABLE 4.1. INTERPERSONAL CONTACTS							
	Valid N	Sum	% of Total	Mean	Min	Max	Std. Dev.
1990/1 Data							
CONTACTS MADE							
Contacts made in SA	80	312	58	3.9	0	15	3.06
Contacts with SA Crystallographers	80	200	37	2.5	0	8	2.27
Contacts made abroad	80	223	42	2.8	0	12	2.8
Contacts: Crystallographers abroad	80	104	19	1.3	0	10	2.43
Total contacts made	80	535	100	6.7	0	27	5.08
Total contacts with Crystallographers	80	304	57	3.8	0	18	3.61
CONTACTS RECEIVED	80	205	28	2.6	0	25	4.45
2001/2 Data							
CONTACTS MADE							
Contacts made in SA	78	309	52	4.0	0	20	3.12
Contacts with SA Crystallographers	78	202	34	2.6	0	10	2.48
Contacts made abroad	78	264	48	3.6	0	18	4.09
Contacts: Crystallographers abroad	78	158	26	2.0	0	10	3.46
Total contacts made	78	593	100	7.6	0	32	6.33
Total contacts with Crystallographers	78	358	60	4.6	0	22	5.13
CONTACTS RECEIVED	78	239	29	3.1	0	29	4.87

(Descriptive statistics: Contacts maintained 1990/1 & 2001/02)

The average total number of interpersonal communication links that were actively maintained by individual respondents was 6.7 in 1990/1 and 7.6 in 2001/2 and this ranged between a minimum of 0 to a maximum of 27 (1990/1) and 32 (2001/2). Of these, 57% (1990/1) and 60% (2001/2) were to scientists listed in the *World directory of crystallographers*. Of the total contacts maintained 58% (1990/1) and 52% (2001/2) were with persons in South Africa, and of these 37% (1990/1) and 34% (2001/2) were to registered crystallographers in South Africa. Of the total contacts maintained, 42% (1990/1) and 48% (2001/2) were to persons abroad, of which 19% and 28% were to listed crystallographers. The respondents received on average 2.6 (1990/1) and 3.1

⁹ The % contacts made is that of the total of all contacts made, while the % contacts received is that of the total of contacts made and received.

(2001/2) contacts and this ranged between a minimum of 0 to a maximum of 25 and 29. The "contacts received" data represent 28% (1990/1) and 29% (2001/2) of all contacts made and received.

From this data it is clear that there was an overall increase in the level of interpersonal communication in the 2001/2 data set. To establish if these differences were significant the results for the two data sets were compared by means of the t-test¹¹ for two dependent samples. The significance threshold level¹² was set at $p \leq .05$ and it can be seen from Table 4.4.a. below that significant differences in communication levels occurred in most categories other than for contacts made in South Africa (both the total contacts in South Africa and with South African crystallographers). The significant increases in the 2001/2 study for interpersonal communication can mainly be explained by the greater international mobility of South Africans since 1994, the general move to global interaction and collaboration, and the ubiquitous use of electronic modes of communication that has made communication over long distances feasible and far more affordable.

TABLE 4.1.a. Interpersonal Contacts: T-Test for Significant Differences 1990/1 data compared with 2001/2			
	1990/1 Mean	2001/02 Mean	p
Contacts made in SA	3.9	4.0	0.320
Contacts with SA Crystallographers	2.5	2.6	0.320
Contacts made abroad	2.8	3.6	0.044
Contacts with Crystallographers abroad	1.3	2.0	0.050
Total contacts made	6.7	7.6	0.045
Total contacts with Crystallographers	3.8	4.6	0.047
Contacts Received	2.6	3.1	0.042

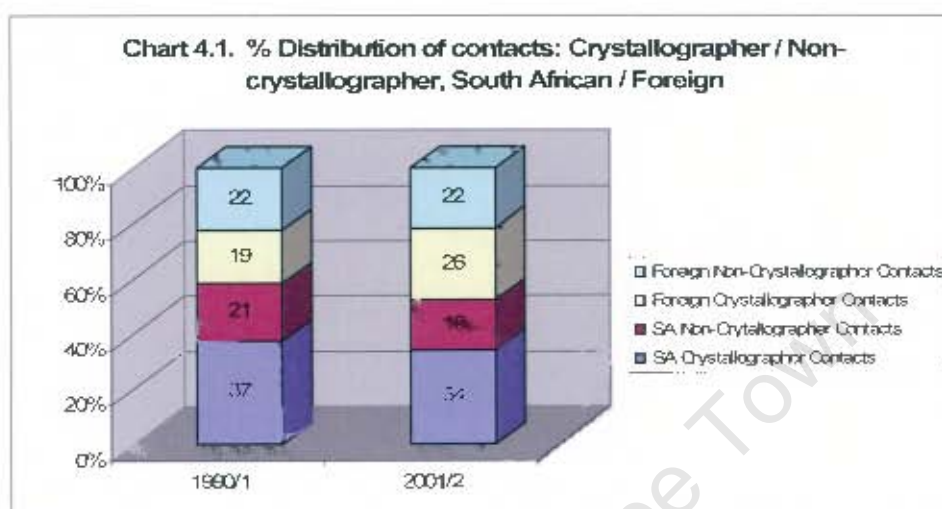
T-test for Dependent Samples, differences marked in red are significant at $p < 0.05$

In Chart 4.1 below the distribution of contacts made to South African and foreign crystallographers and non-crystallographers is depicted. The largest proportion of contacts (37% in 1990/1 and 34% in 2001/2) was for the contacts the respondents maintained with their fellow crystallographers in South Africa (i.e. interaction between the respondents). In 2001/2 this was

¹¹ A t-test calculates whether the difference in two population means is statistically significance. If the t test statistic is larger than the critical value associated with the predetermined p level then the observed difference is significant. (Frankfort-Nuechtnis & Nuechtnis, 1996:598). (cf. also 3.10.1.) The t-test for dependent samples was used for this longitudinal study (there was a 63% level of commonality between the two populations)

¹² In the social sciences, according to Rubin and Babbie (1993: 482-3), the most common cut-off point is a significance or probability level set at 0.05 (cf. also 3.10.1.)

followed by contacts maintained with persons abroad who were listed crystallographers (26%), while in 1990/1 the ratios were almost equal for the other three categories of person they contacted.



It is thus clear that strong communication ties are maintained within the crystallographic fraternity as the majority of all contacts maintained were between the respondents and South African crystallographers or other crystallographers abroad (57% in 1990/1 and 60% in 2001/2). This would strongly suggest the presence of the 'invisible college' phenomena within this community.

4.4.1. INTERPERSONAL COMMUNICATION ACCORDING TO SUB-CATEGORIES OF THE POPULATION

The data for the two studies were further analysed to produce cross tabulations between the various sub-categories of the population (the independent variables) and the different categories of interpersonal communication (the dependent variables). It was evident from this analysis that the sub-categories of the population generally also followed the total population's pattern of maintaining higher contact levels in 2001/2 than in 1990/1.

ANOVA/MANOVA¹³ statistics were then calculated for each data set to establish which cross

¹³ ANOVA/MANOVA is a statistical test of the difference of means of two or more groups and is used to measure the effects of the independent variable on the dependent variable/s. ANOVA (Analysis of variance) examines the effect of the independent variable, whereas MANOVA (multivariate analysis of variance) compares the effect of two or more independent variables (Bohmsstedt &

tabulations were significant. A threshold significance level was set at $p = .05$ and all cross tabulations that fell outside this level were disregarded. From Table 4.1.1. below it can be seen that variation in work environment, work structure, position, age and qualification all produced significant results. The covariance between the variables and the strength of the effect for each category of interaction was measured by calculating the Wilks' lambda¹⁴ and the F ratios¹⁵ for the significant cross tabulations (cf. also 3.10.1.). The results are depicted in Table 4.1.1. below (those correlations that have significant lambda scores and F ratios are marked in red).

If the three work environments are considered it is clear that the respondents in industry and at the research institutes were more active in initiating and maintaining interpersonal communication links than their counterparts at the universities. The respondents in industry generally initiated slightly more contacts than their counterparts in the research institutes. The only instance where the respondents at universities initiated more contacts than the population average and where they ranked second to the research institute respondents was their contacts with foreign crystallographers. However, it is abundantly clear that the sub-category of respondents who received the most contacts was the university respondents. The research institute respondents received on average approximately half and the industry respondents a quarter of the contacts that the university respondents had received. These results clearly substantiate the assertion made in 4.2.1 and 4.3.1. that the industry R&D divisions are very conscious of the potential isolation imposed by the confidentiality restrictions of their work environment and they thus make a concerted effort to maintain contacts and thus keep abreast of new developments in their field. It was further also observed in 4.2.2. and 4.3.2. that the research institute environment had very strong feelings about interacting with leading scientists worldwide. The university scientists are clearly less dependent on maintaining personal contacts to acquire new knowledge while it would appear that their expertise is valued as they are frequently approached by the other two environments to share their knowledge. The significant Wilks' lambda and F scores for this cross tabulation respectively ranged from 0.48003 and 8.7266 for 1990/1. and 0.37733 and 11.015 for 2001/2 and this is not an excessively strong correlation, albeit stronger in the second study. The reason for this could be that the small variation between the research institute and

Knoke, 1994:116, 123, 132). (cf. also 3.10.1.).

¹⁴ Wilks' lambda is a measure of the proportion of variance and the effect of the independent variable on a combination of dependent variables. Its value ranges between 0 and 1, with values close to 0 indicating the group means are different and values close to 1 indicating the group means are not different (equal to 1 indicates all means are the same) (Everitt & Dunn, 2001: 219-220). (cf. also 3.10.1.).

¹⁵ An F test statistic is the ratio of the between group and within group mean squares. If the F ratio is larger than the critical value associated with the predetermined p level then it can be assumed that the effect of the independent variable on the dependent variables is significant (Bohnstedt & Knoke, 1999:116, 123, 132) (cf. also 3.10.1.).

industry responses suppressed the marked difference with the university respondents.

TABLE 4.1.1. CONTACTS MADE & RECEIVED BY Sub-categories of the Population						
Averages, Wilks' lambda & F scores for p = 0.05						
CONTACT CATEGORY	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
WORK ENVIROMENT	INDUSTRY		RESEARCH		UNIVERSITY	
CONTACTS MADE						
Total	8.7	9.6	8.0	8.9	5.7	6.5
Total with crystallogs.	4.5	4.9	4.5	4.7	3.4	4.4
In S Africa	4.9	5.0	4.3	4.8	3.3	3.4
With SA crystallogs.	3.5	3.5	2.9	3.0	2.1	2.2
Foreign	3.8	4.4	3.2	3.9	2.4	3.2
With foreign crystall.	0.9	1.7	1.6	2.3	1.3	2.1
CONTACTS RECEIVED						
90/91: Wilks lambda=.48003, F(10, 146)=8.7268, p=.00421; '01/02: Wilks lambda=.37733, F(14, 138)=11.015, p=.00311						
WORK STRUCTURE	STRUCT. GRPS		UNSTRCT. GRPS		LONERS	
CONTACTS MADE						
Total	8.2	9.3	5.9	7.3	3.8	4.3
Total with crystallogs.	4.5	5.5	3.6	4.3	2.2	3.0
In S Africa	4.6	4.7	3.7	3.7	2.2	2.3
With SA crystallogs.	2.9	3.0	2.5	2.6	1.4	1.4
Foreign	3.5	4.2	2.2	3.0	1.6	2.1
With foreign crystall.	1.6	2.3	1.1	2.0	0.8	1.6
CONTACTS RECEIVED						
90/91: Wilks lambda=.03561, F(10, 146)=77.198, p=.00083; '01/02: Wilks lambda=.03400, F(14, 138)=78.115, p=.00089						
QUALIFICATION	FOREIGN PHD		SA PHD		SA M/HON	
CONTACTS MADE						
Total	7.7	8.6	7.5	8.0	3.5	4.1
Total with crystallogs.	3.8	4.4	4.6	5.2	1.8	2.3
In S Africa	4.6	4.7	4.3	4.2	2.2	2.3
With SA crystallogs.	2.3	2.3	3.1	3.3	1.3	1.4
Foreign	3.2	4.2	3.2	4.0	1.2	1.9
With foreign crystall.	1.5	2.2	1.5	2.1	0.7	1.5
CONTACTS RECEIVED						
90/91: Wilks lambda=.49948, F(10, 146)=7.9368, p=.03457; '01/02: Wilks lambda=.52019, F(14, 138)=7.7581, p=.04010						
POSITION	JUNIOR		MID-LEVEL		SENIOR	
CONTACTS MADE						
Total	2.7	3.3	6.4	7.2	9.7	10.4
Total with crystallogs.	4.5	5.5	4.5	5.0	3.4	3.9
In S Africa	1.8	1.8	3.5	3.7	5.8	5.8
With SA crystallogs.	1.3	1.3	2.0	2.1	3.7	3.8
Foreign	0.9	1.1	2.8	3.3	4.1	5.1
With foreign crystall.	0.3	0.7	1.3	1.9	2.0	3.0
CONTACTS RECEIVED						
90/91: Wilks lambda=.02786, F(10, 146)=84.606, p=.00004; '01/02: Wilks lambda=.03252, F(14, 138)=77.902, p=.00015						
AGE CATEGORIES	20-35		36-50		51-70	
CONTACTS MADE						
Total	3.9	4.5	8.4	9.0	5.1	6.1
Total with crystallogs.	2.0	2.7	4.1	5.1	3.8	4.8
In S Africa	2.4	2.5	4.9	5.0	2.9	3.0
With SA crystallogs.	1.3	1.3	3.1	3.1	2.3	2.2
Foreign	1.5	2.0	3.6	4.3	2.2	3.6
With foreign crystall.	0.7	1.5	1.5	2.3	1.4	2.0
CONTACTS RECEIVED						
90/91: Wilks lambda=.03014, F(10, 146)=84.931, p=.00004; '01/02: Wilks lambda=.02612, F(14, 138)=85.048, p=.00003						

The cross tabulation according to work structure indicated that the respondents who worked in

more structured and group-forming environments were collectively the more active communicators and were approached by other crystallographers more frequently. The respondents working in unstructured groups ranked second for all interpersonal communication acts while those respondents who worked on their own made and received the least number of contacts. These results once again correlate with those reported in the previous sections and the observations made during the interviews that working in a group structure has many beneficial outcomes; amongst others it stimulates interpersonal communication and the flow and exchange of information. The significant Wilks' lambda and F scores for this cross tabulation respectively ranged from 0.03551 and 77.198 for 1990/1, and 0.03400 and 78.116 for 2001/2 and this represents a significantly strong correlation.

If the data is analysed according to the respondents' highest qualifications a clear pattern is evident. Interpersonal communication for all types of interaction is at the lowest level for those respondents with the lowest qualifications (i.e. Honours and Master degrees) and at a far higher level for the respondents with a doctorate and this also applies to the average number of contacts received. An interesting observation is that the respondents who held foreign doctorates were slightly more active in instigating contacts in South Africa, while the respondents with local doctorates maintained slightly more contacts with local crystallographers and received more contacts. This latter aspect can be attributed to the fact that all but one of the six crystallographers that emerged as the leaders in the field held South African doctorates (cf. 4.5). The range of Wilks' lambda and F scores for these interactions was respectively: 0.49948 and 7.9368 for 1990/1, and 0.52019 and 7.7581 for 2001/2 and this once again represent fairly weak correlations. Again this could be attributed to the small variation between the local and foreign PhD responses that suppressed the much greater variation between them and those from the lower qualification respondents.

A strong correlation is evident between the level of seniority of the respondents and their interpersonal communication, both initiated by them and the number of contacts received. The Wilks' lambda and F scores respectively ranged between 0.02786 and 84.606 for 1990/1, and 0.03262 and 77.902 for 2001/2. It is clear that the more senior the respondents, the more they communicated on an interpersonal level with all categories (foreign, South African, crystallographer and non-crystallographer contacts) and the more they were contacted. This result is not surprising as one would expect greater interaction from and among the more senior and established researchers. Most of the junior researchers worked in structured group environments

and thus depended on their more senior colleagues to communicate outside the immediate work environment.

When the data was analysed according to the respondents' age categories it was seen that strangely the levels of interpersonal communication were higher for the middle age category (36-50) than for the oldest age group (the youngest age group [20-35], as expected maintained the lowest number of contacts for all types of communication). The Wilks' lambda and F scores for these interactions were significantly strong and respectively ranged between 0.03014 and 84.931 for 1990/1, and 0.02612 and 85.048 for 2001/2.

This was a fairly surprising outcome as one could have expected that with time and thus increase in age, older researchers would build up a larger network of contacts. This was particularly surprising taking into consideration that the respondents in the most senior positions were the most active communicators and one would have assumed that they would also be the older respondents. On further analysing the demographic data it was however seen that only a small majority of the senior respondents (58%) were in the older age category and that 42% were in the middle age category. From this data one would thus presume that although the most active communicators were in the more senior positions, they were also in the 36-50 age category.

4.4.2 THE GEOGRAPHICAL SPREAD OF INTERPERSONAL COMMUNICATION

To investigate the extent of the geographical spread of the respondents' interpersonal communication activities in South Africa it was decided to further analyse the data according to whether the respondents maintained contacts with persons in their local geographical area or whether they went further afield. The geographical distribution of interpersonal interaction for the total population and the various population sub-categories for each data set is depicted in Table 4.2. below. If the overall population is considered it is clear that there was very little differentiation as 52% (1990/1) and 51% (2001/2) of the contacts were made within the respondents' own geographical area and 48% (1990/1) and 49% (2001/2) were outside their areas. It can be seen that the overall pattern had not changed in any significant way in the intervening 11 years.

If the various population sub-categories are considered it can be seen that the respondents who communicated significantly more within their own geographical area were those who worked in research institutes, who worked in unstructured groups, and who were in the 20-35 age category,

held masters or honours degrees, applied crystallography, and worked in Gauteng. The respondents who communicated significantly more with persons outside their geographical area were those who worked at universities, who worked on their own, and who were in a middle position, who were older, held doctorates, used crystallography as a tool, and worked in the Free State and Western Cape and to a lesser extent in Natal.

TABLE 4.2. CONTACTS MADE WITHIN AND OUTSIDE THE AREA

1990/1 DATA (N=80)					2001/2 DATA (N=73)				
TOTAL POPULATION					TOTAL POPULATION				
Local contact	52%				Local cont.	51%			
Wider contact	48%				Wider cont.	49%			
WORK ENVIRONMENT					WORK ENVIRONMENT				
	Industry	Research	University			Industry	Research	University	
Local contact	56%	81%	35%		Local cont.	55%	78%	37%	
Wider contact	44%	19%	65%		Wider cont.	45%	22%	63%	
WORK STRUCTURE					WORK STRUCTURE				
	Struct. Grp.	Unstruct. Grp.	Loners			Struct. Grp.	Unstruct. Grp.	Loners	
Local contact	51%	89%	35%		Local cont.	52%	61%	33%	
Wider contact	49%	40%	55%		Wider cont.	48%	39%	67%	
POSITION					POSITION				
	Junior	Middle	Senior			Junior	Middle	Senior	
Local contact	52%	40%	58%		Local cont.	60%	38%	57%	
Wider contact	38%	50%	45%		Wider cont.	40%	51%	43%	
AGE RANGE					AGE RANGE				
	20-35	36-50	51-70			20-35	36-50	51-70	
Local contact	80%	55%	40%		Local cont.	77%	54%	38%	
Wider contact	20%	45%	50%		Wider cont.	23%	48%	52%	
QUALIFICATIONS					QUALIFICATIONS				
	Foreign Doct.	SA Doct.	% Hons/Masters			Foreign Doct.	SA Doct.	% Hons/Masters	
Local contact	44%	55%	56%		Local cont.	43%	53%	68%	
Wider contact	56%	44%	14%		Wider cont.	57%	47%	12%	
APPLICATION OF CRYSTALLOGRAPHY					APPLIC. CRYSTALLOGR.				
	Pure	Tool	Applied			Pure	Tool	Applied	
Local contact	43%	28%	71%		Local cont.	45%	25%	70%	
Wider contact	57%	73%	29%		Wider cont.	55%	75%	30%	
GEOGRAPHICAL AREA					GEOGRAPHICAL AREA				
	Gauteng	Free State	Natal	W Cape		Gauteng	Free State	Natal	W Cape
Local contact	70%	0%	43%	9%	Local cont.	70%	0%	40%	8%
Wider contact	30%	100%	57%	91%	Wider cont.	30%	100%	60%	92%

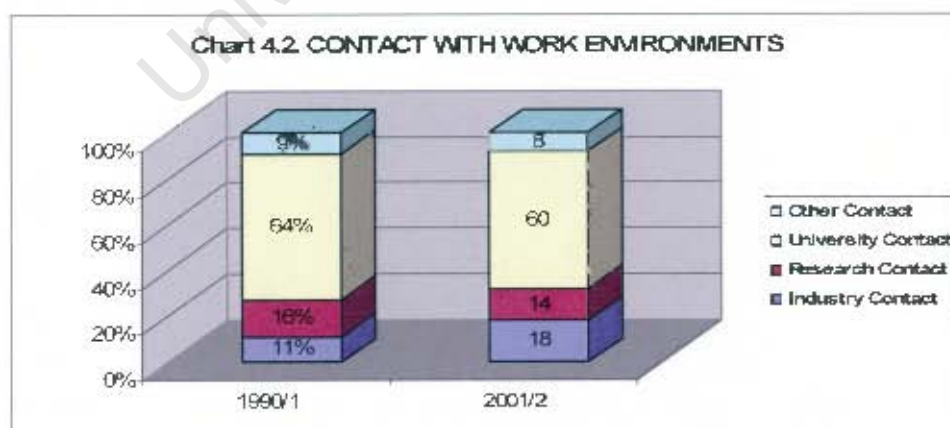
An explanation for these findings could be that

- the Gauteng area contains a sufficient critical mass of expertise in the field to obviate the need to communicate extensively outside the area;
- all the research institutes and the majority of the industries in the study were situated in Gauteng, while the universities were more evenly distributed throughout the country as a whole;
- the respondents who worked on their own and who were not part of a local network more frequently forged links further afield than their counterparts who worked in some form of group structure;

- the respondents in middle positions generally were less bound by the communication bonds of the groups they worked in and ventured further afield more readily than their senior counterparts and even more so than their more junior counterparts;
- the older respondents were the ones that communicated further afield;
- the respondents with doctorates had wider communication links because of their more extended exposure to the research environment; and that
- the applied crystallographers communicated far more actively with persons further afield.

4.4.3. CONTACT BETWEEN WORK ENVIRONMENTS IN SOUTH AFRICA

The data was further analysed to establish the work categories of the persons with whom the respondents regularly communicated on an interpersonal basis in South Africa. These results are represented in Chart 4.2, below. It can be seen that by far the most communication took place between the respondents and persons conducting research at universities (64% 1990/1, 60% 2001/2). The communication with persons at research institutes only represented 16% (1990/1) and 14% (2001/2) of the instances and even fewer respondents communicated with persons in industry (11% in 1990/1 and 18% in 2001/2). The latter result, however, indicates a slight increase in activity with industry in 2001/2. This can be attributed the fact that in the intervening period both the research institutes and the universities were forced to engage in more contract work and this was often with some or other industrial concern (cf. also 4.2.). Interaction with 'other' categories represented 9% (1990/1) and 8% (2001/2) of the instances and mostly consisted of contact with clients and suppliers of equipment.



4.4.4. ACTIVE COMMUNICATORS

During the various interviews it became abundantly clear that a core number of respondents were repeatedly being identified as the leading crystallographers in South Africa. These crystallographers were not only frequently approached for information, but also initiated acts of information communication on a regular basis. The reasons given for making contact with these persons related mostly to their expertise and knowledge of crystallography as a basic science as well as its various applications. The respondents who were most frequently contacted indicated that they were approached, amongst others, to provide assistance in solving crystal structure problems, to help to solve combinatorial problems, to do analytical work on the diffractometer, to provide assistance with diffractometer problems, to assist with computer software problems, etc. Another important reason for interaction was involvement in the South African Crystallographic Association. In Table 4.3, below the range of contacts made and received is depicted. It can clearly be seen that the most active crystallographers (top 25% and 10%) maintain far more contacts than the respondents in general (i.e. the population aggregate).

Table 4.3 Range of contacts made & received						
N 1990/1 = 80, N 2001/2 = 78						
	Minimum	Population Average	Top 25% Average	Top 10% Average	Maximum	
Made 1990/1	0.0	6.7	17.1	22.3	27.0	
Made 2001/2	0.0	7.6	21.4	25.1	32.0	
Received 1990/1	0.0	2.6	10.1	18.2	25.0	
Received 2001/2	0.0	3.1	12.2	20.1	29.0	

To provide a profile of these active communicators, the crystallographers who made and received the most contacts (top 25%) were identified from the interpersonal information communication data obtained for 1990/1 and 2001/2 (cf. also 4.4.) and this analysis according to the population sub-categories is outlined in Table 4.4, below. It was interesting to note that there was a 75% correspondence between the respondents in the central network of most active communicators for the two studies (the level of commonality between the two study populations was 63%, cf. also chapter 3.4.5.). There was therefore only a slight variation in the profiles of the central networks of the two studies.

From Table 4.4, below it can be seen that the crystallographers who received the most contacts (the top 25%) mostly worked in structured, but also in unstructured groups, at universities where almost all were either 'pure' crystallographers or used it as a 'tool'. As can be expected the distribution by specific subject field was mostly in the fields where crystallography was research

in its pure form and to a lesser extent used as a tool, thus chemistry, physics (part of the 'other' category) and geology. Almost all of these respondents were in senior positions in the 36-50 age category with slightly more holding South African than overseas doctorates. The majority worked in Gauteng, with Southern Gauteng having a slight edge over Northern Gauteng. As mentioned this profile varied only slightly between the 1990/1 and 2001/2 studies.

TABLE 4.4. MOST ACTIVE COMMUNICATORS - Top 25%
Distribution by Population Subcategories

		Contacts Received (%)		Contacts Made (%)	
		1990/1	2001/2	1990/1	2001/2
WORK ENVIROMENT	University	80	75	45	40
	Research	15	20	25	30
	Industry	5	5	30	30
WORK STRUCTURE	Struct. Groups	60	60	75	75
	Unstruct. Groups	30	30	25	25
	Loners	10	10	0	0
APPLICATION	Pure	50	45	30	25
	Tool	30	30	15	15
	Applied	20	25	55	60
SUBJECT	Chemistry	50	40	30	25
	Other	25	20	25	20
	Mineral/Geology	10	15	25	25
	Materials sci.	15	25	20	30
POSITION	Senior	85	95	80	80
	Mid-level	15	5	20	20
	Junior	0	0	0	0
AGE CATEGORIES	51-70	15	25	10	15
	36-50	80	70	85	80
	20-35	5	5	5	5
QUALIFICATION	SA Phd	60	55	75	75
	Foreign Phd	40	45	25	25
	SA M/Hon	0	0	0	0
GEOGRAPHICAL AREA	North Gauteng	25	30	30	30
	South Gauteng	40	35	45	45
	Free State	10	5	10	10
	Natal	10	10	5	0
	Western Cape	15	20	10	15

When the profile of the core group of crystallographers who received the most contacts is compared with that of the respondents who initiated the most communication acts, a number of differences surface. The active communication initiators were far more equally distributed among the three work environments and as a consequence there was a shift away from a preponderance of respondents conducting *pure* crystallographic research and using it as an analytical tool in basic research, to those who applied crystallography in industry and the research institutes. The

subject distribution thus also shifted more towards the applied disciplines such as materials science and mineralogy. More of this category worked in structured groups and none on their own. This category also mostly held senior positions (with only a slight shift to the middle position) and the predominant age was even more embedded in the 36-50 age category. There was further a shift from a small majority of respondents with South African doctorates to a large majority of 75%. The geographical distribution hardly varied between the core recipients and initiators.

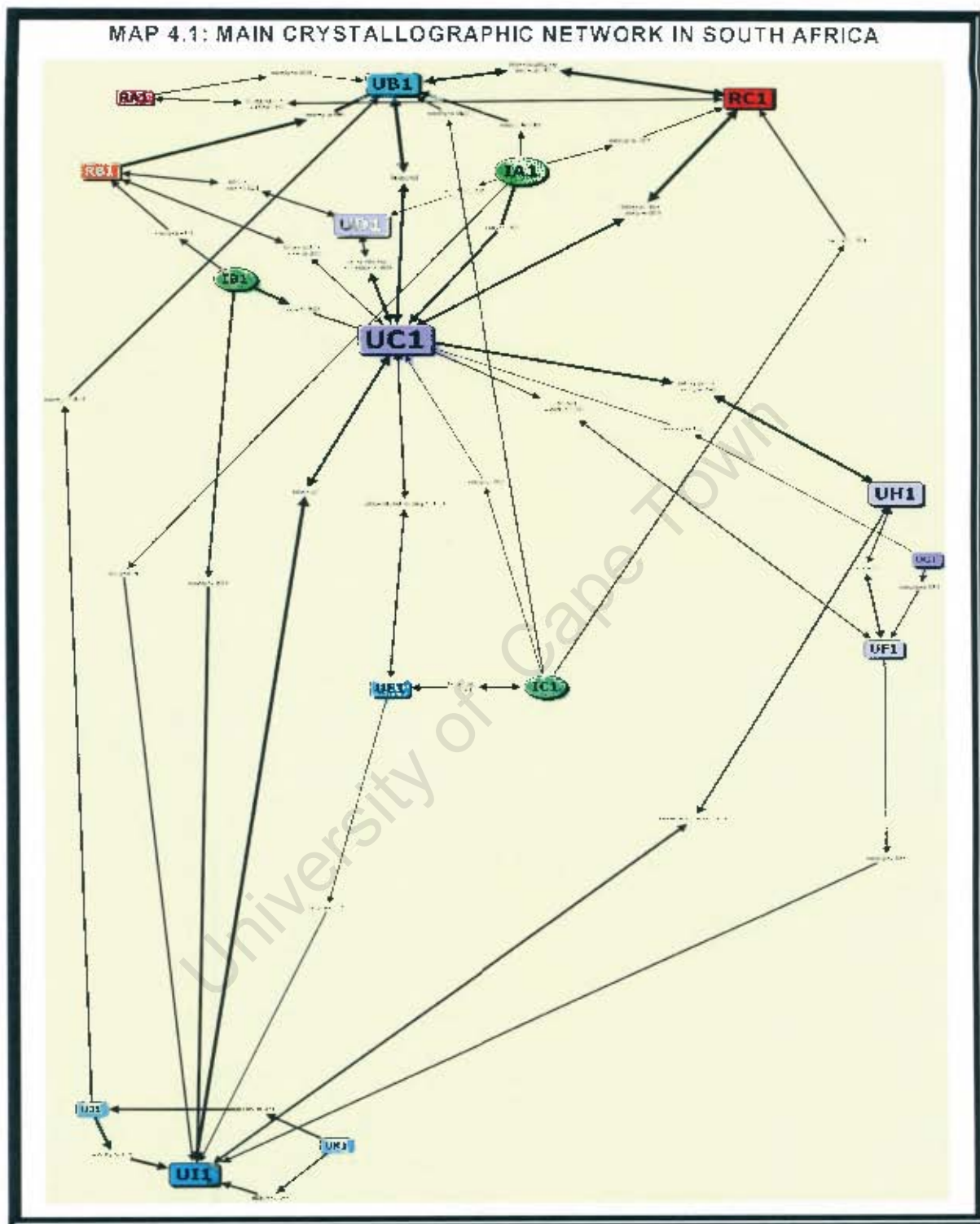
Within this core group of communicators, eight crystallographers were contacted considerably more frequently than the other members of the central network and they generally also appeared to be the most prominent members of the crystallography fraternity. The membership of this nucleus of very active crystallographers did not vary between the two studies and in both studies they represented 10% of the total population of respondents. The slight difference in profile between the 1990/1 and 2001/2 studies was thus only due to these respondents' changed work situations, changed locations and movement into an older age category and they

- all held senior positions;
- 75% headed structured groups, and the other two were leaders of unstructured groups;
- three held overseas doctorates and five held local doctorates;
- in 1990/1 only one of these core members was in the 51-70 age category (the other seven were between 36 and 50) and by 2001/2 two were now in the 51-70 age group;
- most of these respondents were conducting *pure* crystallographic research at universities and one of the two who were involved in applied research at research institutes had moved by the time of the second study to a university where he then utilised crystallography as a *tool*;
- the majority of these crystallographers worked in the field of chemistry and the three non-chemists were either in mineralogy, physics (other category), or materials science;
- by far the majority were located in either South or North Gauteng, one worked in the Western Cape and the one respondent who was in Natal in 1990/1 had also moved to North Gauteng by 2001/2.

Of these eight respondents, one crystallographer emerged as the person who was by far the most frequently approached for information, for assistance in solving problems and advice in general.

A number of respondents referred to him as the “doyen or boss” crystallographer in South Africa. He was a senior academic, in the 51-70 age group, had a South African doctorate and was the leader of a structured group working in the field of chemistry as a *pure* crystallographer in South Gauteng. This ‘doyen’ crystallographer and the other seven who were approached the most frequently all served on a number of important boards, committees, etc. within the general field of science, they were actively involved in their professional associations and played a leading role in these institutions, they published profusely, they served on editorial committees, were sought out for external examining purposes and generally emerged as the archetypal ‘sociometric stars’ in their field.

To graphically depict the interpersonal interactions that were maintained between the core actors in the crystallography community in South Africa a social network map was constructed using the CmapTools software produced by the Institute for Human and Machine Cognition (see Map 4.1. below). The map indicates the key players as nodes and the linking lines the strength (thickness of the line) and direction (arrow and commentary) of the interaction. The nodes are colour coded, with the blue shades indicating universities, green industry and red shades the research institutes. The eight key actors in the community are indicated as follows: UC1 was the so-called doyen crystallographer at a university in Gauteng, the other role players in Gauteng were UB1, UD1 (both at universities), RC1, and RB1 (at research institutes), IA1 (in industry); UH1 at a university in Natal; and UI1 at a university in Cape Town. The networks that surround them are also depicted.



4.5. PROFESSIONAL ACTIVITY, SCIENTIFIC ELITES AND INFORMATION COMMUNICATION

A number of studies have indicated that information communication involvement and professional activity and productivity are closely related (refer to chapter 2.1., 2.2., 2.3., 2.7.). Reference was further also made in chapter 2.2.1. and 2.3.1.1. to *scientific elites* and *technological gatekeepers*. The former according to Price (1971, 1975, 1986) are the eminent men of science who have been accorded recognition in their disciplines, who have achieved a standard of excellence in their work, who are highly productive and visible in their professional community and who have a strong influence over the scientific communication system in their field. *Technological gatekeepers* (cf. Allen et al., 1970) indirectly act as intermediaries in organisations to ensure the effective flow of information within and without organisations. It has been seen that both the *elites* and the *gatekeepers* are very involved not only with their immediate work situation, but also the wider science community that they operate in. They generally serve on editorial boards and the committees of their professional organisations: they maintain a high profile and they are highly productive both as far as encoded output and other output measures are concerned. They achieve this by attending more conferences, by having more extensive personal contact with colleagues outside the organisation, and by engaging more actively with the published literature than their less active colleagues.

It would thus appear that the more prominent a role a person plays in his/her professional life, the more active the person would be in the communication of information in his/her field. To establish whether these patterns were evident amongst the respondents in this study the researcher obtained information during the interviews that related to their involvement in professional activities. The respondents were asked to indicate whether they had acted as referees and members of editorial boards of scientific and/or professional journals; whether they were involved with their professional institutions (both South African and international); and further to provide information on their encoded research output (cf. Section D., Questions 15 & 16, Appendix B & C). The research output and professional involvement (i.e. activity counts for each activity of each respondent) data were totalled and then the top 10% extracted by means of a filtering operation to establish the most productive and professionally active respondents. These were then correlated with the data relating to inter-personal communication activity (top 10%).

When the filtered research output data was correlated it was seen that all the crystallographers who were the recipients of the most information communication approaches and 65% of those who initiated the most communication acts were among the group of crystallographers with the highest research output counts. It can be seen from Table 4.5, below that the aggregate overall research output count of the most active communicators was 8.0 in 1991 and 10.1 in 2001/2. This compares very favourably with Garfield's (1990:230) fourteen year longitudinal study that investigated the publication output of so-called *elite* scientists (the 1000 most cited scientists in the Institute for Scientific Information's databases) and which established that the most highly cited scientists were achieving publication counts of approximately nine papers a year¹⁶. Although the validity of publication counts as a criterion of scientific excellence and productivity has often been queried on the grounds that a crude count of publications ignores factors such as quality and length of publication, this researcher would like to agree with Price's (1986:37) statement that "on the whole there is, whether we like it or not, a reasonably good correlation between the eminence of a scientist and his production of papers". The best researchers thus tend to have many publications, and only rarely will these be trivial and uncited, while lack of success tends to terminate publication.

Channel	Averages		Averages	
	All Respondents		Top Communicators	
	1990/1	2001/2	1990/1	2001/2
Patents	0.1	0.2	0.8	1.1
Reports	0.9	1.3	3.3	4.2
Conference Presentations	1.0	1.2	2.3	3.1
Publications	1.9	2.3	6.0	7.5
OVERALL	2.5	3.2	8.0	10.1

The filtered data relating to the crystallographers' general professional involvement (i.e. those respondents who were the most actively involved in commitments such as editorships, refereeing, etc. [top 10%]) were correlated with the most active initiators and recipients of communication acts and with those who had the highest encoded research outputs. Once again it was seen that high levels of communality existed between the active information communicators (particularly the recipients of information contacts, almost 100% coincidence) and research output and professional activity. The breakdown by population sub-categories for these highly productive and active crystallographers is depicted in Table 4.6. below.

¹⁶ Refer also to Price (1975:176; 1986: 48-50).

TABLE 4.6. PROFILE OF THE MOST PRODUCTIVE & ACTIVE CRYSTALLOGRAPHERS (Top 10%)

WORK ENVIRONMENT	COMMUNICATION INTERACTION %		RECORDED RESEARCH OUTPUT %					PROFESSIONAL ACTIVITY %		
	Received	Made	Reports	Patents	Publications	Conf. Present.	Overall	Editors	References	Officers
UNIVERSITY	81	45	0	0	100	100	50	80	77	81
RESEARCH INST.	18	33	88	13	0	0	25	20	23	18
INDUSTRY	0	22	13	88	0	0	25	0	0	0
APPLIC. OF CRYST.										
Pure	75	30	0	0	75	88	41	59	57	57
Impure	8	15	0	0	25	12	9	21	20	24
Applied	18	55	100	100	0	0	80	20	23	19
WORK STRUCTURE										
Structured	75	84	88	98	63	88	78	81	77	76
Unstructured	25	8	13	4	32	30	20	20	21	20
Loners	0	0	1	0	5	2	2	0	2	4
POSITION										
Senior	100	81	63	63	88	88	75	80	71	84
Midrise	0	18	13	25	0	13	13	0	28	5
Junior	0	0	25	13	13	0	13	0	3	0
AGE										
20-25	0	0	38	25	13	13	22	0	2	4
26-30	69	80	25	75	50	50	50	70	72	75
31-35	31	20	38	0	38	38	28	30	26	21
QUALIFICATION										
SA PhD	63	75	63	75	75	63	69	80	68	79
For PhD	38	25	25	25	25	38	28	51	31	30
M/None	0	0	13	0	0	0	3	0	0	0
AREA										
S. Gauteng	42	38	15	75	38	31	40	42	24	40
N. Gauteng	38	43	75	13	29	42	40	40	39	30
Free State	0	0	7	13	8	7	9	0	13	12
Natal	8	8	1	0	0	0	0	0	8	0
W. Cape	13	13	3	0	25	21	12	20	16	20

High %: 68% - 100%
 Moderate %: 38% - 60%
 Low %: 0% - 33%

It is clear from Table 4.5. that the respondents who were the most active in the widest range of activities were those who had worked in universities (except for patents and reports where, for the former, the industry respondents and, for the latter, the research institute respondents were the most prolific); who worked in a structured environment, who were in senior positions; who were in the 36-50 age range, who held a South African doctorate; who were *pure* crystallographers (except for patent and report output and in this instance the applied crystallographers were the most prolific); and who worked in Northern or South Gauteng (although it was seen that as far as area was concerned there was a more equitable distribution across the country other than for patent and report output). The lowest activity ratings went to those respondents who worked in industry (except for patent output), who worked on their own, who were in a junior position, who were in the youngest age category, who held lower qualifications, and who worked in the Free State and Natal.

From the above it would appear that high productivity, professional involvement and interpersonal information communication are intricately interwoven. It is thus submitted that this study has produced sufficient evidence of the presence of an *elite* group of scientists within the crystallography community which as Price (1971:74-5) has stated comprise the eminent men of

science who have been accorded recognition in their disciplines, who have achieved a standard of excellence in their work, who are highly productive and visible in their professional community, and who are intimately involved with (and often have control over) the scientific communication system in their field.

It is further clear that the *sociometric stars or elites* in the crystallography community in South Africa mostly worked in a work environment that was more conducive to collegiate interaction where the profit motive and the concomitant restrictions were less evident. Working together in formal or loosely structured groups stimulated information communication, professional activity and productivity. It was further evident that these elites clustered at the basic science, and specifically the 'pure' crystallography side, of the basic to applied spectrum and that Gauteng provided a sufficiently large critical mass of scientists working in the same field to stimulate interaction and productivity.

4.6. CONCLUDING REMARKS

It clearly emerged that the respondents' work environment and work structure largely determined communication patterns and the interaction with information. The organisational ethos that prevailed in each of the three work environments (industry, the research institutes and the academic institutions) generally determined specific work structures which in turn impacted in varying ways on the communication of and interaction with information.

The success of the work dynamic in all three work environments largely depended on strong leadership and although all members participated, the group leader was generally the driving force. Strong leadership resulted in the development of a good team spirit and active inter- and intra-group communication of information. The group leader thus played a very important and active role in maintaining the strongest links with the external environment and a typical *gatekeeper* role was adopted. They encouraged the cross fertilisation of ideas and new knowledge and constant interaction with both the formal and informal information communication channels in their field. It was further clear that a core number of respondents were the leading crystallographers in South Africa, the *scientific elites*, and that they were driving the information communication process. These crystallographers were not only frequently approached for information, but also initiated acts of information communication on a regular basis.

Although the basic information communication model remained fairly constant from the 1990/1 to the 2001/2 study, certain significant changes did surface during the second study. The variation was predominantly caused by the impact of the escalating electronic information environment, a new political dispensation in South Africa, as well as financial and structural changes in the work environments.

A more detailed discussion of these results will be provided in chapter 6.

University of Cape Town

CHAPTER 5

THE CRYSTALLOGRAPHERS USE AND PREFERENCE FOR CHANNELS AND MODES OF COMMUNICATION

5.1. INTRODUCTION

In Chapter 2.4 reference was made to Paisley's (1980) well known assertion that the way and medium in which information is communicated can have a significant effect on the communication process. It was seen that information may be communicated by means of various combinations of mode and channel and that the mode of communication is the physical state in which it is encoded while the channel of communication is the medium by which information is conveyed from sender to receiver. Channels of communication can further be categorised as either formal channels (i.e. when information is archived), or informal channels, or a combination of both of these. Both formal and informal channels can also be classified into personal and impersonal channels. The former category involves personal communication between individuals while the latter category refers to channels where the information is first recorded and then transferred.

A number of studies have indicated that accessibility, familiarity and ease of use of information modes and channels are important aspects that often provide the reason for selection and frequency of use far more conclusively than high reward or quality factors (cf. Chapter 2.4). It has, however, further been found that while these aspects determine the initial selection of channels, information and ideas are accepted and adopted in relation to the reputability and quality of the channel that conveys the information.

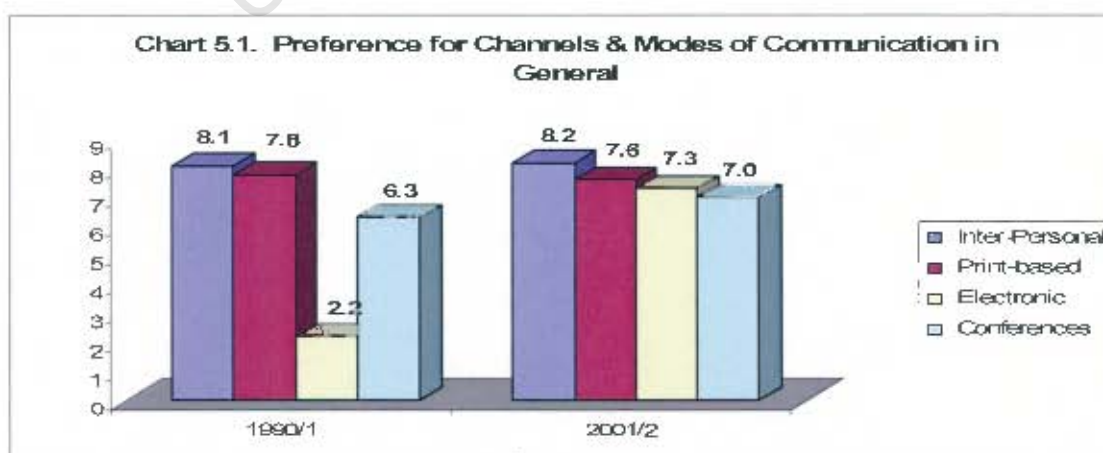
To establish the effect of channels and modes of communication on the information communication process and to ascertain the South African crystallographers' use of and preference for such modes and channels, a series of questions relating to these factors were put to the respondents (cf. Questions C4-C14, Appendix B & C).

5.2 OVERVIEW OF THE PREFERRED CHANNELS AND MODES OF COMMUNICATION

It was established during the pilot studies and from the review of the literature that the main categories of information communication channels and modes that the crystallographers generally engaged with were direct person to person exchange of information (the more informal inter-personal channels and modes of information communication), and the more formal, indirect, recorded channels that were usually either in print or electronic formats (modes). Conferences were further frequently mentioned as forming an important constituent of the communication process and, although strictly speaking consisting of a range of modes and channels, it was taken as a distinct category.

The respondents were thus asked in both studies to discuss the role that these four categories of modes and channels played in the information communication process and to rate the value of each channel on a rating scale of 10 (used very frequently / very highly rated) to 0 (not used / of no value) (cf. Appendix B & C, Question C4). The average rated responses for the study population are depicted in Table 5.1. and Chart 5.1. below.

	Average Ratings			
	Inter-Personal	Recorded		Conferences
		Print-based	Electronic	
1990/1	8.1	7.8	2.2	6.3
2001/2	8.2	7.6	7.3	7.0



While both inter-personal and print-based communication modes were clearly highly rated, the former attracted slightly higher ratings than print-based modes. Conferences were also considered to play an important role in the communication process, only more so in the 2001/02 study than in the 1990/1 study. The ratings awarded to electronic modes varied considerably from the very low values in the 1990/1 study to the very high value ratings awarded in 2001/2.

The t-test¹⁷ for two dependent samples was used to establish whether the data for the two studies showed statistically significant differences. Table 5.2. reflects the results of the t-test and it can be seen that significant differences ($p < 0.05$) were scored for the much higher ratings obtained in the 2001/02 study for electronic modes and conferences. The very substantial increased rating for electronic modes came as no surprise as this was commensurate with the worldwide escalation in availability of electronic media and systems and the general move towards an electronic information environment. The increase in the value rating given to conference attendance can be attributed to the general trend towards globalisation and the fact that the political change in 1994 has made it far more tenable for South African scientists to attend international conferences. There has always been a need for South African scientists (who are geographically far removed from the main science epicentres) to both stay abreast with the forefront of international science and to publicise and receive feedback on their own research endeavours.

**Table 5.2.. T- Test for significant between study differences:
Mode Preferences, 1990/1 & 2001/2**

		Mean	Std. Dv.	N	Diff.	t	p
1990/1	Inter-Personal	8.2	1.580	80			
2001/2	Inter-Personal	8.2	1.644	78	0.000	0.000	1.000
1990/1	Print-based	7.8	1.714	80			
2001/2	Print-based	7.6	1.748	78	-0.244	-1.223	0.225
1990/1	Electronic	2.1	1.377	80			
2001/2	Electronic	7.3	2.182	78	5.192	20.749	0.000
1990/1	Conferences	6.3	2.300	80			
2001/2	Conferences	7.0	2.431	78	0.664	2.240	0.028

Scores in red are significant at $p < .05000$

5.2.1. PREFERENCE FOR MODES OF COMMUNICATION ACCORDING TO SUB-CATEGORIES OF THE POPULATION

The data was further analysed by cross tabulating the dependent variables of mode preferences with the population sub-categories as independent variables. ANOVA¹⁸ statistics were then

¹⁷ See chapters 4.4. and 3.10.1 for a definition of the t-test.

¹⁸ See chapters 4.4. and 3.10.1 for definitions of ANOVA, Wilks' lambda and F scores.

calculated for each data set to establish which cross tabulations were significant. A threshold significance level was set at $p \leq .05$ and all cross tabulations that fell outside this level were disregarded. The mean ratings of the significant results as well as the Wilks' lambda significance statistic and the F ratios are depicted Table 5.3 below. Statistically significant differences were scored for categorisation according to work environment, crystallographic application, position and age in both the 1990/1 and 2001/2 data-sets.

TABLE 5.3. MODE & CHANNEL PREFERENCES by POPULATION SUB-CATEGORIES										
	Mean Ratings of the Significant Results								N	
	Inter-Personal		Print-based		Electronic		Conferences			
	1990/1	2001/02	1990/1	2001/02	1990/1	2001/02	1990/1	2001/02		
Work Environment										
Industry	8.6	8.8	5.6	4.8	1.0	5.9	2.9	3.2	13	11
Research	8.4	8.6	7.9	6.8	3.6	7.8	6.7	8.2	18	17
University	7.9	7.9	8.5	8.5	1.9	7.4	7.2	7.4	49	50
	2001/2 WORK ENV; LS Means Wilks lambda=.03585, F(8, 144)=77.063, p=0.0000									
	1990/1 WORK ENV; LS Means Wilks lambda=.05496, F(8, 144)=50.847, p=0.0000									
Crystal Application										
Applied	8.5	8.7	6.7	6.1	5.0	6.3	2.5	6.4	31	29
Tool	7.5	7.9	8.1	8.4	3.3	7.5	1.9	7.8	26	24
Pure	8.3	7.8	8.9	8.5	7.6	7.3	1.8	7.9	23	25
	2001/2 CRYSTAL APPLICATION; LS Means Wilks lambda=.35643, F(8, 144)=11.736, p=0.0000									
	1990/1 CRYSTAL APPLICATION; LS Means Wilks lambda=.28233, F(8, 144)=16.317, p=0.0000									
Position										
Senior	9.5	9.6	8.9	8.5	2.6	5.4	2.6	7.9	6.5	33
Middle	8.0	8.0	7.7	7.2	1.8	7.8	1.8	5.6	7.1	24
Junior	6.1	6.0	6.3	5.6	1.6	6.2	1.6	3.3	4.4	21
	2001/2 POSITION; LS Means Wilks lambda=.08737, F(8, 144)=12.937, p=0.0000									
	1990/1 POSITION; LS Means Wilks lambda=.08440, F(8, 144)=15.179, p=0.0000									
Age Range										
51-70	8.9	9.1	8.8	8.1	2.5	7.0	7.5	8.3	19	26
36-50	8.8	8.7	7.9	7.5	2.0	7.1	6.6	7.5	37	30
20-35	8.5	8.3	6.8	7.0	1.9	6.0	5.0	4.7	24	22
	2001/2 AGE RANGE; LS Means Wilks lambda=.38996, F(8, 144)=10.825, p=0.0000									
	1990/1 AGE RANGE; LS Means Wilks lambda=.47476, F(8, 144)=13.3493, p=0.0000									

From the above it can be seen that as far as interpersonal communication and variation according work environment was concerned, all work environments regarded this as an important mode in the communication process. In both studies the industry respondents, however, scored slightly higher values than the other two environments and this result correlates with comments made by the industry scientists that they prefer discussing problems with colleagues or experts to finding the answer in the literature. This view was aptly expressed as follows:

I will if necessary gladly catch a plane and fly to the right persons anywhere in the world to have them help us than scratch around in the literature to find the answer

There were distinctive differences among the value ratings that each of the three work environments awarded to print-base modes of communication. It is clear that the university respondents valued this mode by far the highest, that the industry respondents awarded by far the lowest ratings, and that the research institute respondents took a midway stance that ranged from the high ratings in the first study to the moderate ratings given in 2001/02. Comments made

during the interviews suggest that the university respondents valued print-based modes not only for the information that they conveyed, but specifically also for the publication vehicle they provide for their research outputs. The industry respondents were more concerned with problem solving issues as well as product and service outcomes than with transferring their research outcomes into the public domain. The research institutes moved from a predominantly non-profit research environment in the early 1990's to the situation that pertained in 2002 where cost recovery, profits and the domination of contract research had become the norm. These situational changes would thus explain why the value ratings these respondents gave to print-based modes shifted from the high levels in the first study to moderate levels in the second study.

The very significant increase in the value ratings awarded by all the work environments to electronic modes in the second study came as no surprise. It can, however, be seen that the industry respondents awarded relatively lower ratings than the other two environments. This can generally be ascribed to their awareness of the possibility of industrial espionage and the real threats to security breaches that pertain to the electronic environment (cf. comments made to this effect in chapter 4). It is further interesting to note that the research institute crystallographers returned the highest positive ratings in both studies for this mode. This can be attributed to observations made during the interviews that the research institutes generally are early adopters of new innovations and technology.

Conferences clearly play a rather insignificant role in the industry environment and this is in direct contrast to the high value ratings awarded by the other two environments. A number of the industry respondents indicated during the interviews that conferences have a limited value since most conference papers and discussions are very theoretically oriented. A number of university and industry respondents commented during the study that it is very important for them to regularly attend conferences to network with experts in the field, to publicise their work and have it evaluated, and also to stay abreast with new innovations. The research institute respondents were very aware of South Africa's remoteness from the main science research centres and they thus made a concerted effort to attend as many international conferences as possible.

The ratings awarded by the respondents in the three crystallography application areas indicate that while the applied crystallographers followed a pattern similar to that of the combined responses from industry and the research institutes, the *tool* and *pure* crystallographers closely emulated the university respondents. All three categories rated inter-personal communication

modes highly; the applied crystallographers rated print-based modes and to a lesser extent electronic modes far lower than the other two categories (this applied to both studies); this category further rated conferences slightly higher in the 1990/91 study and then in the 2001/2 study awarded lower ratings than the *pure* and *tool* crystallographers.

The variation in responses among the three age and position categories followed very similar patterns. It can be seen that the more senior and older respondents valued inter-personal modes of communication considerably more than the junior and younger crystallographers. This tendency could be related to the assumption that the more senior respondents and thus possibly also the older respondents have generally established themselves in their professions and have over the years built up a substantive circle of colleagues with whom they communicate, collaborate and generally interact. The high values awarded to print-based modes by the older and more senior respondents can largely be explained by comments made during the interviews that they valued print-based publications for the vehicle they provide to publish their research output. The older and more senior respondents' high conference ratings could be linked to their greater ability to secure funding, their more advanced research standing that ensures that their papers are more readily accepted at international conferences, and that they are also called on to officiate more frequently than their younger, more junior counterparts.

The only instance where the younger and more junior respondents awarded higher ratings than their senior counterparts was for electronic modes in the second study. It can be argued that this may be ascribed to the fact that younger people (and thus often those in a more junior position) generally adapt to and adopt modern technologies more readily than the older generations. In the first study, where very low ratings were awarded to this mode, a reversal to this pattern occurs. At the time of the 1990/1 study the main use of electronic modes was for online searching by means of vendors such as Dialog. These services were expensive and searches were also generally conducted by some intermediary and the more senior respondents were thus in a better position to request and afford such services.

5.3. PREFERRED MODES OF INTERPERSONAL COMMUNICATION

Having established the main categories of modes and channels that the crystallographers used in the information communication process, it was decided to investigate channel and mode use in greater detail. The first aspect that the respondents were thus asked to discuss was interpersonal communication and to specifically indicate their preferred modes of interaction when

communicating with colleagues at work, within South Africa, and finally with colleagues abroad (cf. Question C5, Appendix B & C). The answers provided by the respondents were grouped into the following four main interpersonal communication mode categories:

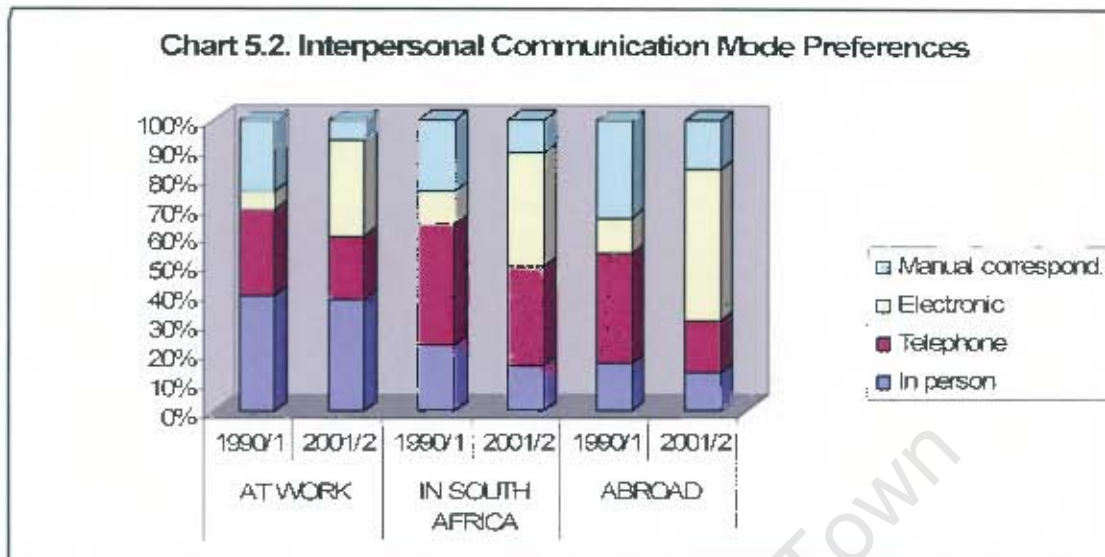
Face-to-face interaction; using the telephone; electronic modes such as e-mail; and manual methods of correspondence such as letter writing.

The respondents' aggregated value ratings for each mode at work, in South Africa and abroad are outlined in Table 5.4. and Chart 5.2 below (a rating scale of 10 [used very frequently / very highly rated] to 0 [not used / of no value] was applied).

TABLE 5.4. Interpersonal Communication Mode Preferences						
	Means					
	AT WORK		IN SOUTH AFRICA		ABROAD	
	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
In person	9.8	8.8	3.8	3.3	2.3	2.4
Telephone	7.3	4.9	6.9	7.1	5.4	3.2
Electronic	1.6	7.6	1.9	8.3	1.8	9.5
Manual correspond.	6.0	1.5	4.1	2.3	4.8	3.1

The results obtained from both the studies clearly indicate that within the immediate work environment by far the preferred mode of interpersonal communication was direct face-to-face communication, and it can further be seen that this mode attracted particularly high ratings in the first study. In 1990/1 the next most important mode was telephonic communication followed by manual correspondence, while electronic modes hardly featured. The situation changes considerably in the second study and it can be seen that electronic modes generally replaced manual correspondence and telephonic communication in importance (the former more so than the latter). It is probably also the reason why the face-to-face mode preference rating dropped slightly.

If communication within South Africa is considered, the data for 1990/1 shows that the preferred mode of communication was using the telephone, followed by manual correspondence and face-to-face interaction, while electronic modes attracted very low ratings. In 2001/02 there is once again a reversal with electronic modes becoming the dominant mode of interaction followed closely by telephonic communication. The responses with regard to communication outside South Africa followed a fairly similar pattern to that obtained within the borders. The only significant difference pertains to the 2001/02 results where the importance of telephone use dropped considerably in favour of the use of electronic modes.



To establish whether the outcomes for the two studies showed statistically significant differences, the data for the two studies were subjected to the t-test for dependent samples. Table 5.5. reflects the results of the t-test and it can be seen that in most instances highly significant statistical differences ($p \leq 0.001$) were obtained between the responses of the two studies. The only instances where this did not occur were for the use of the telephone within South Africa and face-to-face communication with contacts abroad.

It is clear that the most consequential difference between the results of the two studies with regard to interpersonal mode preferences was the considerable increase in the use of and preference for electronic modes in the second study. It can be seen that as the distance between the persons interacting increases (and thus cost implications become significant) electronic modes have almost supplanted other forms of interpersonal communication. The use of manual methods has steeply declined over the last few decades and has become virtually irrelevant in the twenty first century.

**Table 5.5. T- Test for Significant between study differences:
Interpersonal Media Preferences, 1990/1 & 2001/2**

	Mean	Std. Dv.	N	t	p
Telephone					
At work 1990/1	7.3	1.8	80	-10.325	0.000
At work 2001/2	4.9	3.2	78		
S Africa 1990/1	6.9	3.7	80	2.533	0.513
S Africa 2001/1	7.1	3.8	78		
Abroad 1990/1	5.4	2.1	80	-15.776	0.000
Abroad 2001/2	3.2	2.7	78		
Manual correspond.					
At work 1990/1	6.0	1.0	80	-40.670	0.000
At work 2001/2	1.6	1.7	78		
S Africa 1990/1	4.1	1.7	80	-14.307	0.000
S Africa 2001/1	2.3	2.5	78		
Abroad 1990/1	4.8	2.9	80	-15.357	0.000
Abroad 2001/2	3.1	3.3	78		
Face-to-face					
At work 1990/1	9.8	0.6	80	-3.763	0.000
At work 2001/2	8.8	2.6	78		
S Africa 1990/1	3.8	2.0	80	-3.381	0.001
S Africa 2001/1	3.3	2.9	78		
Abroad 1990/1	2.3	1.8	80	2.040	0.444
Abroad 2001/2	2.4	1.8	78		
Electronic					
At work 1990/1	1.6	0.7	80	18.447	0.000
At work 2001/2	7.6	3.1	78		
S Africa 1990/1	1.9	1.7	80	13.569	0.000
S Africa 2001/1	8.3	2.8	78		
Abroad 1990/1	1.8	0.6	80	36.021	0.000
Abroad 2001/2	9.5	1.8	78		

Differences marked in red are significant at $p < .05000$

5.3.1. PREFERRED MODES OF INTERPERSONAL COMMUNICATION ACCORDING TO SUB-CATEGORIES OF THE POPULATION

The data was further analysed by cross tabulating the dependent variables of interpersonal communication mode preferences with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were used to test for significance between the means of these cross tabulations. Significant differences were scored for both the 1990/1 and 2001/02 datasets for categorisation according to the work environment and crystallographic application. The Wilks' lambda measures of association ranged between $\lambda = 0.42$ and $\lambda = 0.17$. These results are outlined in Table 5.6. below.

It is clear that within the immediate work situation the university and industry respondents

showed a marked preference for face-to-face interpersonal interaction modes (this applied to both 1990/1 and 2001/02). The research institute respondents also showed this preference in 1990/1, but in the 2001/02 study they rated this mode slightly lower than electronic interpersonal communication. The other marked variation in the 2001/02 study was between the industry respondents and the other two work environments where the former gave a far lower rating for electronic modes than the other respondents.

TABLE 5.6. Interpersonal Channel Preferences by Population Sub-categories (Significant results)

Work Environment	Means												N
	AT WORK				IN SOUTH AFRICA				ABROAD				
1990/1	Teleph.	Corresp.	In pers.	Electr.	Teleph.	Corresp.	In pers.	Electr.	Teleph.	Corresp.	In pers.	Electr.	
INDUSTRY	7.9	5.5	9.9	1.4	9.0	3.1	6.0	4.1	7.8	3.1	4.2	1.6	14
RESEARCH	7.8	5.9	9.5	1.6	8.1	3.4	3.9	2.6	5.7	4.6	2.3	1.9	18
UNIVERSITY	7.0	6.2	9.3	1.7	5.9	4.7	3.0	1.0	4.6	5.4	1.8	1.9	48
1990/1 WORK ENV; LS Means Wilks lambda=.42292, F(24, 122)=6.1490, p=.00000													
2001/2													
INDUSTRY	5.2	1.0	9.1	3.7	8.7	1.0	6.8	6.4	6.9	1.0	5.1	8.5	11
RESEARCH	5.2	1.0	7.1	7.9	9.1	2.2	2.4	7.1	3.4	2.2	2.4	10.0	17
UNIVERSITY	4.7	1.8	9.3	8.3	6.1	2.6	2.8	9.1	2.3	3.9	1.8	10.0	50
2001/2 WORK ENV; LS Means Wilks lambda=.17182, F(24, 128)=7.5331, p=.00000													
Crystal. Application													
1990/1													
APPLIED	7.8	5.7	9.7	1.5	8.5	3.3	4.8	3.3	6.6	3.9	3.2	1.8	32
TOOL	6.8	6.2	9.7	1.5	5.7	4.6	2.4	1.0	4.5	4.5	1.6	1.8	22
PURE	7.2	6.2	9.9	1.9	6.0	4.7	3.6	1.0	4.7	6.2	1.9	1.9	26
91 A/P/T; LS Means Wilks lambda=.31853, F(24, 134)=4.2451, p=.00000													
2001/2													
APPLIED	4.9	1.0	8.1	6.2	8.5	1.8	4.3	6.8	4.5	1.8	3.4	8.7	29
TOOL	4.3	1.7	8.6	8.0	6.0	3.0	3.1	9.4	2.5	3.9	2.1	10.0	24
PURE	5.3	2.0	9.6	8.8	6.6	2.5	2.1	8.9	2.3	4.1	1.5	10.0	25
91 A/P/T; LS Means Wilks lambda=.42176, F(24, 128)=2.8790, p=.00000													

The industry and research institute respondents rated the use of telephones for interpersonal communication within South Africa far higher than their university counterparts (both studies). The latter group, in turn, rated manual correspondence (in 1990/1) and electronic modes (in 2001/02) far higher than the other two environments. The industry respondents further also rated face-to-face contact within South Africa far higher than the other groups. This work environment once again awarded higher ratings to the use of the telephone and face-to-face interaction when communicating abroad (both studies); while the university respondents gave higher ratings for manual correspondence than the other two work environments (both studies). Far higher scores were given by the university and research institute respondents than the industry respondents for electronic modes of interpersonal communication in 2001/02.

The differences between the work environments' preference for electronic modes of interpersonal communication could be attributed to a greater tendency for scientists at universities and research institutes to be *early adopters* of new innovations and also of industry's wariness of electronic

security breaches. The explicit preference expressed by the industry participants during the interviews for face-to-face contact, even if it meant travelling extensively to achieve this, or if that was not possible the use of the telephone rather than more indirect methods, was justified by stating that the value of immediate and reciprocal engagement far outweighed the direct costs involved. The university respondents operated under far more stringent budget constraints than their counterparts in the research institutes and even more so than the industry scientists. This would explain that while within their own institutions they were very much in favour of face-to-face communication they were not prepared or able to travel to achieve this.

If the variation between the responses obtained from the three crystallographic application categories are examined it can be seen that although there are slight differences between the responses of the *pure* and *tool* crystallographers, the greatest variation pertained to the *applied* crystallographers. The latter group were generally the least inclined to engage in indirect methods of interpersonal communication (such as manual correspondence and electronic communication), and consequently generally showed a greater preference for face-to-face and telephonic modes of interpersonal communication. These differences were particularly marked when communicating outside their own work environment. It is suggested that these variations can be attributed to the fact that almost all the crystallographers who classified themselves as working in the applied field were attached to either a research institute or to some industry and the *applied* pattern thus closely follows that of the combined research institute and industry responses.

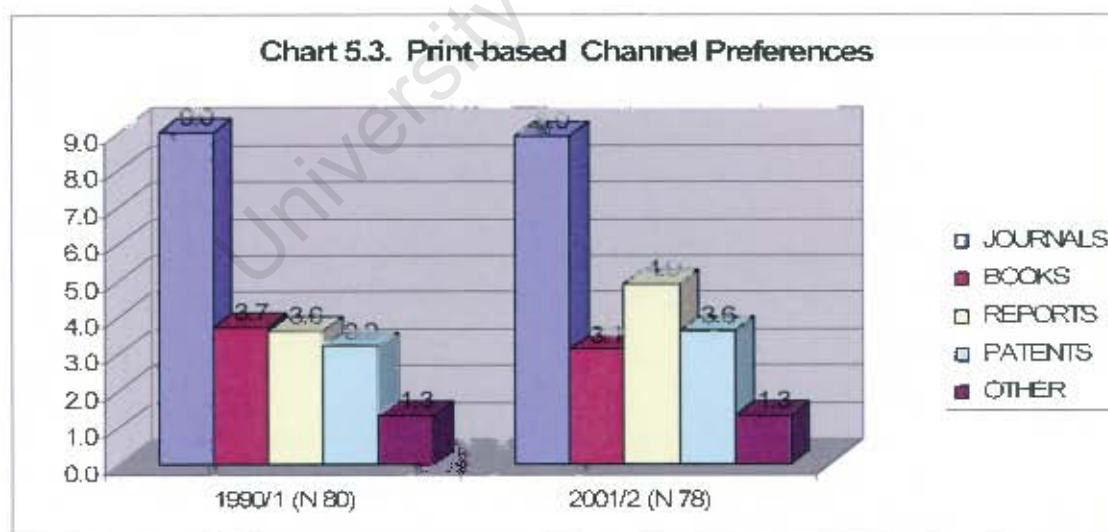
5.4. PRINT-BASED INFORMATION COMMUNICATION CHANNEL PREFERENCES

Studies that have investigated channel selection have generally found that disciplinary affiliation and the nature of the work engaged in has a significant affect on channel selection and use. Information channels that are more closely attuned to the work situation are therefore most frequently utilised and valued and it has for example been found that while scholarly journals are the most frequently used and valued information channel in the basic sciences, applied scientists working in industrial environments again value internally produced reports and patent specifications far higher (cf. chapter 2.4.2. and 2.4.3.). To establish the categories of print-based information communication channels that the crystallographers generally used and preferred the respondents were asked to indicate and rate the most important print-based channels used in their work environment (cf. Question C6, Appendix B & C). From the responses received it became

clear that the main channel categories that were used by the respondents were journals, monographs, internally produced reports, patent specifications, and a variety of other lesser used sources that ranged from review publications, to reference works to trade literature.

The average rated responses for the value awarded to each channel category are outlined in Table 5.7, and depicted in Chart 5.3, below (a rating scale of 10 [used very frequently / very highly rated] to 0 [not used / of no value] was applied). It is clear that journals were by far the most valued print-based information communication channel that was used by the crystallography community as a whole (this applied to both studies). Not one of the other categories attracted high ratings, other than reports that in 2001/02 was given a moderately important rating. The *other* channels that were used were specifically awarded very low ratings in both studies.

Table 5.7. Print-based Information Communication Channel Preferences					
Mean ratings					
	JOURNALS	BOOKS	REPORTS	PATENTS	OTHER
1990/1 (N 80)	9.0	3.7	3.6	3.2	1.3
2001/2 (N 78)	8.9	3.1	4.9	3.6	1.3



The t-test for dependent samples indicated that there were statistically significant differences between the two studies for the results obtained for books, reports and patent specifications with levels of significance, $p \leq 0.034$ (cf. Table 5.8, below). In the second study the rating awarded to

books dropped slightly, while the ratings given to patent specifications increased slightly and those for reports increased quite considerably. The latter two increases can be interpreted in the light of the comments made in Chapter 4 that referred to changes in organisational ethos at the universities, but particularly the research institutes where greater emphasis was being placed on income generating contract research and the subsequent greater reliance on report and patent literature.

**Table 5.8. T-Test for significant between-study differences:
Print-based Channel Preferences 1990/1 & 2001/2**

		Mean	Std.Dv.	N	Diff.	t	p
1990/1	JOURNALS	9.0	1.304	80	-0.115	-0.953	0.343
2001/2	JOURNALS	8.9	1.642	78			
1990/1	BOOKS	3.7	1.640	80	-0.615	-3.789	0.000
2001/2	BOOKS	3.1	1.768	78			
1990/1	REPORTS	3.6	3.440	80	1.333	5.466	0.000
2001/2	REPORTS	4.9	3.111	78			
1990/1	PATENTS	3.2	3.313	80	0.410	2.159	0.034
2001/2	PATENTS	3.6	3.442	78			
1990/1	OTHER	1.3	0.923	80	-0.064	-0.583	0.562
2001/2	OTHER	1.3	0.737	78			

Differences marked in red are significant at $p < 0.050$

5.4.1. PRINT-BASED INFORMATION COMMUNICATION CHANNEL PREFERENCES ACCORDING TO SUB-CATEGORIES OF THE POPULATION

The data was further analysed by cross tabulating the dependent variables of preferred print-based information communication channels with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were used to test for significance between the means of these cross tabulations. Significant differences were scored for both the 1990/1 and 2001/02 data-sets for categorisation according to the work environment, crystallographic application, and position. These results are outlined in Table 5.9, below.

Table 5.9. Printed-based Channel Preferences by Population Sub-categories (Significance in all)

	Journals		Books		Reports		Patents		Other		N	
	1990/1	2001/02	1990/1	2001/02	1990/1	2001/02	1990/1	2001/02	1990/1	2001/02	1990/1	2001/02
Work Environment												
Industry	6.7	5.7	1.7	0.9	9.1	9.1	9.0	9.3	0.3	0.4	13	11
Research	8.6	8.2	2.7	1.6	6.2	7.8	5.1	6.6	2.2	1.6	10	17
University	9.9	9.9	4.7	4.0	1.0	3.0	0.9	1.3	1.3	1.4	49	50
	2001/2 WORK EN; LS Means Wilks lambda=.83442, F(10, 142)=62.341, p=0.00000 1990/1 WORK EN; LS Means Wilks lambda=.91146, F(10, 146)=121.80, p=0.00000											
Crystal. Application												
Applied	7.8	7.3	2.3	1.6	7.2	8.0	6.6	7.4	1.4	1.1	31	29
Tool	9.8	9.8	4.5	4.0	1.0	3.1	1.4	1.5	1.6	1.6	23	24
Pure	9.9	9.9	4.8	3.9	1.0	3.0	0.5	1.3	1.1	1.2	28	25
	2001/2 Crystal. Application; LS Means Wilks lambda=.29187, F(10, 142)=17.405, p=0.00000 1990/1 Crystal. Application; LS Means Wilks lambda=.11908, F(10, 146)=29.205, p=0.00000											
Position												
Senior	9.2	9.3	2.9	2.7	4.6	6.4	4.1	4.0	2.0	1.3	33	33
Middle	9.2	8.8	3.6	2.9	2.9	4.8	2.9	4.3	1.2	1.3	24	24
Junior	8.8	8.5	6.0	3.8	2.5	2.6	2.1	2.3	0.7	1.2	23	21
	2001/2 POSITION; LS Means Wilks lambda=.30733, F(10, 142)=11.415, p=0.00000 1990/1 POSITION; LS Means Wilks lambda=.31904, F(10, 146)=11.248, p=0.00000											

The cross tabulation according to the work environment indicates that the industry respondents placed much higher value ratings on patent specifications and reports than on journals and particularly books and the 'other' channels. The university respondents in turn returned an almost 100% 'very important' response for journals and a higher than overall study population aggregate value rating for monographs. The research institute respondents manifested responses that reflected a position somewhat between that of the university and industry respondents by awarding almost equally high preference ratings to journals, reports and patents. The ratings they awarded to reports and patents increased in 2001/02, and this would tend to confirm the assertion made that the change in emphasis towards a more profit oriented approach in the workplace played a role in awarding a value rating to a specific channel (this increase is also evident, albeit less marked, between the 1990/1 and 2001/02 ratings given by the university respondents).

The differentiation according to crystallographic application once again shows that the *tool* and *pure* crystallographers emulated the university respondents and the *applied* crystallographers that of a combined research institute and industry responses.

If the responses according to position categories are considered, it can be seen that the more senior respondents placed a far higher value on patents and reports and a slightly higher value on journals than the junior positions categories. The junior position categories again placed a greater value on books.

5.5. ELECTRONIC MODES OF COMMUNICATION

When the respondents were asked in 1990/1 to discuss the role and impact of electronic media and communication networks on the information communication process (cf. Question C7, Appendix B) it was found that the respondents at that time had minimal interaction with such media and networks. The limited interaction that did take place was restricted to searching electronic bibliographic databases by means of vendor services and an intermediary; being the recipients of electronic SDI output; referring to the CD-ROM version of the Cambridge Crystallographic database for structural data; and the hitherto infrequent usage of communication networks such as BIDNET that were available in South Africa at the time.

The respondents were again queried in 2001/02 on their interaction with the electronic environment (cf. Question C7, Appendix C). From the responses received and comments made during the interviews it is clear that a marked shift in the use of electronic modes of communication had occurred in the intervening period between the two studies and that the electronic environment has had a considerable effect on the communication process.

The following comments recorded during the interviews clearly express the respondents' views on this topic:

E-mail and Internet have had a fundamentally positive impact on our possibilities to communicate and cooperate with colleagues all over the world very rapidly. Research projects can be organised without any personal contact and results/questions may be discussed almost instantly and at very low cost. Listservs and newsgroups are available for virtually all topics. At the same time, most necessary information, can be obtained through the Internet. The research world has become a much more close-knit world.

Most of our communication at work, especially to other local and international universities is done via e-mail. Apart from interpersonal communication, research information is communicated and shared by e-mail and the WWW. It has most definitely facilitated 'group associations, collaborative research, establishment of communities of practice'. In our research group alone we've established several overseas contacts by using the electronic communication media, probably as a result of the ease and speed of communication.

Electronic media have most certainly improved communication with colleagues both in South Africa and overseas. Scientific data can to some degree be freely exchanged between researchers with the aid of electronic media. Research results can be more readily compared and different viewpoints easily discussed between different groups regardless of their geographical position. This is vital for collaborative research.

Electronic media have had very little influence at work, but elsewhere in South Africa they have facilitated more frequent communication and greatly improved frequent and rapid communication worldwide. Things have been sped up so much by electronic communication that time to actually think about results

thoroughly before publishing them has become a real problem.

Our department is spread out over 3 buildings making face-to-face communication difficult. E-mail is a far more effective method of getting information to a large number of people than a memo, and much quicker than making 20 phone calls. E-mail is my chief means of communication elsewhere in South Africa, it is a more reliable method to ensure that a message reaches its destination than the ordinary post. I find it easier than making a phone call as one can clearly express exactly what one wants to know or say since one has time to go over the message. I do all my overseas communication by e-mail and it has assisted with the development of collaborations.

Electronic media has impacted positively on the communication at work, elsewhere in South Africa and overseas. It is an easy way to communicate with a large number of people and it is the only way of communicating with scientists in Africa and is most probably going to save scientific research in Africa in the long run.

Email is a vital tool in communication. It offers the option of adding attachments that add a vital functionality for exchanging information which can take on a variety of forms. This is not possible with more conventional media like fax, letters, telephone and even personal interaction. It has opened the door to the "outside" world and made communication with workers within the country and beyond as easy as communication with workers in ones immediate physical location.

5.5.1. THE IMPACT OF ELECTRONIC MEDIA ON INFORMATION COMMUNICATION AND ON INTER-PERSONAL INTERACTION

The respondents were further specifically requested to comment on and rate the impact that the use of electronic media had had on the general communication of information in their immediate work environment, elsewhere in South Africa and finally worldwide (cf. Question C.7.a., Appendix C) They were also asked to indicate the effect that the use of electronic communication media had had on interpersonal interaction with colleagues and other experts, e.g. had it facilitated or possibly inhibited group associations, collaborative research, etc. (cf. Question C.7.b., Appendix C). A rating scale of 10 [used very frequently / very highly rated] to 0 [not used / of no value] was applied and the aggregate ratings obtained from the study population are outlined in Table 5.10. and depicted in Chart 5.4. below.

Rated Means	In General			Inter-personal Interaction
	At work	In South Africa	Worldwide	
2001/2 (N 78)	7.7	7.5	8.5	6.3

It is clear that the respondents in all instances were of the opinion that electronic media had made a positive impact, albeit in varying intensity. The highest rated impact was for worldwide information communication (8.5), while the use of electronic media for inter-personal communication attracted the lowest ratings (6.3). The reason for the former rating relates to the ease and relative low cost of using electronic media and systems to access information from anywhere in the world, while the latter lower rating is in line with the general preference for face-to-face interpersonal communication that was expressed during the interviews. The following are extracts from the comments made in this regard:

Face-to-face meetings are important for motivational purposes but for information exchange e-mail is better.

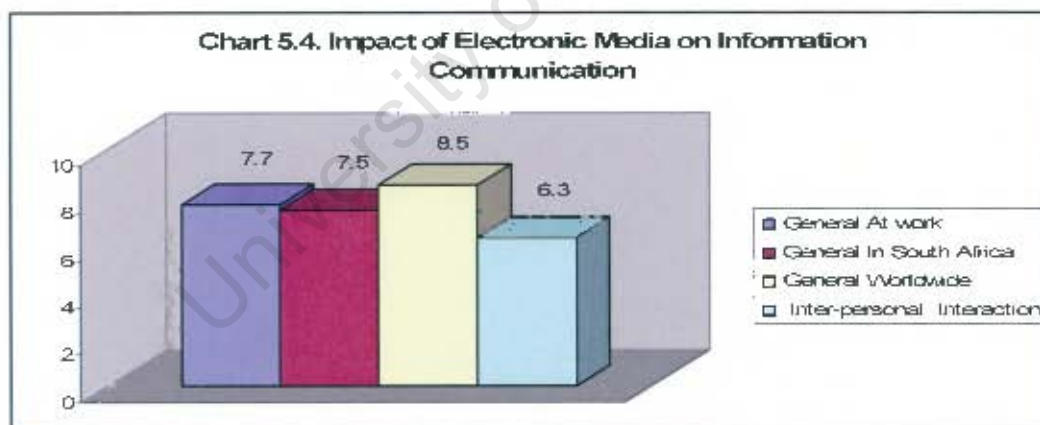
I still prefer face-to-face communication as it is still the most effective method to communicate ideas.

The ideal is face-to-face communication, followed by telephone and e-mail, which are on a par to me.

Face-to-face communication is always preferable, but e-mail communication is fast and has virtually become the norm.

I prefer personal communication, but if I need to reach a large group of people then I use email.

It is not always possible to interact face-to-face and virtual contact is a vital form of staying in touch.



5.5.1.1. Impact of electronic media on information communication according to the population sub-categories

The data was further analysed by cross tabulating the impact values of electronic media with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were used to test for significance between the means of these cross tabulations. The only

significant differences that were obtained for the 2001/02 data-set was for categorisation according to the work environment. The Wilks' lambda measure of association recorded a strong association of λ of 0.78. These results are outlined in Table 5.11. below.

Rated Means	General	General	General	Inter personal	
WORK ENVIRONMENT	At work	In South Africa	Worldwide	Interaction	N
Industry	6.0	7.2	7.6	5.0	11
Research institutes	7.8	7.1	7.6	5.6	17
University	8.0	7.7	9.0	6.8	50

2001/2 WORK EN; LS Means Wilks' lambda=.7755, F(8, 144)=2.4131, p=.01785

There was significant variation in the impact ratings given by the three work environments for the effect of electronic media on information communication within their immediate work situation, worldwide, and also for inter-personal interaction. The university and research institute respondents indicated a far greater impact within their immediate work situation than the industry respondents, while the university respondents again returned higher ratings for the impact on worldwide information communication and inter-personal interaction than both the industry and research institute respondents. It would thus appear that the greatest positive impact of electronic media was observed by the university respondents and that the industry respondents were the least influenced.

5.5.2. INFORMATION SEARCHING AND THE USE AND VALUE OF VARIOUS ELECTRONIC INFORMATION COMMUNICATION CHANNELS

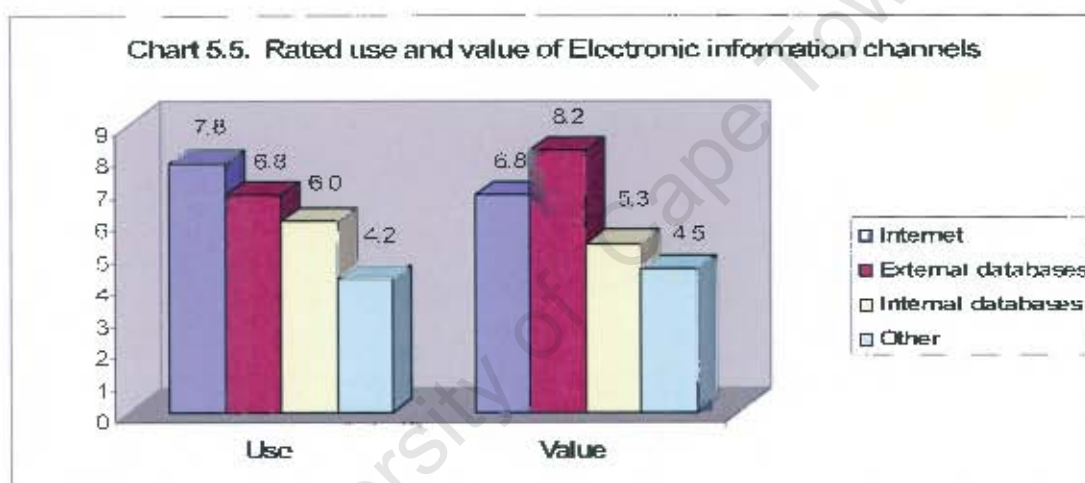
The 2001/02 respondents were further probed on the electronic information channels they most frequently used when searching for work-related information and then asked to rate the value of each channel on a rating scale of 10 (used very frequently / very highly rated) to 0 (not used / of no value). The electronic channels that were mentioned fell into one of the following categories:

- The Internet and the World Wide Web (WWW)
- External databases (e.g. CD-ROM's) that their organisations subscribed to
- Internally produced databases that were available on their Intranets
- Other sources which included *subject gateways, portals, etc.*

The aggregated use frequencies and value ratings for each of the above categories are depicted in Table 5.12. and Chart 5.5. below.

Table 5.12. Electronic information channel use and value								
2001/2 (N 78)	Internet		External databases		Internal databases		Other	
	Use	Value	Use	Value	Use	Value	Use	Value
Rated Means	7.8	6.8	6.8	8.2	6.0	5.3	4.2	4.5

The most frequently used electronic channels for information-seeking purposes were the Internet/WWW followed by external databases subscribed to, internally produced databases and other channels. It is interesting that the value ratings did not mirror the usage ratings and externally produced databases such as CD-ROM's subscribed to, far outranked the Internet, the channel used most frequently. The databases their own organisations produced, surprisingly, attracted fairly low usage and value ratings.



The following pertinent comments were recorded relating to the varying views the respondents had on the value of electronic media when searching for information:

The INTERNET is often useful when starting a new research project to get oriented while subject gateways, portals are more useful to get more detailed information afterwards. CD-ROM databases are good to conduct a literature search or to obtain lateral information concerning a specific subject or publications of an author of interest. This I follow up by contacting other workers in the field and as a last resort going through the journals manually.

One is often swamped by useless information on the INTERNET and using it may be quite time-consuming. Subject gateways / portals are very useful and CD-ROM databases are absolutely essential.

CD-ROMs are important when embarking on an initial search for information, following this I find further information by tracing citations/references in articles that I have read and found pertinent. The Internet and e-journals are particularly useful to keep-up-to-date in my field. I usually start with an Internet search,

followed by a journal search and then I use links obtained from these to search further. This may include other media such as CD ROMS, establishing personal contact etc.

Electronic databases are often incomplete or fail due to inadequate search engines and search strategies. I find the most useful literature by searching for recent review articles in a specific field, finding out who does the most relevant work in that area, searching for their papers in library databases and then using these, and references cited in them to expand the information database. I also use a current electronic database, updated every 6 months, that we subscribe to as an important starting point when looking for something specific.

5.5.2.1. Information searching and the use and value of various electronic information communication channels according to the population sub-categories

Analysis of variance (ANOVA) statistics that were used to test for significance when the electronic information channel use data was cross tabulated showed significant differences for categorisation according to the work environment and application of crystallography. These results are outlined in Table 5.13. below.

	Internet		External databases		Internal databases		Other		N
	Use	Value	Use	Value	Use	Value	Use	Value	
Work Environment									
Industry	3.6	3.7	5.5	9.1	9.1	7.3	1.8	1.5	11
Research	7.1	4.3	2.4	5.6	7.9	6.8	2.9	4.1	17
University	8.9	8.1	8.6	8.9	4.7	4.3	5.1	5.2	50
2001/2 Work Environment, LS Means Wilks' lambda=.29373, F(16, 135)=7.1835, p=.00000									
Crystal Application									
Applied	5.7	4.5	4.0	7.1	7.9	6.7	2.9	3.4	29
Tool	9.2	8.5	8.1	9.0	5.4	5.4	4.2	5.0	24
Pure	8.8	7.8	8.8	8.8	4.4	3.4	5.6	5.2	25
2001/2 Crystal Application, LS Means Wilks' lambda=.48822, F(16, 135)=3.8825, p=.00001									

The industry respondents clearly not only used the Internet infrequently, but also assigned low value ratings to this channel. This is not a surprising outcome given the comments made by the industry respondents with regard to the security restrictions that many of them operated under and which prevented them from freely using the Internet. They further, although using external databases only moderately, assigned very high value ratings to this channel. The value ratings they awarded to internally produced databases were surprisingly not as high as their very high frequency of use for this channel would have led one to expect.

The research institute respondents also showed fairly marked differences between the use and value ratings they awarded to electronic information channels. Although they used the Internet frequently, they also awarded low value ratings to this channel, and while indicating a very low

use of external electronic databases they awarded fairly good value ratings to them. The use and value ratings they awarded to internally produced databases were high, a clear indication of the quality of such internally produced databases.

The university respondents were the only work environment category that assigned almost equal use and value ratings to the electronic information channels they used. The Internet and external databases were very heavily used by them and rated highly. It is not clear why this result was obtained, given the predominantly negative comments made of the value of information found on the Internet. The low use and value ratings awarded to internally produced databases was not surprising as this work environment generally had less proactive library services than the other two. They were also the only work environment category to award moderate use and value ratings to 'other' channels such as subject gateways and portals.

It is once again clear that the variation in the cross tabulations for the three crystallography application categories showed similarity between the responses of the *pure* and *tool* respondents on the one hand and the university respondents on the other, while the applied crystallographers, again returned responses somewhat between that of the industry and research institute responses.

5.5.3. THE USE AND VALUE OF ELECTRONIC JOURNALS

A number of studies have indicated that journals are considered to be the most valued information communication channel by scientists in general. This fact was confirmed by the results obtained pertaining to print-based journals (cf. 5.4.) and the researcher thus wished to establish to what extent electronic journals were being used; what value was attributed to them as an information source and as a publication medium; and how they rated in comparison to print journals (cf. question C.7.d., Appendix C). The aggregate rated responses to these questions are outlined in Table 5.14.a & b and Charts 5.6. a. & b. below.

Table 5.14. Electronic journals:			
a. Mean Rated Use and Value			
2001/02 (N 78)	Frequency of use	Value as Info source	Value as Publ medium
	5.7	7.4	3.2
b. Compared with Print journals (% scores)			
Print jnls more important	Equally important	E-jnls more important	Don't know
67%	24%	3%	6%

From the table and charts it is clear that although electronic journals were only used moderately, their information content was highly valued. They were further also not really used as a vehicle to publish research in. When compared to print journals only 3% of the respondents rated them higher than print journals while 67% rated print journals higher. From the comments made it would appear that the respondents were not that concerned about the mode of the communication channel, but were more concerned about availability and access. The slow speed of electronic access is notorious in South Africa due to bandwidth problems and the range of journals available in electronic format at the time of the study was fairly limited. A further concern that was expressed and which related particularly to publication aspects was that of the archiving problems that pertain to electronic formats. Respondents were also concerned that they might only reach a limited audience if they were to publish in the electronic mode. The following extracts express a typical view of the respondents' opinions on this matter:

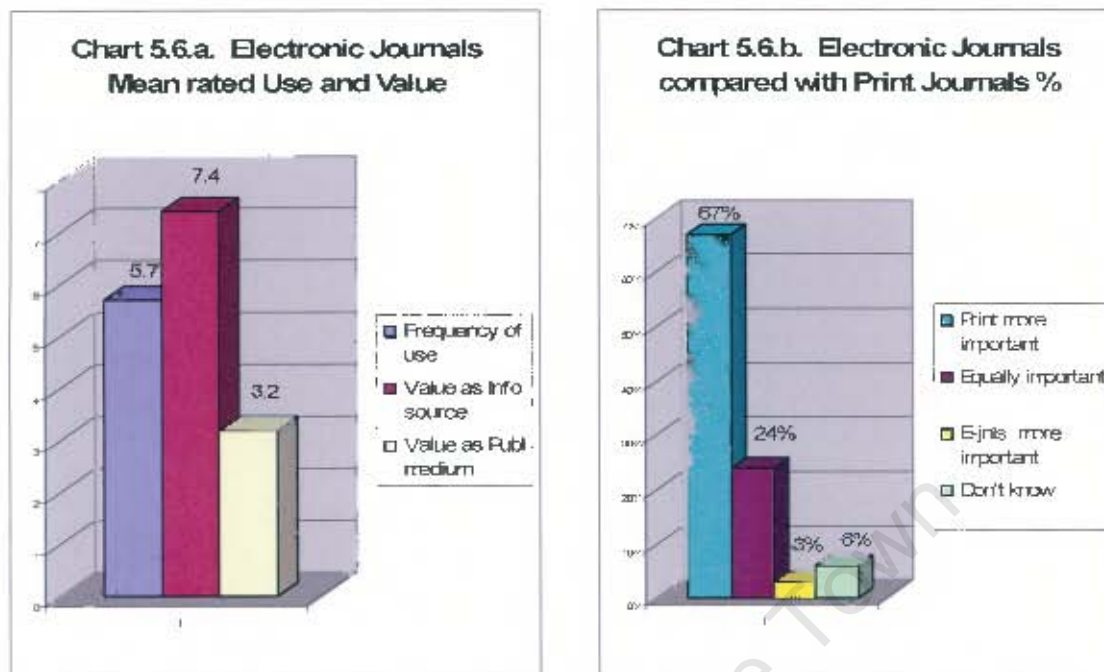
In South Africa the use of e-journals is extremely difficult because of the slow network and limited number of subscriptions. I am also personally suspicious of electronic only journals because not convinced that their archiving policy is sufficiently firm to guarantee the reading of a paper in say 20 years time.

I would be very happy if electronic journals were to replace printed journals. Journal issues contain only a few articles of interest and with e-journals only those articles of interest could be printed, avoiding a lot of wastage. Also, electronic journals are available to everyone immediately. It is a pity that electronic journals are not more generally available in South Africa - this would give researchers in this country a real competitive edge.

Printed media are indispensable at present for archival information and overview reading.

Most of the journals that I prefer to publish in are still only available in print format. It is not the electronic format that is not the worry, it is whether the journal is rated and reaches a wide audience and I am not yet convinced that electronic journals do that.

These responses of course reflect the position at the time of the study (2001/2) and it can be argued that opinions might have changed in the interim period as was observed by Tenopir and co-workers (2003) when they differentiated between the evolving and advanced stages of electronic media adoption (cf. also Hallmark, 2003, 2004 and chapter 2.6.)



5.5.3.1. The use and value of electronic journals according to the population sub-categories

The data was further analysed by cross tabulating the value and use of electronic journals with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were used to test for significance between the means of these cross tabulations. The Pearson's chi-square test¹⁹ was used to measure the statistical significance of the percentage variation between the categorical preference ratings for print and electronic journals. Significant differences were scored in both instances for categorisation according to work environment and application of crystallography. These results are outlined in Table 5.15.a & b below.

The measures of association were very significant for variation according to work environment for both the assessment of e-journal use and value (Wilks' $\lambda = 0.43$; $F = 12.6$) and comparison with print journals ($\chi^2 = 42.3$; $\text{phi}^{20} = 0.74$). It is clear that the respondents in industry made the

¹⁹ Pearson's chi-square test (χ^2) is a non-parametric test of statistical significance and is one of a variety and the most widely-used chi-square test. It tests a null hypothesis that the relative frequencies of occurrence of observed events follow a specified frequency distribution. Pearson's chi-square can be used to assess both goodness of fit (i.e. whether or not an observed frequency distribution differs from a theoretical distribution) and tests of independence (i.e. whether paired observations on two variables, expressed in a contingency table, are independent of each other) (Agresti, 1996: 231-236; Bohmstedt & Knobe, 1994:167).

²⁰ Phi is a symmetric measure of association that indicates the strength of variation between pairs of discrete variables. Phi is derived by dividing a χ^2 value by N (the total number of observations) and then squaring the root of the product and is also interpreted as a Pearson r. Its values range between -1.00 and 1.00 (maximum association relationship) and 0.00 that indicates no relationship (Bohmstedt & Knobe, 1994:158).

least use of electronic journals, rated their value the lowest, hardly rated them as a publication vehicle and were ambivalent as to whether they preferred print or electronic journals. The research institute respondents, although awarding the highest possible value rating to the information content of electronic journals, did not use this journal mode more than moderately, awarded very low publication value ratings to it, and they held the view that print journals are more important than electronic journals. The university respondents were the category that made the most frequent use of electronic journals, regarded their information value highly, and although rating their value as a publication vehicle fairly low, still gave the highest rating for this aspect of the three work environments. Almost two thirds of the university respondents gave a 'more important' rating to print journals, while just over one third rated electronic and print journals of equal importance.

The variation according to application of crystallography showed weaker correlations than that for work environment. In this instance the Wilk's λ was 0.82, and F was 2.5 for the use and value of e-journals, while when compared to print journals the χ^2 was 18.1 and phi was 0.48. This could once again be attributed to the fact that the applied crystallographers generally worked both in industry and in the research institutes and thus returned responses that represent an aggregate of that provided by the two work environments and the *pure* and *tool* crystallographers in turn all worked at universities.

Table 5.15. E-journals:						
a. Use & Value by population subcategories (significant results)						
Means	Frequency of Use	Information Value	Publication Value	N		
WORK ENVIRONMENT						
Industry	4.1	3.6	0.9	11		
Research Institutes	5.4	10.0	1.8	17		
Universities	6.2	7.3	4.2	50		
	LS Means Wilks lambda=.43465, F(6, 146)=12.576, p=.00009					
CRYSTAL APPLICATION						
Applied	4.9	7.4	1.6	29		
Tool	6.3	7.5	4.8	24		
Pure	6.2	7.2	3.6	25		
	LS Means Wilks lambda=.82303, F(6, 146)=2.4888, p=.02538					
b. Compared with Print Journals by population subcategories (significant results)						
WORK ENVIRONMENT	Print more important %	Equal importance %	E-jnts more important %	Don't know %	Total %	N
Industry	35%	12%	0%	45%	100%	11
Research Institutes	100%	0%	0%	0%	100%	17
Universities	62%	34%	4%	0%	100%	50
	Pearson Chi-square: 42.30761; df=6; p=.00000; Phi=.7364817					
CRYSTAL APPLICATION						
Applied	72%	10%	0%	17%	100%	29
Tool	67%	25%	8%	0%	100%	24
Pure	80%	40%	0%	0%	100%	25
	Pearson Chi-square: 18.11162; df=6; p=.00596; Phi=.4818715					

5.6. THE ROLE OF CONFERENCES IN THE COMMUNICATION PROCESS

It was mentioned in 2.5. that conferences have ever since their inception been highly valued for the role that they play in providing a forum to transfer and publicise current *state of the art* information. They are valued for not only promoting scientific and technological innovations, but also for facilitating the informal transfer of information by means of the collegiate process and for stimulating the exchange of ideas and opinions amongst attendants. They further thus provide a vehicle for scientists to make new, and maintain old interpersonal contacts.

5.6.1. INFORMATION COMMUNICATION VALUE OF CONFERENCES

The respondents were asked to indicate the role that conferences played in their work environment in facilitating the communication of scientific information and also to rate the value on a scale of 10 (used very frequently / very highly rated) to 0 (not used / of no value) (cf. Questions C8 – C10, Appendix B & C). The mean rated responses for both studies are outlined in Table 5.16. below, while the t-test for significant between study differences is given in Table 5.17 below.

Table 5.16. Mean Rated Value for Conference Attendance						
1990/1 (N 80)			2001/2 (N 78)			
6.3			7.0			

Table 5.17. T-Test for significant between-study differences: Value of conference attendance						
Rated Mean Values	Mean	Std.Dev.	N	Diff.	t	p
1990/1	6.3	2.520	80	0.782	1.995	0.050
2001/2	7.0	2.535	78			

T-test for Dependent samples: Differences in red are significant at p = 0.050

These responses corroborate those obtained in 5.2 and it thus confirms that while the respondents in both studies valued conferences, the 2001/02 ratings were significantly higher than those obtained in 1990/1.

As was mentioned in 5.2 this difference can be attributed to the fact that South African scientists, since the change in the political dispensation in 1994, are now encouraged to attend international conferences. The responses outlined in Table 5.16. are, however, not as high as was expected from the enthusiasm shown for conference attendance during the interviews. This lower than expected rating can be explained by the fact that international travel is prohibitively costly and this prevents many South African scientists from travelling abroad and participating at conferences as frequently as they would like to.

The following summary of the comments made during the interviews clearly indicate the scientists' views of the benefits of conference attendance:

- They furnish participants with the means to announce and publicise new research, work being done, products that have been developed, etc. to a knowledgeable, critical and interested audience.
- New research announced at conferences can often be as much as one to two years in advance of publication and are invaluable for keeping abreast of research fronts.
- Often, the only information available on a topic is transmitted through the medium of conferences as it may never formally appear in the published literature.
- Conferences thus provide an easy way to establish the 'state of the art' of a research area and insight into new directions, innovations, practice, equipment, etc. in a field.
- Conferences engender interactive communication, peer evaluation and immediate feedback from the experts in a field and the environment stimulates the generation of new ideas.
- They provide the opportunity to readily establish the identity, contributions, and activities of individuals, or groups in a field.
- Isolation can be effectively counteracted by attending conferences, particularly international conferences. This is of specific value to countries such as South Africa that are geographically isolated from the forefront of international activity.
- The benefit most frequently mentioned and enthused about was that they provide an ideal forum to establish contacts and nurture interaction among colleagues and fellow researchers across national boundaries and even across disciplines. Many individual researchers turn to small meetings, limited to a few selected specialists, as a means of informally keeping up-to-date and in touch with colleagues rather than try to cope with the rapid increase in published literature.

The data was analysed further to establish if there was variation in opinion among the population sub-categories. The ANOVA statistical tests again mirrored that obtained in 5.2.1, and showed significant differences for categorisation according to work environment and position for both 1990/1 and 2001/2; crystallographic application for 1990/1 and age for 2001/2. The results have been graphically depicted in Charts 5.7.a - d. below (the tables for these results mirror that presented in 5.2.1, and were not duplicated here).

Chart 5.7.a. Value of Conferences by Work Environment

1990/1: $F(2, 77)=7.5025, p=.001$
2001/2: $F(2, 75)=15.291, p=.000$

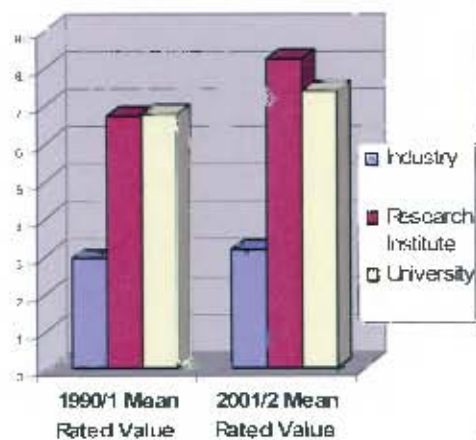


Chart 5.7.b. Value of Conferences by Crystal. Application

1990/1: $F(2, 77)=5.4753, p=.005$
2001/2: $F(2, 75)=11.710, p=.001$

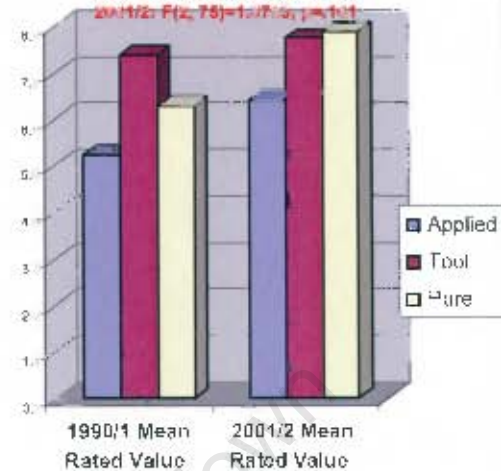


Chart 5.7.c. Value of Conferences by Position

1990/1: $F(2, 77)=145.08, p=0.000$
2001/2: $F(2, 75)=67.336, p=0.000$

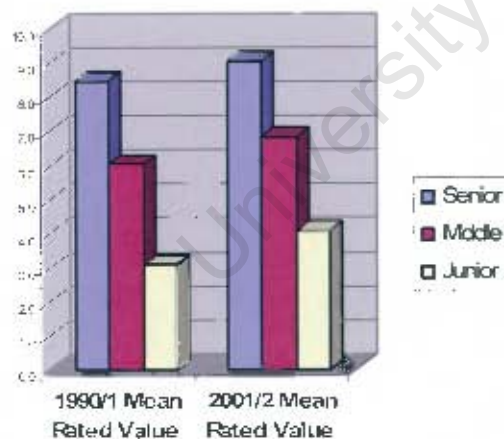
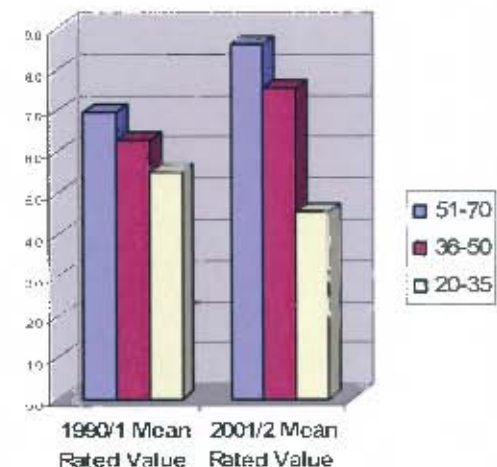


Chart 5.7.d. Value of Conferences by Age Range

1990/1: $F(2, 77)=1.8158, p=.169$
2001/2: $F(2, 75)=26.656, p=.000$



In summary it can be restated that the industry, the junior, youngest and to a far lesser extent the applied crystallography respondents awarded lower ratings to the value of conferences than the other categories. This trend applied to both studies and only the intensity of the value awarded

varied. It is further evident that the value of conferences increased incrementally with age and the seniority of the position. The latter trend can be explained by the fact that the more senior (and thus then generally older) the respondents the more established and eminent they had become and the more readily could they present papers and further also attract funding to attend conferences.

The low ratings returned by the industry respondents can be attributed to the following factors that emerged during the interviews (cf. also 5.2.1.):

- Most conferences are too theoretical and not tailored to meet their applied and often multidisciplinary needs
- International conferences have a limited value as research conducted elsewhere in the world is not always applicable to the local situation
- They cannot deliver papers as their research is confidential.

It is thus clear that although they do attend conferences and they do deliver the odd paper, the general consensus of this group was that, as they were more interested in new products and processes, they preferred to attend trade fairs that have direct relevance for their. They further commented that they find that by maintaining close ties with local universities they import new ideas and theoretical innovation more effectively than by being exposed to these issues at conferences, but they also did state that conferences can be very useful to make interpersonal contacts.

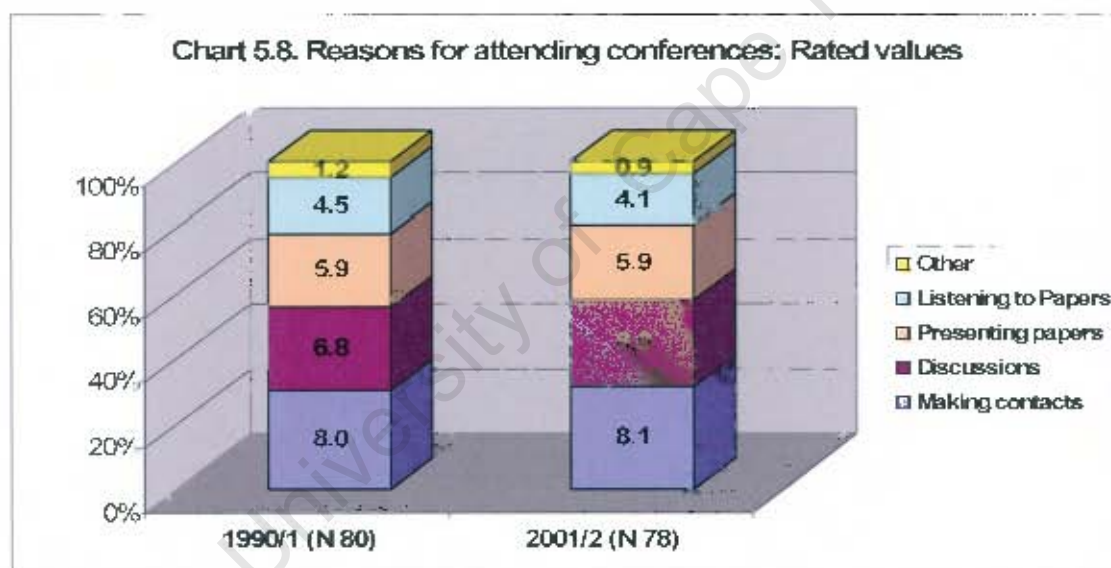
The high ratings given to conferences by the research institute respondents who are also generally engaged in research of a more applied nature, clearly indicates that they have been far more successful in bridging the divide between theory and practice. If the responses according to application of crystallography are considered, it can be seen that although the variation is not very substantial, the applied crystallographers returned the lowest ratings. This is mainly because the ratings of the applied crystallographers are clearly an aggregation of the industry and research institute responses where the low and high ratings offset each other. The *pure* and *tool* crystallographers showed very little variation, and while the former rated conferences slightly higher in the second study, the *tool* crystallographers reversed the value ratings in the 1990/1 study.

5.6.2. REASONS FOR ATTENDING CONFERENCES

In question C9 (cf. Appendix B & C) the respondents were asked to state the reasons why they attended conferences and to indicate the relative importance of each reason on a rating scale of 10

(very important) to 0 (not at all important). The responses received were grouped into the categories of *making contacts*, *holding discussions*, *presenting papers*, *listening to papers* and *other* (e.g. officiating, etc.). The mean importance rating for each category is outlined in Table 5.18. and Chart 5.8. below. The responses for both studies followed the same trend and by far the most highly rated reason for attending conferences was to make new and nurture old interpersonal contacts. Lower down the rating scale was discussions, both formal and informal, followed by presenting papers, listening to papers and a few other reasons such as officiating, organising the conference, etc.

Rated means	Making contacts	Discussions	Presenting papers	Listening to Papers	Other
1990/1 (N 80)	8.0	6.8	5.9	4.5	1.2
2001/2 (N 78)	8.1	6.9	5.9	4.1	0.9



The t-test that measured significant differences between the two studies showed no significant variation between the two studies at p levels < 0.05 (cf. Table 5.19. below).

Table 5.19. T-Test for significant between-study differences:

Reasons for attending conferences							
Means ratings		Mean	Std. Dev.	N	Diff.	t	p
Making contacts	1990/1	8.0	2.465	80	0.077	0.208	0.836
Making contacts	2001/2	8.1	2.284	78			
Discussions	1990/1	6.8	2.231	80	0.077	0.245	0.807
Discussions	2001/2	6.9	2.340	78			
Presenting papers	1990/1	5.9	3.067	80	0.038	0.178	0.859
Presenting papers	2001/2	5.9	2.725	78			
Listening to Papers	1990/1	4.5	1.912	80	-0.372	-1.663	0.100
Listening to Papers	2001/2	4.1	1.846	78			
Other	1990/1	1.2	1.636	80	-0.308	-1.292	0.200
Other	2001/2	0.9	1.299	78			

T test for Dependent samples: no differences were significant at $p = 0.050$

5.6.2.1. Reasons for attending conferences according to sub-categories of the population

The data was further analysed by cross tabulating the rated reasons given for attending conferences with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were used to test for significance between the means of these cross tabulations. Significant differences were scored for both the 1990/1 and 2001/2 data-sets for categorisation according to the work environment, crystallographic application, position, and age. These results are outlined in Table 5.20. below.

Table 5.20. Rated Reasons for Attending Conferences by Population Sub-categories (significant results)

	Making contacts		Discussions		Presenting papers		Listening to papers		Other		N	
	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
Work Environment												
Industry	9.1	8.3	5.7	6.4	1.1	0.9	2.1	2.2	1.3	1.2	14	11
Research	7.9	8.5	6.2	6.5	5.2	4.8	4.3	4.1	0.8	0.9	18	17
University	7.6	7.7	7.3	7.1	7.5	7.5	5.3	4.5	1.3	0.8	19	50
*1990/1 WORK ENV: Le Means Wilks lambda=.14638, F(10, 146)=23.563, p=0.00000 2001/2 WORK ENV: Le Means Wilks lambda=.38702, F(10, 142)=33.938, p=0.00000												
Application of Cryst.												
Application	8.4	8.9	6.0	6.6	3.4	3.5	3.4	3.6	1.0	1.2	32	23
Teach	8.6	8.0	8.0	7.6	8.1	7.5	4.6	4.2	1.3	0.7	22	24
None	6.8	7.3	6.7	6.5	7.2	7.3	5.8	4.7	1.2	0.7	25	25
*1990/1 Cryst. application: Le Means Wilks lambda=.34139, F(10, 146)=13.366, p=0.00000 2001/2 Cryst. application: Le Means Wilks lambda=.33005, F(10, 142)=13.518, p=0.00000												
Position												
Senior	9.7	9.9	8.7	8.7	7.2	7.2	3.8	3.1	1.7	1.6	33	33
Middle	6.7	6.5	7.0	7.3	6.0	5.5	4.4	4.1	0.8	0.6	24	24
Junior	4.7	4.9	3.7	3.5	4.0	4.5	6.9	5.7	0.8	0.0	23	21
*1990/1 POSITION: Le Means Wilks lambda=.07783, F(10, 146)=37.870, p=0.00000 2001/2 POSITION: Le Means Wilks lambda=.08185, F(10, 142)=35.516, p=0.00000												
Age Range												
23-34	5.7	5.5	4.8	4.3	4.8	5.3	5.7	5.4	0.6	0.7	24	22
35-40	8.9	8.8	7.3	7.5	5.8	5.6	3.9	3.6	1.0	1.1	37	30
51-70	9.0	9.4	8.1	8.3	7.7	6.9	4.3	3.6	2.2	1.2	19	26
*1990/1 AGE RA: Le Means Wilks lambda=.30332, F(10, 146)=5.4794, p=0.00000 2001/2 AGE RA: Le Means Wilks lambda=.33782, F(10, 142)=6.4276, p=0.00000												

The Wilks' λ and F statistic was the strongest for variation according to position (respectively 0.078, 38 and 0.081, 35.5 in 1990/1 and 2001/2002), followed by work environment (respectively 0.15, 23.6 and 0.087, 33.9 in 1990/1 and 2001/2002), then application of crystallography (respectively 0.341, 10.4 and 0.33, 10.5 in 1990/1 and 2001/2002), and finally age (respectively

0.50, 5.9 and 0.393, 8.4 in 1990/1 and 2001/2002).

It is clear that although all work environments rated 'making' contacts very highly; the industry respondents basically only attended conferences for the contacts they can make or maintain and to a lesser extent for discussions they can have with colleagues. It can further be seen that the more senior and older respondents and both the *tool* and the applied crystallographers also rated the networking feature of conferences very highly.

Engaging in formal and informal discussions at conferences was an important feature for all the work environments, but slightly more so for the university respondents than the other two work environments. The more senior and older respondents also valued this aspect higher than their junior and younger counterparts. It is further clear that the *tool* crystallographers rated discussions the highest of the three crystallography application groups.

The university respondents, the *tool* and *pure* respondents, the more senior and the older respondents rated the presentation of papers and posters far higher than any of the other population sub-categories. The younger and junior position respondents, in both studies, and the *pure* crystallographers in the 1990/1 study were the only categories that returned a higher than average importance rating to listening to papers as a reason for attending conferences.

5.6.3. CONFERENCE MODE PREFERENCE

In 1990/1 electronic modes were not generally utilised for conference presentations, but in the intervening period the situation changed considerably and the crystallographers were thus queried in 2001/2 on whether they engaged in this mode of conference participation. The overwhelming negative response (only 17% engaged with electronic conferences) was fairly surprising and on being explicitly asked to indicate their preference between traditional and electronic modes, the overwhelming majority indicated a preference for traditional conferences (94%).

The reason given for this very clear disinclination to engage in electronic conferences was that although the electronic format does overcome all travel-related problems and costs they do not provide the opportunity for face-to-face interpersonal interaction, and this in their view is the most important aspect of conference attendance. The outlined comments below clearly encapsulate these views:

Conferences serve a totally different function than other communication media such as e-mail, they are about networking, chance meetings and general impressions.

I have an overwhelming preference for the personal attendance of conferences particularly those that specialise in the theme I work in.

Electronic communication might eventually replace the need for large conferences, as costs are high and travelling is time consuming, but I find the main use of a conference is to meet on a one-to-one level.

Electronic conferences are not used by us, mostly due to bandwidth problems. I think though that I would always prefer personal attendance which enables personal contact.

Personal conference attendance is very suited to research development and the testing of new ideas.

5.7. INFORMATION GATHERING AND CHANNEL SELECTION

In chapter 2.1 it was seen that one of the main motivating forces that drive the information communication process in science is the need to gather information (the other is the scientists' need to transfer knowledge into the public domain, usually in the form of information, but also as a product, service, etc.). It is further suggested that information gathering is fundamentally driven by a trichotomy of information needs, viz.; a need to stay abreast of new developments in a specific field; a need for exhaustive information covering all aspects on a topic; and a need for information to answers specific questions. Each of these needs, it is suggested, would require the use of different information gathering methods, channels and modes of communication. To investigate these assumptions the respondents were therefore questioned on these aspects and asked to apply a rating scale of 10 [used very frequently / very highly rated] to 0 [not used / of no value] (cf. Questions C11 – C13, Appendix B & C.).

5.7.1. KEEPING UP-TO-DATE

It is generally accepted that it is a fundamental requirement that any person permanently engaged in research should keep up-to-date with the latest information being generated in his/her field of endeavour. The respondents were therefore requested to first discuss how they kept up-to-date and then to rate the usefulness of the methods that they used. An examination of the methods that the respondents mentioned could essentially be categorised into the following five methods:

- Regularly scanning current print journals or printed current awareness (CA) publications - categorised for the purposes of this study as scanning '*print media*'. The ratio was approximately 70:30 in favour of journal scanning vis-à-vis CA publication scanning for both studies.

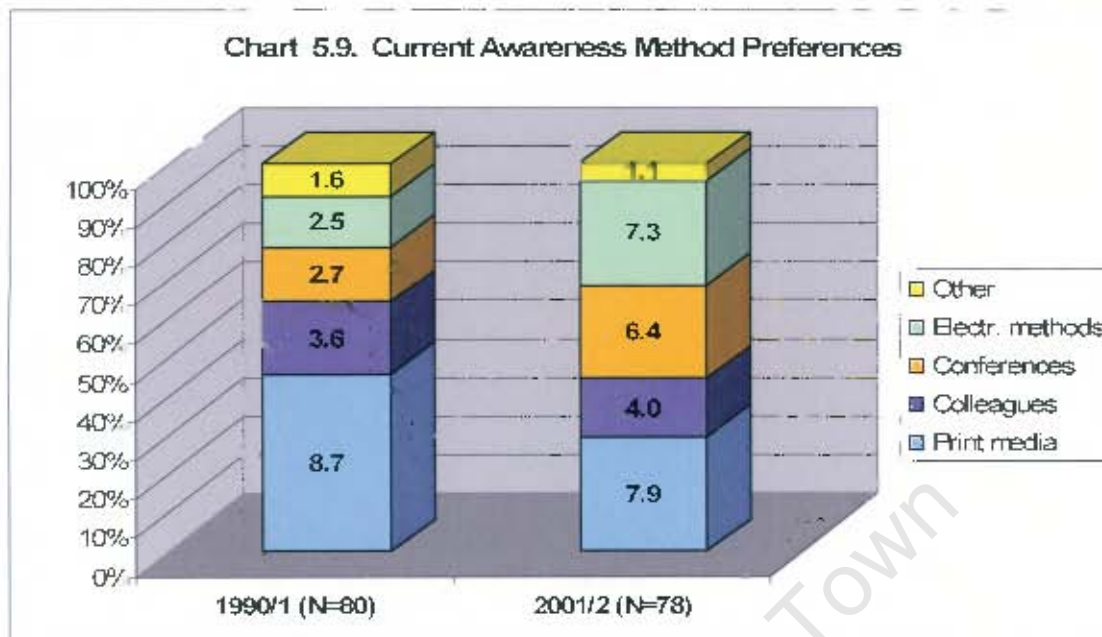
- Regularly communicating with colleagues and other experts in the field to discuss new development in the field - categorised as '*colleagues*' in the tables below.
- Regularly attending conferences to gather new information either by listening to presentations or engaging in informal personal discussions with experts, etc. - categorised below as '*conferences*'.
- Regularly perusing output from electronic alerting services and scanning electronic journals on a regular basis (2001/2 only). These are categorised in the tables below as '*electronic methods*'.
- A variety of '*other*' methods that ranged from keeping track of work produced by 'favourite authors', to students' work, to serendipitously finding information.

The preference ratings for each of these categories were aggregated and the results are depicted in Table 5.21, and Chart 5.9, below.

Table 5.21. CURRENT AWARENESS METHOD PREFERENCES					
Rated means	Print media	Colleagues	Conferences	Electronic methods	Other
1990/1 (N=80)	8.7	3.6	2.7	2.5	1.6
2001/2 (N=78)	7.9	4.0	6.4	7.3	1.1

From the above it can be seen that in 1990/1 the scanning of the latest print journals and CA publications was by far the most highly rated method to keep up to date. This was followed (at a much lower rating) by communication with individuals (colleagues or other experts), and then almost equally by conference attendance and electronic CA methods. The 'other' methods listed attracted a very low rating.

In 2001/02 although scanning printed published media again attracted the highest ratings, the differential between it and the second most favoured category, electronic methods, was not very substantial. Conference attendance attracted the third highest ratings and communication with colleagues/experts attracted the fourth highest ratings, albeit at a much lower level. Other methods used were again rated much lower than any of the other categories.



The t-test for dependent variables was conducted to establish whether the variation in the results for the two studies was statistically significant. From Table 5.22, below it can be seen that between-study variations were significant for all variables except communication with colleagues where it can be seen that the ratings awarded were very similar. The greatest differences between the two studies were the ratings awarded to conference attendance and electronic CA methods.

Table 5.22. T-Test for significant between-study differences of Current Awareness Methods

Rated means	Year	Mean	Std. Dev.	N	Diff.	t	p
Print media	2001/2	7.9	2.598	78			
Print media	1990/1	8.7	1.847	80	-0.744	-2.145	0.025
Colleagues	2001/2	4.0	3.199	78			
Colleagues	1990/1	3.6	2.920	80	0.359	0.766	0.446
Conferences	2001/2	6.4	4.001	78			
Conferences	1990/1	2.7	2.402	80	3.679	7.194	0.000
Electronic methods	2001/2	7.3	3.257	78			
Electronic methods	1990/1	2.5	1.792	80	4.719	12.257	0.000
Other	2001/2	1.1	1.579	78			
Other	1990/1	1.6	1.549	80	-0.474	-2.117	0.037

Differences in red are significant at $p < .05000$

The increased rating for electronic methods is not surprising as this was in keeping with the international trend towards greater adoption of electronic media and methods (cf. comments in 5.2). The very substantial increment in the rating awarded to conference attendance from 1990/1 to 2001/2 was surprising and the only clarification would be similar to that given in 5.2 where the increase was attributed to greater globalisation and the attendant need to interact with other

scientists over the world and also the greater ease with which South African scientists can travel.

5.7.1.1. Keeping up-to-date according to sub-categories of the population

The data was further analysed by cross tabulating the dependent variables of CA preferences with the population sub-categories as independent variables. ANOVA statistics were used to test for significance between the means of these cross tabulations. Significant differences were scored for both the 1990/1 and 2001/2 data-sets for categorisation according to the work environment, and crystallographic application. These results are outlined in Table 5.23. below.

Table 5.23. Current Awareness Preferences by Population Sub-categories (Significant results)												
	Print media		Colleagues		Conferences		Electronic methods		Other		N	
	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
Work Environment												
Industry	8.99	8.38	3.34	6.55	0.40	1.64	4.46	9.18	2.31	1.35	14	11
Research	8.96	7.41	2.08	2.59	2.82	7.65	3.53	9.71	1.75	1.12	18	17
University	9.02	8.04	3.91	3.88	2.88	7.00	1.51	6.56	1.62	1.06	48	50
	1990/1 WORK EN; LS Means Wilks lambda=.42300, F(10, 134)=7.2032, p=.00000											
	2001/2 WORK EN; LS Means Wilks lambda=.50575, F(10, 142)=5.7974, p=.00000											
Crystal. Application												
Applied	8.63	7.85	2.88	4.21	2.05	5.17	3.91	8.41	1.81	1.17	32	29
Tool	8.85	7.83	4.08	4.67	3.00	7.00	1.73	6.67	1.50	0.71	22	24
Pure	8.73	8.16	4.00	3.04	3.36	7.20	1.36	6.48	1.45	1.44	26	25
	1990/1 Crystal. application; LS Means Wilks lambda=.51387, F(10, 146)=5.7670, p=.00000											
	2001/2 Crystal. application; LS Means Wilks lambda=.75005, F(10, 142)=2.1962, p=.02120											

The Wilks' λ and F statistic showed average strength in the relationships: work environment was respectively 0.42, 7.2 in 1990/1 and 0.5, 5.8 in 2001/2002); and application of crystallography was respectively 0.51, 5.8 in 1990/1 and 0.75, 2.2 in 2001/2

There was thus very little variation amongst the three work environments as far as the value ratings they awarded to the scanning of print media, other than that the research institute respondents rated this method slightly lower in 2001/2 where than the other two work environments. It was further interesting to note that the industry respondents gave this method the highest ratings of all the CA methods used. The research institute respondents awarded the lowest ratings of the three work environments for interaction with colleagues/experts as a CA method, and in 2001/2 the industry respondents rated this method considerably higher than the other work environments. The industry respondents consistently gave low ratings in both studies for conferences as a means to keep up-to-date, and while the other two environments also awarded fairly low ratings in 1990/1, they both rated this method highly in 2001/2. Both the research institute and industry respondents rated electronic CA methods very highly in the 2001/2 study, considerably higher than the university respondents. There was further very little variation in the low ratings awarded by all three work environments to the 'other' categories used.

It is clear that although all three environments valued print media highly as a means to keep up-to-date the value attributed to the other CA methods varied considerably. The industry respondents' high rating of colleagues/experts in 2001/2 can be explained by the considerable value they generally placed on seeking out experts when they required information. It is suggested that the important role that conferences play in the research institute and university environments (in both instances far more so in 2001/2) is because of the greater all round current awareness benefits that these scientists derive from conference attendance if compared to their industry counterparts. The lower value attributed to electronic methods to keep up-to-date by the university respondents can be related to comments made which indicated that the libraries that served the universities were less proactive in providing electronic push services than in the other two work environments.

The three crystallography application categories also attributed almost equally high values to scanning print media. The main variation between methods for this categorisation related to differences in ratings awarded to approaching colleagues/experts, attending conferences, and using electronic CA methods. It can be seen that the respondents who applied crystallography generally differed considerably to those who used it as a *tool* or conducted *pure* crystallographic research. The applied crystallographers awarded far higher ratings to electronic methods and far lower ratings to conferences than the *tool* or *pure* crystallographers. In 1990/1 the applied crystallographers also rated colleagues considerably lower than the other two groups, but in 2001/2 the pattern changes in that the *tool* and *applied* crystallographers gave higher ratings to colleagues than the *pure* category. It can thus once again be seen that the applied response pattern closely emulated the combined responses of the industry and research institute responses and the *pure* and *tool* responses that of the university respondents.

5.7.2. FINDING INFORMATION FOR NEW RESEARCH PROJECTS

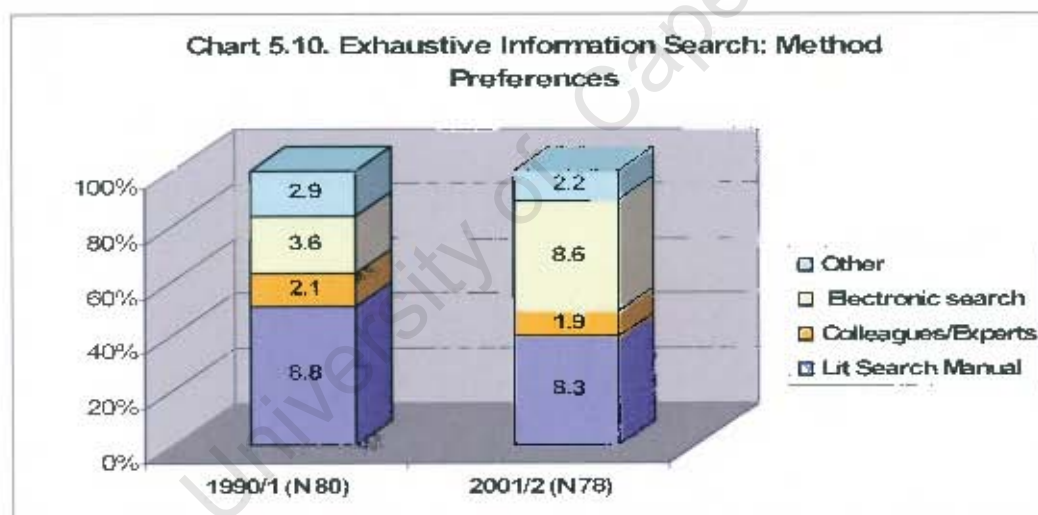
It is generally accepted that most researchers would first establish the state-of-the-art of a field before undertaking new research in that area. This avoids unnecessary duplication, provides methodological insight and usually helps clarify conceptual issues. It was thus decided to question the crystallographers on how they approached information gathering before they engaged in new research and to rate the value of each method that they used.

The methods that the respondents indicated that they predominantly used when conducting an exhaustive search for information can essentially be categorised into the following four methods:

- Conducting a manual search of the printed published literature.
- Conducting an online search of various electronic databases and the Internet.
- Contacting colleagues or experts to provide the required information.
- Other lesser used methods that included random unsystematic searching, and following up references found in useful sources.

In Table 5.24, and Chart 5.10, below the aggregated ratings for the main methods that the respondents used to gather information before undertaking a new project are tabled and presented.

Table 5.24. EXHAUSTIVE INFORMATION SEARCH: METHOD PREFERENCES				
Rated Means	Lit Search Manual	Colleagues/Experts	Electronic search	Other methods
1990/1 (N 80)	8.8	2.1	3.6	2.9
2001/2 (N 78)	8.3	1.9	8.6	2.2



Although most respondents used more than one method concurrently, it can be seen that in 1990/1 by far the most valued method was to conduct systematic manual literature searches for published print material. The next most valued method, but at a far lower rating, was to conduct electronic searches. It was established in 1990/1 that the manual searches were generally conducted personally by the crystallographers, while the online searches were generally delegated to the staff of the library. The 'other' methods they used were rated next in value and an unexpected outcome was that a high percentage of these were for random, unsystematic searching or browsing. The use of colleagues attracted the lowest rating. In 2001/2 a fairly similar pattern

emerges, except for online searching that surpasses manual literature searches. The surprising factor is that manual searches still attracted such high ratings. It was further interesting to gather that online searches were now conducted personally by most of the crystallographers from their own desktop computers.

A t-test for dependent variables was conducted to establish the level of significance in the variation between the results for the two studies (cf. Table 5.25, below). It can be seen that between-study variations were significant for almost all the variables (other than asking colleagues/experts for information), and it is clear that the greatest differences between the two studies were for the higher ratings awarded to electronic searching methods in 2001/2 (this in alignment with the global pattern and the general increase in use of and value awarded to electronic methods in the second study).

Table 5.25 T-Test for significant between-study differences for Exhaustive Information Search Methods

Rated Means		Mean	Std.Dv.	N	Diff.	t	p
Lit Search Manual	2001/2	8.3	2.399	78			
Lit Search Manual	1990/1	8.8	1.578	80	-0.436	-2.184	0.032
Colleagues/Experts	2001/2	1.9	3.286	78			
Colleagues/Experts	1990/1	2.1	3.410	80	-0.206	-1.423	0.159
Electronic search	2001/2	8.6	2.327	78			
Electronic search	1990/1	3.6	1.377	80	4.949	22.076	0.000
Other	2001/2	2.2	3.603	78			
Other	1990/1	2.9	3.328	80	-0.641	-4.0843	0.000

T test for Dependent Samples. D differences in red are significant at $p < .05000$

5.7.2.1. Finding information for new research projects according to sub-categories of the population

The data was further analysed by cross tabulating the dependent variables of exhaustive information retrieval methods with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were used to test for significance between the means of these cross tabulations. Significant differences were scored for categorisation according to the work environment, crystallographic application and position (both the 1990/1 and 2001/2 datasets). These results are outlined in Table 5.26, below.

Table 5.26. Exhaustive Information Search Preferences by Population Sub-categories (significant results)

	Lit. Search Manual		Colleagues		Electronic search		Other		N	
	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
Work Environment										
Industry	7.7	6.9	2.3	1.5	4.3	9.3	0.9	0.0	14	11
Research	8.6	8.4	0.0	0.2	3.6	8.2	1.6	0.4	18	17
University	9.2	8.6	2.8	2.6	3.5	8.6	3.9	3.4	48	50
	1990/1 WORK EN; LS Means Wilks lambda=.66437, F(8, 148)=4.1969, p=.00015 2001/2 WORK EN; LS Means Wilks lambda=.75838, F(8, 144)=2.6694, p=.00919									
Application of Cryst.										
Applied	8.2	7.8	1.0	1.1	3.9	8.6	1.3	0.5	32	29
Tool	9.4	8.4	3.1	3.4	3.6	8.9	4.9	4.1	22	24
Pure	9.0	8.9	2.5	1.4	3.3	8.3	3.1	2.5	26	25
	1990/1 Cryst. Application; LS Means Wilks lambda=.73530, F(8, 148)=3.0744, p=.00311 2001/2 Cryst. Application; LS Means Wilks lambda=.76038, F(8, 144)=2.6423, p=.00986									
Position										
Senior	7.9	8.9	2.7	3.3	4.1	8.4	4.2	3.9	33	33
Mid-Position	8.9	8.3	1.8	1.0	2.6	8.7	3.0	1.7	24	24
Junior	9.1	7.6	1.4	0.8	1.2	8.8	1.5	0.3	23	21
	1990/1 POSITION; LS Means Wilks lambda=.78641, F(8, 148)=2.1611, p=.02681 2001/2 POSITION; LS Means Wilks lambda=.77463, F(8, 144)=2.4616, p=.01618									

The measures of association for these cross tabulations were not particularly strong with the Wilk's lambda ranging between $\lambda = .66$ and $\lambda = .79$ and the F statistic between 4.2 and 2.2. It can be seen that the industry respondents in both the studies showed the greatest predilection for electronic search methods and by far the lowest preference ratings for manual methods. In 1990/1 the university respondents gave the highest ratings for manual search methods and they also in both the studies rated colleagues as well as 'other' search methods (e.g. unsystematic browsing), far higher than the other two work environments. It is further interesting to note that the research institute respondents awarded equally high ratings for manual and electronic search methods in the 2001/2 study.

As far as variation according to application of crystallography is concerned, it can be seen that the *tool* and *pure* crystallographers awarded only slightly higher ratings to manual methods than the applied crystallographers (both studies), and that there was hardly any difference amongst the three categories in the ratings they gave to electronic methods. The greatest differences among the three categories were the far higher ratings given by the *tool* category to colleagues and *other* methods in both studies. The reason for the latter differences could be explained by observations made during the interviews by the tool crystallographers that because they used crystallography as an analytical tool they often have to depend on the *pure* crystallographers' for assistance with crystallographic analyses.

The variation according to position is only particularly marked for the relatively greater value attributed by the senior respondents for approaching colleagues/experts and 'other' methods (both

studies). It is interesting to note that while the more senior respondents appeared to use and rate electronic methods relatively higher in 1990/1 and the junior respondents gave the lowest ratings, the position is reversed in 2001/2. This, it is suggested relates to the previous explanation given that in 1990/1 online searching was conducted by means of vendors and was expensive, and when it became more generally available and affordable the more junior and younger scientists were enthusiastic adopters.

5.7.3. FINDING INFORMATION TO SOLVE A PROBLEM IN THE WORK SITUATION

The third main need category that gives rise to information gathering is when researchers encounter problems in the work situation. The respondents were thus asked to indicate how they generally went about it to find information to resolve their work-related problems, the communication channels they used and the usefulness of these channels.

The methods that the respondents indicated that they predominantly used can essentially be categorised as follows:

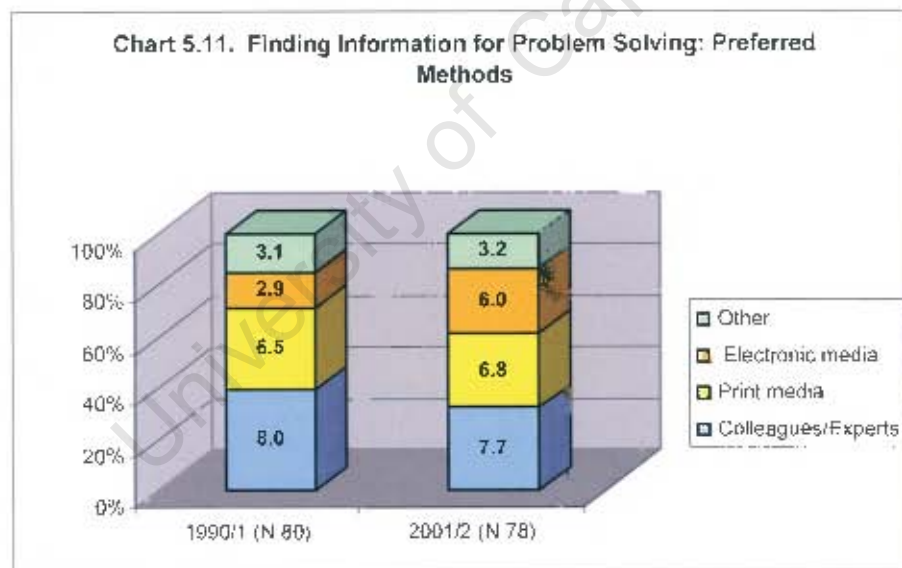
- Approaching a colleague or some other expert to help them solve the problem. This referred to either colleagues within the respondents' own organisation, or an expert in the field in South Africa, or less frequently experts abroad.
- Looking for a solution in the literature in the field. The respondents were asked to differentiate between the value of print and electronic media and the rated responses have been reported separately for these two categories.
- Finding their own solution to the problem and other lesser used methods that included specifically attending conferences to find an answer to the problem. These more infrequently used methods were conflated with the 'other methods' responses.

The aggregated ratings for the importance attributed to the main methods that the respondents used to find information to solve problems are tabled and presented in Table 5.27. and Chart 5.11. below.

Rated Means	Print Media	Colleagues/Experts	Electronic Media	Other methods
1990/1 (N 80)	6.5	8.0	2.9	3.1
2001/2 (N 78)	6.8	7.7	6.0	3.2

It was found in both studies that approaching a person who could provide the solution to their problem was the most used and valued method. Comments made during the interviews indicated that colleagues in the workplace were the most highly valued as they were familiar with the specific situation and could provide immediate and relevant assistance. If their colleagues could not assist them, they approached local experts external to the organisation and then experts abroad. Information found in the literature (both print and electronic) played a far less important role in problem solving than when information was required to keep up-to-date or when doing an exhaustive search for information. This can be attributed to the need for rapid answers and feedback and the highly situation specific nature of work-related problems.

Finding a solution in electronic media, such as searching the Internet only really featured in the 2001/2 study. The 'other' methods used mainly referred to situations where the respondents rated finding their own solutions to problems above other approaches they followed. As can be seen this was not the predominant method used to resolve problem situations.



T-tests for dependent variables were conducted to establish whether the variation in the results for the two studies were statistically significant (cf. Table 5.28. below). It can be seen that the only significant variations were obtained for the ratings awarded to finding solutions to problems in some or other electronic medium. In 2001/2 electronic media were valued substantially higher than in 1990/1.

**Table 5.28. T-Test for significant between-study differences:
Information for problem solving**

Rated Means		Mean	Std.Dev.	N	Diff.	t	p
2001/2	Print media	6.8	3.539	78			
1990/1	Print media	6.5	3.552	80	0.346	0.723	0.472
2001/1	Colleagues	7.7	3.433	78			
1990/1	Colleagues	8.0	3.203	80	-0.359	-0.674	0.502
2001/2	Electronic media	6.0	3.827	78			
1990/1	Electronic media	2.9	1.932	80	3.141	6.545	0.000
2001/2	Other	3.2	3.637	78			
1990/1	Other	3.1	3.570	80	0.128	0.272	0.787

T-test for Dependent samples, differences in red are significant at $p < 0.050$

5.7.3.1. Finding information to solve a problem according to the sub-categories of the population

The data was further analysed by cross tabulating problem-solving information gathering methods with the population sub-categories as independent variables. Analysis of variance (ANOVA) statistics were applied to test for significance between the mean scores of the cross tabulated variables. Significant differences were scored for categorisation according to the work environment and crystallographic application (both the 1990/1 and 2001/2 data-sets). These results are outlined in Table 5.29. below.

Table 5.29. Information for Problem Solving: Preferred Channels by Population Sub-categories (Significant results)

	Print media		Colleagues		Electronic media		Other		N	
	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
Work Environment										
Industry	3.9	3.8	3.3	3.1	4.5	3.1	0.3	0.0	14	11
Research	5.1	5.5	3.2	2.8	2.9	5.4	2.4	2.5	18	17
University	7.9	8.0	7.3	7.3	3.3	6.5	4.2	4.1	48	50
	1990/1 WORK EN: LS Means Wilks lambda=.61067, F(8, 144)=5.137, p=.00001 2001/2 WORK EN: LS Means Wilks lambda=.67465, F(8, 144)=3.9145, p=.00033									
Application of Cryst.										
Applied	4.4	4.9	9.2	8.3	2.3	5.0	1.5	1.4	32	14
Isol	7.2	7.8	8.0	7.9	2.8	5.4	4.2	4.5	22	18
Pure	8.2	8.2	6.7	6.7	3.7	7.8	4.2	4.0	25	48
	1990/1 Cryst. Application: LS Means Wilks lambda=.63861, F(8, 144)=4.6501, p=.00040 2001/2 Cryst. Application: LS Means Wilks lambda=.59154, F(8, 144)=3.8453, p=.00084									

It can be seen that although the data analysed according to the respondents' work environment shows distinct differences between the three work environments, the measures of association are not particularly strong (the Wilks' lambda and F statistic for 1990/1 and 2001/2 was respectively, $\lambda = .61$, $\lambda = .68$; and $F = 5.2$, $F = 3.9$). In both studies the respondents in industry rated approaching their colleagues and experts in the field (both local and abroad) substantively higher than any other method to find information to solve a problem. The research institute respondents while in 1990/1 giving almost as high ratings for this method assigned lower ratings in 2001/2. The university respondents, in both 1990/1 and 2001/2, awarded the highest ratings to print media of all the problem solving information sources they used and subsequently also rated them higher than any of the other work environments.

The ratings for electronic sources of information were low for all work environments in 1990/1, with the university respondents scoring marginally higher ratings than the research institute respondents who in turn were slightly higher than industry. The electronic media ratings, as mentioned above, increased considerably in 2001/2 and it can be seen that the university and research institute respondents still attributed higher ratings to this mode than the industry respondents. While the industry respondents hardly used 'other' methods to find information to solve problems, the research institute and university respondents progressively rated these methods slightly higher. It would thus appear that while the industry respondents almost exclusively relied on inter-personal information gathering to resolve problems, the other two work environments spread their options more evenly and the university respondents valued print sources particularly highly.

The cross tabulations according to the respondents' application of crystallography also showed moderate levels of association (the Wilks' lambda and F statistic for 1990/1 and 2001/2 was respectively, $\lambda = .64$, $\lambda = .69$; and $F = 4.7$, $F = 3.6$). It can be seen that as far as the value attributed to print media, the *pure* crystallographers valued this source the highest of the three application groups followed closely by the *tool* crystallographers (this applied to both studies). The importance of colleagues and other experts as a means to solve problems was the highest among the *applied* respondents (in both studies), closely followed by the *tool* crystallographers. The *pure* crystallographers awarded the higher ratings to the use of electronic sources for problem solving purposes than the other two groups (in both studies, only more so in 2001/2). The *tool* and *pure* respondents attributed higher ratings to *other* methods than the *applied* respondents (in both studies).

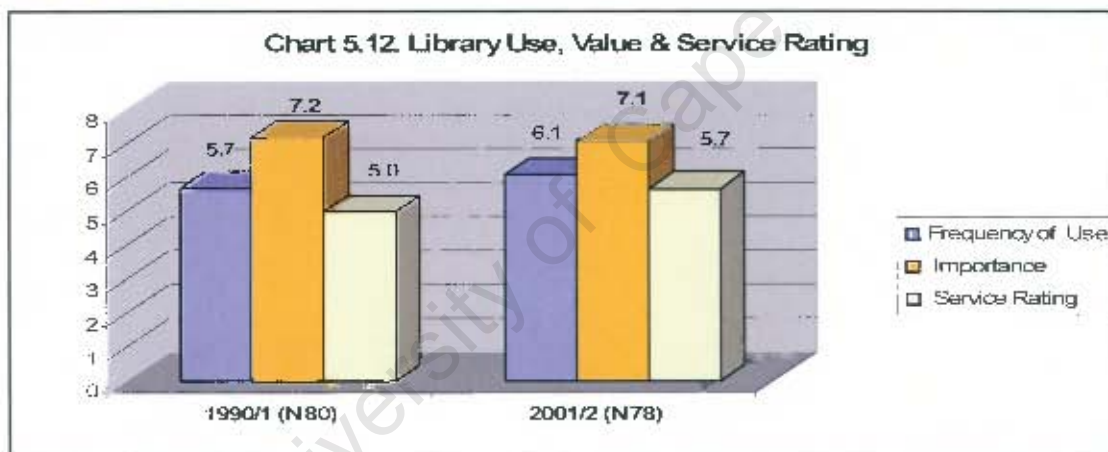
5.8. THE USE AND VALUE OF LIBRARIES

A number of studies have indicated that the information facility serving a community can impact considerably, both positively and negatively, on the information communication process of that community (cf. also chapter 2.7.3.). For example, the mere existence of a convenient and well-organised collection of literature and formal information services or, on the other hand, the integration into an efficient informal information communication system may have a very positive effect on that user group's interaction with information. Conscious and unconscious needs for information may be stimulated by efficient facilities to meet them which then activate

the communication process, while inadequate facilities tend to stifle information needs and the communication of information.

To establish the role that their organisational libraries played in the communication process, the respondents were asked to indicate how frequently they used their libraries, to rate their libraries' contribution to the information communication process, and to rate the service provided by their libraries (a rating scale of 10 [used very frequently / very highly rated] to 0 [not used / of no value] was applied; cf. Question C14, Appendix B & C.). The aggregated ratings are depicted in Table 5.30. and Chart 5.12. below.

Rated Means	Frequency of Use	Importance	Service Rating
1990/1 (N 80)	5.7	7.2	5.0
2001/2 (N 78)	6.1	7.1	5.7



It is evident that in both studies, while the libraries were highly rated for their contribution they made to the information communication process, the use made of them and the service ratings given were much lower ratings. This seeming anomaly can be explained by the fact that many respondents stated during the interviews that they rarely personally used the library as they either sent a junior staff member or a student to find material in the library on their behalf, or they requested the library staff to search for the information they required. The low service rating can, in turn, be explained by the large number of university respondents who were dissatisfied with the services provided in the 1990/1 study and the frustration that the respondents at the largest research institute had with their library in 2001/2. It was evident that the generalised view was that the main value of their libraries resided in the information resources offered rather than in the services provided.

The t-test that was conducted indicated that the only significant between-study variations were for the ratings awarded to library service provision (cf. Table 5.31, below). The satisfaction with library service provision was higher in 2001/2 than in 1990/1. This can largely be explained by comments made by the university respondents that with the greater use of electronic media and services their libraries had become more effective and could now offer a more personalised service.

**Table 5.31. T-Test for significant between-study differences:
Library Use, Value & Service rating**

Rated Means	Mean	Std Dev	n	Diff	t	p
2001/2 Library Use	6.1	2.618	78			
1990/1 Library Use	5.7	2.668	80	0.346	1.027	0.307
2001/2 Library Value	7.1	1.699	78			
1990/1 Library Value	7.2	1.673	80	-0.090	-0.401	0.689
2001/2 Library Service	5.7	1.585	73			
1990/1 Library Service	5.0	2.358	80	0.718	2.716	0.008

T-test for Dependent samples, differences in red are significant at $p < 0.050$

5.8.1. THE USE AND VALUE OF LIBRARIES ACCORDING TO THE POPULATION SUB-CATEGORIES

The data was further analysed by cross tabulating library value, use, and service ratings with the population sub-categories as independent variables. The ANOVA statistical tests that were run produced significance scores for categorisation according to the work environment, crystallographic application and position categories (both the 1990/1 and 2001/2 data-sets). These results are outlined in Table 5.32, below.

Table 5.32. Library Use, Value & Service rating by Population Sub-categories (Significant results)

	Frequency of use		Importance		Service rating		N	
	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
Work Environment								
Industry	4.0	3.9	8.1	8.4	5.9	7.4	13	11
Research	5.2	5.1	7.2	7.2	5.2	5.6	18	17
University	8.4	8.9	8.9	8.8	3.9	5.4	49	50
	1990/1 WORK EN; LS Means Wilks lambda=.59870, F(6, 150)=7.3100, p=.00000 2001/2 WORK EN; LS Means Wilks lambda=.73931, F(6, 146)=3.9667, p=.00105							
Application of Cryst.								
Applied	4.7	4.8	7.8	7.5	8.5	8.3	31	29
Tool	5.7	6.7	7.3	6.8	4.3	5.8	23	24
Pure	7.1	6.9	6.5	6.8	3.7	5.0	26	25
	1990/1 Crys. Application; LS Means Wilks lambda=.57733, F(6, 150)=7.9025, p=.00000 2001/2 Crys. Application; LS Means Wilks lambda=.78868, F(6, 146)=3.4209, p=.00345							
Position								
Senior	3.9	4.4	8.8	8.5	8.8	7.2	33	33
Middle	6.3	6.0	7.0	6.9	4.8	5.6	24	24
Junior	7.9	3.7	5.2	5.1	2.5	3.4	23	21
	1990/1 POSITION; LS Means Wilks lambda=.25206, F(6, 150)=24.796, p=.00000 2001/2 POSITION; LS Means Wilks lambda=.25240, F(6, 146)=24.101, p=.00000							

Although very clear differences surfaced in the responses received from the three work environments, the measures of association were only moderately strong (The Wilks' lambda and F statistics ranged respectively for 1990/1 and 2001/2 between $\lambda = 0.60$, $\lambda = 0.74$ and $F = 7.3$, $F = 4.0$). The respondents in industry, although personally using their libraries infrequently, awarded the highest value ratings to their contribution to the information communication process and service provided. During the interviews it became clear that a very harmonious relationship existed between these respondents and their libraries and although their libraries were usually situated within the research divisions, these respondents (particularly the more senior ones) rarely had to visit the libraries as a very proactive service was provided by the library staff.

The university respondents personally used their libraries the most frequently of the three work categories, but they also awarded slightly lower value estimates and considerably lower service ratings than the other two categories. The latter view varied considerably between the two studies, and while the comments made during the 1990/1 interviews indicated general dissatisfaction with the service offered, the sentiment in 2001/2 was far more positive. The impression gained was that with the advent of electronic media and services, the university libraries were now offering more user-oriented and value-added services.

The pattern of responses from the research institutes respondents fell somewhat in between that of the university and industry respondents. It was interesting to note that a number of respondents attached to the largest research institute were very dissatisfied in 2001/2 with their organisation for considerable down-scaling library services. There was obvious disagreement with the argument that the general availability of electronic information sources made libraries redundant.

The variation in responses according to how the respondents applied crystallography once again indicates the applied crystallographers followed the pattern of the aggregated responses of the industry and research institute respondents and the *pure* and *tool* respondents that of the university respondents. It should however be noted that the *tool* respondents' responses, particularly in 1990/1, veered slightly in the direction of that of the applied crystallographers. The data as analysed by the position categories of the respondents shows that while the frequency of library use increases as the position categories drop from the senior to the more junior categories, the value placed on the library's role in the communication process and the library service ratings increased from the junior to the senior categories.

5.9. RESEARCH OUTPUT AND PUBLICATION DETAILS

The research process reaches its peak when the results of the study are transferred into some or other output. This could, depending on the circumstances (usually the nature of the research and the work environment) result in some or other publication in the public domain; the production of an unpublished internal report; the patenting of an invention; the production of a physical entity, or the introduction of a process. This final stage signals the transfer of the interaction with the communication system from the informal to the formal domain and the conclusion of the research project. The information communication process thus culminates when scientific information generated during the research process becomes public knowledge (cf. also chapter 2.1., 2.2. & 2.3.).

The publication of research findings in basic science is regarded by this community not only to constitute the culmination of the research process but also to form the basis of the communication process. Ziman (1969:318) has often been quoted for arguing that the results of research in science can only become completely scientific once they have been published and this body of recorded knowledge not only forms an integral part of the scientific communication process and but underpins the advancement of science.

Applied science's interaction with the publication process, by nature, occupies a position of lesser importance than in basic science. An applied scientist is concerned, primarily, with producing a physical or practical end-product (e.g. a patent, a license or new product) which will provide the best solution to a particular problem, rather than with verbal encoding and, as mentioned in Chapter 2.3, this is the basis for differentiating between the information communication processes in basic and applied science.

Although, as indicated above, published literature occupies a much less important position, it still plays a significant role in the communication of technical information. The literature of applied science, however, tends to be of a practical nature and applied scientists as readers become so accustomed to this form of output that they find it difficult to assimilate literature of a more theoretical nature and hence their reluctance to transcend the literature of basic science (cf. the reference to these aspects in chapter 2.3).

To enable the researcher to examine and investigate the research output and publication patterns of the crystallographic community, the respondents were requested to submit a list of their

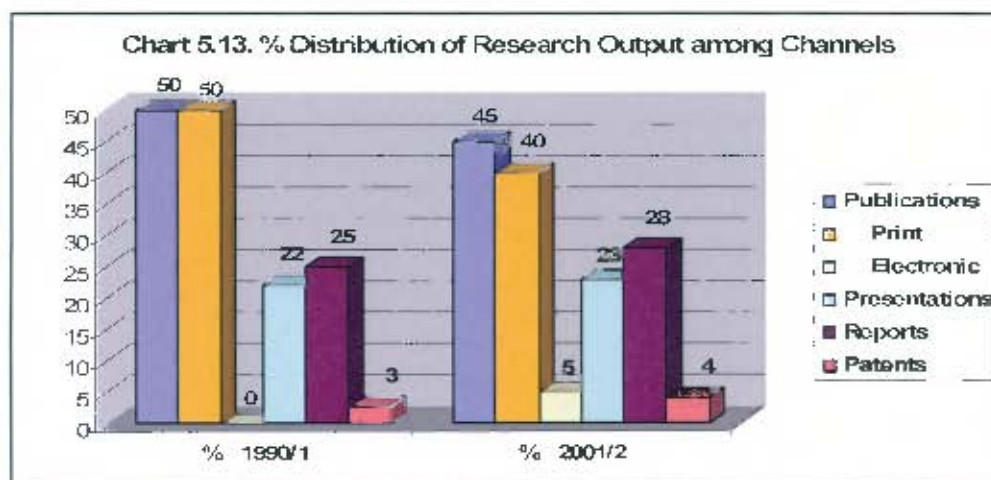
publications, or any other form of encoded research output and further to provide as much detail regarding their research output as possible. The information reported in this section is thus based on the data obtained from these lists together with the responses obtained to Question D16, Appendix B and C; and information obtained during the interviews.

5.9.1. RESEARCH OUTPUT CATEGORIES AND DISTRIBUTION

From the data received it was clear that the research output of the respondents could be grouped into one of the following categories: formal publications such as journal articles, review articles, book chapters, etc.; technical reports that were produced within the organisation; patents that were promulgated; and invited lecture or conference presentations. It was assumed that research that culminated in the production of a product or the generation of a process would be verbally encoded in the format of an internal report produced for the institution or company. Where the confidentiality of the research prevented a respondent from providing the required information, the researcher requested that the average number of reports, patents, etc. submitted per annum be divulged. The researcher received full co-operation from the respondents and is satisfied that the data obtained is a fairly accurate reflection of the research output of each respondent.

The distribution of the research output among the various channels for the entire population is depicted in the Table 5.33. and Chart 5.13. below. It is clear that formal publications constituted almost half (50%) of all forms of encoded output. Internal reports were a quarter (25%) and conference/lecture presentations slightly less (22%), while patents lagged far behind at 3% of the total output.

CHANNELS	% 1990/1	% 2001/2
Publications	50	45
Print	50	40
Electronic	0	5
Presentations	22	23
Reports	25	28
Patents	3	4
TOTAL	100	100



The data was further analysed by cross tabulating the distribution of the research output among the various channels with the population sub-categories as independent variables. The Pearson's chi-square test was used to measure the statistical significance of the percentage variation and significant differences were scored for categorisation according to work environment and application of crystallography (both studies). It is further clear that in all instances the measures of association were very significant (work environment: $\chi^2 = 63.2$ [1990/1], 59.3 [2001/2]; phi = 0.86 [1990/1], 0.81 [2001/2]; application of crystallography: $\chi^2 = 56.5$ [1990/1], 52.9 [2001/2]; phi = 0.73 [1990/1], 0.71 [2001/2]). These results are outlined in Table 5.34. below

In industry the written research output was very clearly technical reports (70%, 1990/1; 75%, 2001/2), with patents (13%, 1990/1; 14%, 2001/2), publications (9%, 1990/1; 6%, 2001/2), and conference/lecture presentations (8%, 1990/1; 5%, 2001/2), lagging far behind. None of the publications was in electronic format. This confirms the statements made by the respondents and findings reported in the literature (cf. chapter 2.3. & 2.4.3.) that researchers in industry are primarily concerned with improving products and production procedures and technical reports thus serve as the main vehicle to convey research outcomes to the company at large. Publication in the publication domain and presentation of papers was perceived to be an ancillary by-product and often not feasible because of the confidentiality of their research.

The industry and research institute environments produced by far the largest proportion of patents, a clear indication of the importance of this channel to safeguard new innovations in the applied science environment. The respondents at research institutes were also prolific producers of reports (even more so in the second study), once again a clear indication of the high percentage

of contract research that they conducted and the confidentiality restriction prevented them from transferring a large proportion of their research outcomes into the public domain.

The university respondents, in total contrast to the other two work environments, almost exclusively transferred their research outcomes into the public domain, mostly as formal publications (71%, 1990/1; 67%, 2001/2) and to a lesser extent as presentations (1990/1, 28%; 29%, 2001/2). The effect of increasing financial constraints and the drive to engage in remunerative contract research can be seen in the marked increase in the proportion of technical reports and patents produced by the university respondents in the second study. They and the respondents from the research institutes were the only crystallographers to utilise electronic mode for publications (albeit only 7% and 5% respectively).

Table 5.34. % Distribution of Research Output among Channels by population sub-categories (significant results)

CHANNELS	Work Environment							
	INDUSTRY		RESEARCH		UNIVERSITY		OVERALL	
	1991	2001/2	1991	2001/2	1991	2001/2	1991	2001/2
Publications	9	5	23	19	71	67	50	45
Print	9	6	23	13	71	60	50	40
Electronic	0	0	0	5	0	7	0	5
Presentations	8	5	16	14	28	29	22	23
Reports	70	75	58	62	1	4	25	28
Patents	13	14	3	5	0	1	3	4
TOTAL	100	100	100	100	100	100	100	100
1991/1: Pearson Chi-square: 63.20561; df=6; p=0.0000; Phi=.5542917								
2001/2: Pearson Chi-square: 59.22501; df=6; p=0.0000; Phi=.5124187								
CHANNELS	Application of Crystallography							
	APPLIED		TOOL		PURE		OVERALL	
	1991	2001/2	1991	2001/2	1991	2001/2	1991	2001/2
Publications	20	14	67	63	71	72	50	45
Print	19	11	67	60	71	69	50	40
Electronic	0	3	0	0	0	5	0	5
Presentations	12	8	31	29	26	27	22	23
Reports	50	58	2	7	0	1	25	28
Patents	7	10	0	1	0	0	3	4
TOTAL	100	114	100	100	100	100	100	100
1990/1: Pearson Chi-square: 58.50401; df=6; p=0.0000; Phi=.7311917								
2001/2: Pearson Chi-square: 52.85533; df=6; p=0.0000; Phi=.7122575								

5.9.2. AVERAGE ANNUAL RESEARCH OUTPUT

From the data that each respondent submitted the researcher calculated the total number of research outputs within each category and then this figure was divided by the number of years that each respondent had been productive to arrive at an aggregate annual output. This information is represented in Table 5.35. below. In 1990/1 the average annual encoded research output for all channels for the entire population of crystallographers was 2.5 and this ranged from 0.12 for patents, to 0.86 for reports, to 0.95 for conference presentations, to 1.92 for publications. By 2001/2 this had increased on average by 28% to an overall output of 3.2 (0.18, 1.28, 1.21, 2.25 respectively for patents, reports, conference presentations, and publications). The range of the

encoded output was from 0.0 to 9.9 in 1990/1 and 0.0 to 12.1 in 2001/2. This growth in the number of publications per person per annum was a general tendency that was observed, not only for the ten year period of the study, but also if the total publication output is analysed over the total period of publication activity (i.e. from the time of first conducting research to the time of the 2001/2 interviews).

TABLE 5.35. ANNUAL RESEARCH OUTPUT		
AVERAGES	1990/1	2001/2
Patents	0.12	0.18
Reports	0.86	1.28
Presentations	0.95	1.21
Publications	1.92	2.25
Overall	2.5	3.2

If the total research output data is analysed according to the various population sub-categories the following trends emerge (cf. Table 5.36 below). The research institute and university respondents were almost equally prolific and both categories showed an increase in output in the second study. The industry respondents were slightly less prolific and also did not increase their output as substantively as the others in 2001/2. The variation among the crystallography application categories was minimal. There was a slight increase in output, the more structured the work environment became and this incremental increase also applied as seniority in position and age increased. The output was much higher for respondents with doctoral degrees and those with a foreign doctorate were slightly more prolific than those with a local qualification.

TABLE 5.36. ANNUAL AVERAGE RESEARCH OUTPUT by Population Sub-categories							
1990/1	2001/2	1990/1	2001/2	1990/1	2001/2	1990/1	2001/2
WORK ENVIRONMENT							
INDUSTRY		RESEARCH INSTITUTES		UNIVERSITIES		OVERALL	
2.1	2.3	2.8	3.2	2.5	3.3	2.5	3.2
CRYSTALLOGRAPHY APPLICATION							
PURE		TOOL		APPLIED		OVERALL	
2.6	3.6	2.4	3.5	2.5	2.8	2.5	3.2
GROUP STRUCTURE							
LONERS		UNSTR. GROUPS		STRUCT. GROUPS		OVERALL	
2.1	2.5	2.5	3.1	2.7	3.3	2.5	3.2
POSITION							
JUNIOR		MIDDLE		SENIOR		OVERALL	
1.2	1.4	2.4	3.0	3.5	4.4	2.5	3.2
AGE RANGE							
20-29		31-50		51-70		OVERALL	
0.4	0.5	2.6	3.3	3.2	4.1	2.5	3.2
DEGREE							
SA-Hons/Masters		Foreign PhD		SA PhD		OVERALL	
1.0	1.2	3.1	3.8	2.8	3.5	2.5	3.2

5.10. CONCLUDING REMARKS

From the above it is very clear that the reason why information is required has a significant impact on the method used to gather information and on the preferred communication channel and mode. The respondents reported during the interviews that they usually used more than one method concurrently and that their responses reflected the generalised situation and preferred methods/channels could vary considerably depending on the specific nature of the information required. It is further clear that the importance and relevance of the methods and channels used varied (in some instances considerably) according to the respondents work affiliation and application of crystallography and also in many instances according to their position.

In a very similar vein, the reason why research was being conducted and particularly the respondents' work environment and application of crystallography impacted on their research output and on the channels and modes of communication used for this purpose.

The variation on channels used for information seeking and research output purposes between the studies generally showed considerable differences. The inherent communication model did not change, but it is clear that the electronic environment had a marked effect on the mode of interaction used and on channel selection for information-seeking purposes. The electronic environment had, however, hardly affected publication output mode use, even in the second study. The other marked difference between the studies was clearly the effect of changed organisational structures and financial models, as well as the positive impact of the new political dispensation in South Africa.

These aspects will be addressed in greater detail in the following chapter.

CHAPTER 6

DISCUSSION OF FINDINGS

6.1. INTRODUCTION

In this chapter a discussion will be presented of the main results derived from the study.

One of the main premises of this thesis is that scientific and technological advance is largely dependent on the efficient communication of ideas, knowledge and information as well as the amount and quality of interaction among scientists and technologists. With the growth of scientific and technological enterprise over the years, the burgeoning information industry, globalisation, and rapid technological advances, the information communication process in science and technology has likewise increased both in size and in complexity and this, in turn, has impacted on the efficacy of the system. It is therefore suggested that to be effective, the information environment, and this includes information professionals, has to comprehend the information communication practices of the scientific and technological communities it seeks to serve.

A factor that is of specific concern to the researcher is the dynamics of information communication behaviour within specific science communities in South Africa. The problems outlined above are compounded by the complexity of the South African society, real economic constraints and above all the fact that our science and technology community is geographically (and in the past also politically) isolated from the forefront of research. The focus of this research project was thus on establishing what factors impact on the communication process within a specific research community in basic and applied science in South Africa, what role informal communication of information plays and particularly what the effect of changes in the socio-economic, political and technological environment have had on the information communication process over the last decades.

6.2. COMMUNICATION OF INFORMATION AMONG THE CRYSTALLOGRAPHERS

It clearly emerged from the empirical study (cf. Chapter 4.2.) that the crystallographers' work environment and work structure largely determined communication patterns and the interaction with information. The organisational ethos that prevailed in each of the three work environments (industry, the research institutes and the academic institutions) generally determined specific work structures which in turn impacted in varying ways on the communication of, and interaction with, information. These ranged from the most structured approach that prevailed in industry, through the less rigidly structured research institutes to the academic institutions where a far more flexible approach was adopted.

The communication of information was closely integrated with and related to the research activities of these respondents, the underlying reason for conducting research, and the information needs engendered by these activities. The communication process was thus basically driven by two categories of need. On the one hand there was a need to obtain information to start up a new research project, to test a theory, to solve a problem, design a system or process, produce a product, and to keep up to date with new developments and research fronts. The other very important driving force was to impart the end result of the research effort to management, the wider organisation, clients, colleagues and, in many instances, to the wider science community and public in general. These interactions with the information communication process were conducted either on a direct interpersonal level (i.e. where informal communication channels were mostly used), and/or on an indirect impersonal level (i.e. where formal communication channels were mostly used).

6.2.1. INTERACTION WITHIN THE ORGANISATIONAL SETTING

As mentioned above, a fairly structured work environment prevailed in industry and researchers were grouped into divisions that were engaged in cognate research areas and these were further divided into smaller more homogeneous research units, or groups, each addressing a specific research project of interest to the company. All the respondents in industry were engaged in applied research, usually either in applied chemistry, mineralogy, or material science.

The research emphasis in these R&D divisions was on developing and implementing new products or techniques, providing technical and product support for the company's production facilities, and in *troubleshooting* and problem solving for the production and management

divisions of the company. This implied that they were very dependent on bilateral interaction with all company divisions and other outside clients that required their services to receive input and feedback to direct their research activities.

In general a good, workable, communication structure prevailed within this sector and this operated at two parallel, but also intersecting, levels where both formal and informal modes and channels of communication were utilised. On the formal level this was driven by the project management structure within which most of the industry crystallographers operated and which enforced regularised reporting and communication of information. In addition all respondents stressed the importance of informal, person-to-person, exchange of information. It was evident that the informal exchange of information was in fact actively encouraged and was the major method of communication when information was required to solve specific problems encountered in the work situation. Face-face communication was the preferred mode of interaction, but e-mail and the telephone were also used extensively. The key person in the R&D communication network was the group leader of the research teams and they generally acted as *gatekeepers* ensuring a two-way communication pathway to and from their groups to the wider company and beyond to the science community in general.

The respondents in industry were particularly aware of the isolation caused by the confidential nature of much of their work, the geographical distance of South Africa from the major international researcher centres, and during the first study, the effect of political isolation on information communication. They were thus very conscious of the necessity to import external information into the work environment and made a concerted effort to engage with external colleagues and other experts, often transcending rigid organisational boundaries. They further also realised that they had to engage with recorded literature, not only to obtain much needed external information, but also to transfer their unique knowledge to wider audiences, and if feasible even to publish in the public domain. The latter aspect, however, was not generally feasible as they were severely hampered by the confidentiality restrictions mentioned above and the profit motivation that was the driving force of their work environment.

The most general encoded research output in this environment was thus some or other technical report that was circulated within the company and, if applicable, further abroad. Such reports are a fundamental component of the communication process in industry and ensure that the outcomes of the research process are encoded for future reference, albeit only within the confines of a

specific organisation. Patent specifications, which of course are directly related to the main business of industry, were another important encoded output. The presentation of conference papers and publications such as journal articles hardly featured in this environment.

The organisational and management structures that were in place in the research institutes, albeit more flexible, were fairly similar to that in industry and these structures also generally determined the formal information communication networks that were in place. Most researchers thus worked in research programmes within divisions that were established according to broad subject, or mission orientated, categories. The greater flexibility in the research institutes and the tendency to delegate responsibility, however, resulted in a fairly-flat organisational structure and a less restricted working environment.

These researchers were also predominantly engaged in applied research in the fields of materials science, mineralogy or applied chemistry. A feature of their work environment was that a large proportion of their research was conducted under contract for some or other external client (more evident in the second study) and they, in turn, often further contracted their research out to various universities, or they collaborated with academics on research projects. These various levels of contract work resulted in a fairly complex information communication structure and it also dictated that the communication process was, despite the fairly open culture and flat hierarchical structure that prevailed, still fairly formalised and structured. One of the consequences was that intellectual property and confidentiality issues impinged on the information communication process (again more evident in the second study) and this was in direct conflict with the underlying culture of information sharing that has always prevailed at these research institutes.

Formal information communication in the research institute divisions was established by means of regular, structured project management meetings. In addition inter-programme seminars were held where the divisional directors and project leaders communicated across program boundaries and this encouraged cross pollination of ideas and facilitated problem solving. The overall communication process was generally mediated by the group leaders who ensured the effective vertical and horizontal communication of information in the work place. As in the industry environment, informal, interpersonal interaction and exchange of information was highly valued, actively encouraged and it occurred on a daily basis.

The research institute researchers further also engaged with the published and other recorded literature to obtain the information they required and to transfer their research output into the public domain, if possible, or to circulate it within their closed community, if confidential. They thus produced reports for each project that they were engaged in, and patents where possible. Although the presentation of conference papers and publication, such as journal articles, played a secondary role, they were far more heavily utilised in the research institute environment than in the industry environment. This was partly because not all research was confidential and partly because of the underlying ethos of sharing information with the wider research community.

The crystallographers that were attached to the twelve academic institutions were basic scientists who were either engaged in *pure* crystallography research or utilised it as an analytical method or *tool* in chemistry (the largest proportion), physics, geology, materials science or biochemistry. The formal research team structure that generally constituted the norm in the other work environments was far less strictly adhered to within the academic environment. A natural evolution towards group forming and collaborative research, however, occurred amongst a large proportion of the academic respondents. Many academics thus worked in structured research groups or less formal unstructured groupings, while a smaller proportion worked on their own (the so-called loners). These working styles predicated three distinctive communication patterns based on the degree of group forming and collaborative research undertaken by the academic respondents.

The structured groups all shared common research goals, they were very directed and focussed, a strong bond existed amongst them, and although collaboration was a very distinctive ethos, each person in the team was encouraged to make his/her own unique contribution. Interactive communication links were maintained amongst members of the group, which ranged from daily, informal contact, to scheduled formal meetings. A further feature of these groups was that they mostly consisted of researchers conducting *pure* crystallographic research and they frequently provided a service to other researchers, often external to their university and in diverse research areas. Such activities resulted in extended communication networks far beyond the field of crystallography.

The *unstructured groups* usually consisted of members of the same department that collaborated, but who did not form as close-knit a research unit as the previous category. The nature of their interaction was thus far less structured and formalised. It was further evident that these

crystallographers were more equitably distributed among the basic disciplines represented in the study and further that most of them utilised crystallography as an analytical tool. It was also observed that there was far less evidence of a group dynamic in these less formal teams, individual members were more independent and personally involved in the communication process, and were less dependent on the group leader to drive the process.

The last category consisted of the academics who worked independently and in virtual isolation. These lone workers primarily used crystallography as an analytical tool and their specific subject fields were fairly equally distributed amongst chemistry, physics, geology and biochemistry. Although they worked outside a group structure, the 'loners' did maintain informal, unstructured communication links with colleagues in their departments, in other cognate fields and outside the university environment. They usually communicated extensively with the main crystallographic group at their university and then mostly with the leader of such a group and the operator of the diffractometer (if available). They also undertook collaborative research, but to a lesser extent than their counterparts in the other two categories. They all regarded formal channels of communication as important links in the communication chain in their work environment.

In all three categories the driving and motivating force for the academic researchers was to receive peer recognition for their research endeavours, to make their research known to as wide a scientific community as possible, and to contribute to the body of knowledge in their field by publishing their research outcomes in the public domain. They also produced project reports and promulgated patents, but to a far lesser extent than the other two environments.

Although the basic information communication model outlined above remained fairly constant from the 1990/1 to the 2001/2 study, certain significant changes did surface during the second study. The variation over the ten years was predominantly caused by the impact of the escalating electronic information environment, structural and other changes in the work environments, and changes brought about by the adoption of a democratic political dispensation in South Africa. These and other variations between the two studies will be discussed in greater detail in 6.6. below.

6.2.2. COMMUNICATION OF INFORMATION OUTSIDE THE IMMEDIATE WORK ENVIRONMENT IN SOUTH AFRICA AND INTERNATIONALLY

It was clear (cf. Chapter 4.3.) that two factors had a considerable effect on the communication of information among the wider community of researchers involved with crystallography in South Africa and abroad. The first related to the professional organisation of this community. The international crystallographic community is very well organised by means of the International Union of Crystallographers (IUCr). From the formal scholarly communication point of view they have been very active in publishing (both in electronic and print formats) some of the most prestigious journals in the field of crystallography. They have actively embraced the electronic environment to enhance and improve the efficacy of their publication procedures, and to provide links to relevant bibliographic and structural databases and other primary publications that are available on the World Wide Web. They provide a number of other online services such as e-mail alerting, tables of contents and details of forthcoming events. These electronic services are made available throughout the world by means of their three international IUCr Web mirror servers (one of which is administered in South Africa).

In addition to their formal publication efforts they further promote interaction by means of their tri-annual congress, to which each country sends a delegation, and other specialist conferences they organise. The Union has also established a network of *Commissions* in a number of specialist areas and which provide a body of experts who can be consulted on a variety of issues. The IUCr thus very effectively creates the platform for interactive co-operation, interaction and exchange of information among the members of the international crystallographic community.

In South Africa, the South African Crystallographic Association has had a similar major impact on communication among the local crystallographic fraternity. It specifically aims to facilitate the communication of information related to crystallographic research in South Africa and further ensures that close links are maintained with the International Union of Crystallographers and the central body of scientific unions in South Africa. Communication within the Association is fairly active, and is mainly driven by the regular symposia that are held in the field in South Africa. These symposia further stimulate informal communication among the members.

The second major factor that affected communication was related to the researchers' access to and interaction with sophisticated crystal analysis equipment and crystal structure databases. Access is specifically required to single crystal diffractometers, and if possible powder and neutron

diffractometry facilities. In South Africa only five institutions have the capacity to acquire and run single crystal diffractometers and all researchers in the field are thus dependent on the analysis services that these five institutions offer to the crystallographic research community in general. The crystallographers from these five institutions maintain very close communication links with each other as well as with researchers at other institutions who approach them for a crystal structure analysis service. South African researchers further rely on the Cambridge Crystallographic Unit (CCU) at Cambridge University in Great Britain; the Joint Commission for Powder Diffraction (JCPD) in the United States of America; the facility at Grenoble in France where a number of countries co-operate to run a large neutron diffractometer facility; and the facilities at the Brookhaven and Rutherford Laboratories for powder diffractometry and other more advanced crystal analysis. A few institutions in South Africa subscribe to the crystal structure databases produced by the CCU and the JCPD and they then again provide access to this data to the local crystallographic community. It is clear that international and local cooperation is excellent and this has resulted in the open and often free exchange of information, data and computer programmes in the field (this even applied to the years when South Africa was politically ostracised by the international community).

From the above it is clear that members of the local and international crystallographic fraternity are closely linked to each other either by their need to access sophisticated equipment or their willingness and ability to provide information and/or a service to outside researchers. The result is that there is constant communication (both person-person as well as by indirect means) between crystallographers within the country and the international community. This interaction and exchange of information was further fostered by the respondents' acute awareness of the importance of exchanging information and cross fertilising ideas by maintaining contact and interacting with other experts in their field and the wider science community. The paucity of a critical mass of experts in many specialist fields in South Africa further encouraged active interaction with international scientists and research facilities.

Where possible, the local crystallographers thus tried to go abroad to visit international centres of excellence, use advanced facilities, attend whatever relevant conferences were being held at the time, and visit suppliers. They also then generally used these opportunities to find international experts to invite to South Africa and where feasible encouraged them to spend sabbatical periods in South Africa where they were then also exposed to the wider South African research community. Scientific meetings and conferences clearly provided an important forum at which

information was regularly exchanged (both formally and inter-personally), where the crystallographers made and fostered contacts, publicised their latest research and also kept abreast of new research fronts. Another important platform of interaction and source of new innovation (particularly in the industry environment) was provided by interacting with suppliers and manufacturers of materials and equipment.

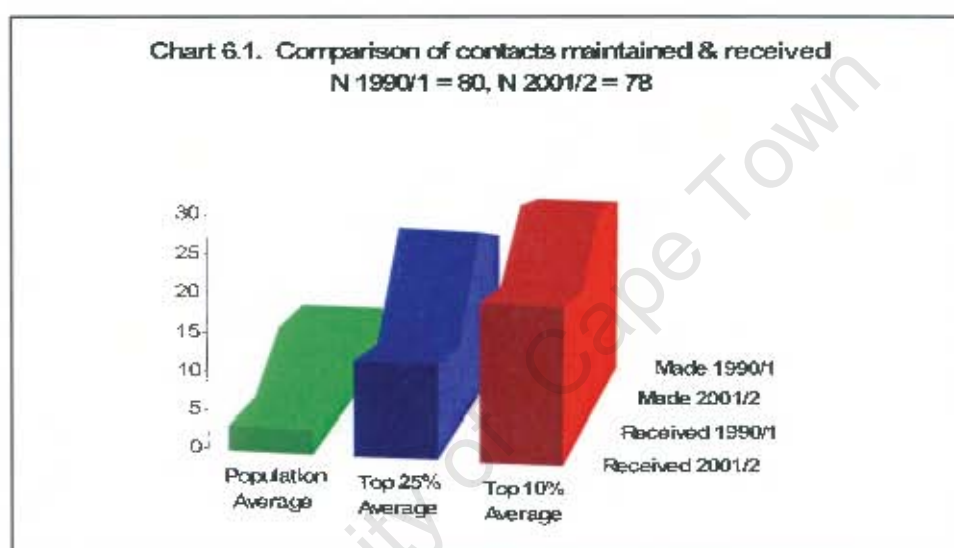
A feature of the respondents' external interaction was that while the applied fields actively approached the basic fields for information and assistance, the converse did not always apply. The interaction in the basic fields was generally between scientists at the same level of expertise and environment. In the second study there was evidence, however, that this aspect seems to be changing with a growing tendency towards greater interaction between the environments, each drawing from the others strengths and expertise. This could be attributed to the fact that over the last decade the university and research institute respondents were forced to engage in more contract research and industry to outsource more research.

The worldwide drive towards increased collaborative research has also had an impact on South African researchers and resulted in greater interaction with colleagues outside the immediate work environment. The increase in use of electronic media and networks has assisted this process as well as the fact that South Africans have generally gained greater international acceptance and increased mobility since the change to a democratically elected government in 1994. The general use of electronic modes of communication has not only widened the scope and ease with which researchers can interact with recorded literature, but also facilitated inter-personal communication. This, despite the fact that face-to-face communication was still the preferred mode of interaction, has been an important factor in South Africa, with its vast distances between main centres and its remoteness from the epicentres of international research.

6.2.3. THE CRYSTALLOGRAPHERS' LEVEL OF COMMUNICATION ACTIVITY

It was seen in Chapter 4.4.4 that there was a relatively small nucleus of crystallographers who were driving the information communication process and who were the most active inter-personal communicators. These active communicators were the recipients and instigators of far more regular information exchanges than the population aggregate. In Chart 6.1. below the aggregate number of professional contacts made and received by individual respondents are compared. The Chart compares the population aggregate with the top 25% and top 10% most active communicators. It can clearly be seen that there is considerable variation between the data for the

population as a whole and that of the top communicators, and this, it is submitted, demonstrates the presence of a core group of respondents that interact and exchange information vigorously. It was further seen in Chapter 4.4. that a substantial majority of the contacts that were maintained were to listed crystallographers and that over half of these were South African (both studies). The strong communication links that were sustained within the crystallographic fraternity and the fact that the greatest activity was contained within a small group of crystallographers would thus suggest the presence of the *invisible college* phenomenon within this community (cf. also Map 4.1. that illustrates these links).



When the geographical spread of communication activity was analysed it was further seen that the Gauteng area contained a sufficient critical mass of expertise in the field to obviate the need to communicate extensively outside the area. The respondents in all the other areas (particularly those in the Free State and the Western Cape) communicated far more widely with persons outside their own area. This could also be partially attributed to the fact that all the research institutes and the majority of the industries in the study were situated in Gauteng (the universities, however, were more evenly distributed throughout South Africa).

6.3. THE CRYSTALLOGRAPHERS' USE AND PREFERENCE FOR CHANNELS AND MODES OF COMMUNICATION

The assertion has often been made that the way and medium in which information is communicated can have a significant effect on the communication process and to test this

assumption this study specifically investigated channel and mode use among the crystallographers (cf. Chapter 5.). A number of studies have indicated that although accessibility, familiarity and ease of use are of prime importance to information users when initially selecting communication modes and channels (cf. Chapter 2.4.), the reputability and quality of the channel that conveys the information is far more significant as a measure to accept and adopt information and ideas.

Paisley's (1980) distinction (cf. Chapter 2.4) between mode (the physical encoding) and channel (medium transferring the message) was adopted for this study and it was further decided to view communication channel categories as lying along a continuum that ranges from formal, indirect, channels which could for example utilise recorded modes of communication, to informal personal channels which could typically relate to oral face-to-face communication between individuals. It was established in the study that the broad categories of channels and modes that the crystallographers generally engaged with in the information communication process were direct person to person exchange of information, recorded channels that were usually either in print or electronic modes, and conferences (although strictly speaking consisting of a range of modes and channels) were further frequently mentioned as forming an important constituent of the communication process.

In the 1990/1 study there was a clear preference for both inter-personal channels and print-based communication modes, and while conferences attracted only a slightly higher than average rating, electronic modes hardly featured at all. There was an almost complete reversal in the 2001/2 study, all four categories were highly rated, and there was hardly any differentiation amongst the preference ratings given by the respondents. These factors will be discussed in more detail below.

6.3.1. INTER-PERSONAL COMMUNICATION OF INFORMATION

The important role of informal communication of information in science has been highlighted by a number of researchers, of which the seminal work of Price (1963) provides one of the foremost expositions of the *invisible college* phenomena (cf. also Chapter 2.2.). Cronin has stated that informal communication did not evolve as a reaction to shortcomings in the formal systems of communication but as a "device created by scientists for scientists to serve a particular set of functions" (1982:229), the most important of which, the researcher suggests, is the interactive nature of the exchange process and the stimulation that collegiate interaction provides.

A number of studies (cf. Chapter 2.2 and 2.3) have indicated that there is a positive correlation between high levels of communication with colleagues and high performance levels and that performance increases if informal communication links are encouraged. Indicators point to the fact that scientists who belong to large informal networks are more actively engaged in collaborative research and publication collaboration, they have stronger citation links, they are more innovative, their ideas are transmitted more effectively, and they generally have more influence on research than their counterparts who do not belong to such informal networks.

From discussions during the interviews (cf. Chapter 4.4. and 5.3.) it was clear that direct personal interaction and exchange of information was very highly valued and by far the preferred mode was face-to-face engagement followed by communication by telephone. It was frequently stated that informal *corridor discussions* generated new ideas and serendipitous problem solving and some respondents were prepared to go to extreme lengths to engage in face-to-face interaction, for example the one respondent as mentioned in the previous chapter was prepared to

...catch a plane and fly to the right persons anywhere in the world to have them help us...

It was, however, further seen that various external and often pragmatic factors impinged on this inherent preference for face-to-face interaction. The most important was the distance factor, and while by far the most respondents indicated a high level of personal interaction in the immediate work environment, this changed to the greater use of the telephone (both 1990/1 and 2001/2), electronic media (2001/2 only) and manual correspondence (1990/1 only) when communicating elsewhere in South Africa and abroad. The greater the distance and the effect of cost factors, the greater the tendency to use the more inexpensive modes, such as manual correspondence in the first study and electronic modes in the second. In 6.7. other factors, such as the work environment, that impinged on mode preferences will be discussed in greater detail.

6.3.2. PRINT-BASED INFORMATION COMMUNICATION CHANNEL PREFERENCES

The main print-based channel categories that the crystallographers generally interacted with were journals, monographs, internally produced reports, patent specifications, and a variety of other lesser used categories that ranged from review publications, to reference works to trade literature (cf. Chapter 5.4.). Of these, journals were by far the most generally used and valued communication channel (this applied to both studies). All other print-based channels attracted

very low ratings, other than technical reports where the use of this channel increased considerably with the increase in contract research that was observed in the 2001/2 study. Studies that have investigated channel selection have generally found that information sources that are more closely attuned to the work situation are more frequently utilised and valued and it was seen that these factors also played a role among the respondents in the three work environments. These factors will, however, be discussed in greater detail in 6.7. below.

6.3.3. ELECTRONIC MODES OF COMMUNICATION

With the rapid expansion of the use of electronic communication modes the question arises to what extent this has affected information communication behaviour. It was seen in Chapter 2.6 that conflicting views were expressed in the literature and while some authors claim its impact is considerable, yet others are of the opinion that science communities view electronic media as merely another mode in which information is communicated. What is certainly undisputed is that electronic modes and networks have been absorbed into the science communication process; they are used extensively; and scientists apply them in a myriad of ways (cf. Chapter 2.6.).

In 1990/1 there was no evidence that electronic media had had any significant impact on the community of crystallographers. The limited interaction that did take place was restricted to delegated online searching and SDI subscriptions (which were very costly); using the electronic versions of the CCU and JCPD databases; and the hitherto infrequent usage of communication networks. There was, however, a complete reversal of the situation in 2001/2 and it was seen that the use and application of electronic media, networks and systems had increased exponentially and become common practice. These findings are very much in line with those of Tenopir et al. (2003) and Hallmark (2003, 2004) that were reported in 2.6.

The general consensus that surfaced from the second study was that electronic media have had a very positive impact and that e-mail, in particular, is a vital tool in communication. It has helped to overcome South Africa's geographical isolation and extended the scope of interpersonal communication and collaboration outside the immediate work environment. It was specifically noted that scientific data and a vast variety of media (text, graphics, audio/video, etc.) can easily be exchanged between researchers, research results can more readily be compared and different viewpoints easily discussed. A further benefit is that wide array of information in electronic format can easily be retrieved.

The most frequently used electronic channels for information-seeking purposes were the Internet followed by CD-ROM databases subscribed to, internally produced databases and then at a far lower rating *other* channels such as subject gateways and portals. It is interesting that the value ratings did not mirror the usage ratings and CD-ROM databases were valued far more highly than the Internet, the channel used most frequently. The databases their own organisations produced, surprisingly, attracted fairly low usage and value ratings. Comments made during the interviews indicated that while the Internet is useful when starting a new research project, subject gateways and portals are more useful to get more detailed information, and CD-ROM databases are invaluable when conducting a detailed literature search or to obtain specific information to solve a problem. According to many of the respondents, the greatest drawback of the Internet is that many searches produce totally irrelevant or low value information.

The crystallographers, although they used electronic journals only moderately, both as a carrier of information and as a publication vehicle, were generally very satisfied with the quality of the information content. From the comments made it would appear that the respondents were not that concerned about the mode of the journal, but were resolute about availability, access, quality considerations, rating levels and whether the journal reaches a wide audience. They were not yet convinced that electronic journals achieve all of the above and were particularly concerned about archiving problems in the electronic environment and the effect this has on maintaining a permanent record of scientific research (cf. comments made above). A specific problem that pertained to South Africa was the bandwidth problems that we have here and the impact this has on speed of access. Printed journals were thus still preferred and considered to be indispensable at the time of the 2001/2 study (again a result similar to that of Tenopir, et al. and Hallmark, cf. 2.6.).

From the above it is clear that the most obvious benefits of electronic communication media and systems are that they eliminate the distance factor and they provide a channel that can be accessed instantaneous all over the world (if the infrastructure is available). They thus facilitate international collaboration and the exchange of information. While the benefits of electronic modes of communication are indubitable, there are, however, some inherent problems that attend to this mode. One of the main areas of concern are that electronic modes and networks are not sufficiently inclusive and that scientific communication may become less visible and only accessible to privileged members of closed communities. A further factor is that the rapid

evolution of information technologies could render current and past electronic media inaccessible and this could effect the permanent archiving of scientific information. The structure of science depends on its permanent body of knowledge that records all scientific endeavour and which underpins its cumulative base, its peer review system and its reward system.

6.3.4. THE ROLE OF CONFERENCES IN THE COMMUNICATION PROCESS

Conferences were valued for a variety of reasons, including amongst others the role that they play in providing a forum to transfer and publicise current *state of the art* information, for promoting scientific and technological innovations, for facilitating informal contact amongst attendants, stimulating the exchange of ideas and opinions, and assisting with the transfer of information by means of the collegiate process (cf. Chapter 5.6.). The crystallographers, despite listing all the important reasons why they valued conferences, returned fairly moderate ratings for their information communication value. The main reasons given during the interviews for this contradiction were high attendance costs (particularly for international conferences) and, to a lesser extent, because many of the applied scientists felt that presentations were too theoretical.

As far as electronic conferences was concerned, it was very clearly stated (and also so rated) that they did not favour this mode of participation. The most important value of conference attendance was the forum that it provides to interact with other scientists, to conduct informal *corridor* discussions and serendipitous information gathering. Although the electronic format does overcome all travel-related problems, the advantages of the medium, in the respondents' view, does not compensate for lack of human interaction.

6.3.5. INFORMATION GATHERING AND CHANNEL SELECTION

It was suggested in Chapter 5.7 that the information gathering process is set in motion by a need for information that can be related either to keeping up-to-date with new developments in a field, or to undertaking new research projects, or to solving problems that occur in the work situation. It was further indicated that each of these information needs predicate the use of different information communication channels and modes and that they have varying effects on the information communication process.

All the crystallographers held very strong views about the necessity to stay abreast with new developments and the latest information being generated in their fields. Although a variety of

methods were used it was seen that by far the most predominant was to scan the latest journals in their field and in 2001/2 the use of electronic current awareness media and services were also very popular. Communicating with knowledgeable persons and attending conferences (the latter applied particularly to 2001/2) were highly rated albeit less so than perusing current journals, etc. (cf. Chapter 5.7.1.).

Almost all the crystallographers commented during the interviews that before starting a new project it is imperative to conduct an exhaustive survey of the literature and establish the state-of-the-art of research in the field. Such a forerunner to a research project obviates duplicating what others have already done, it provides greater methodological insight, and usually helps clarify conceptual issues. Once again, although a variety of methods were used concurrently, it was clear that by far the most popular was to conduct a systematic manual or electronic search of the information in the field (electronic methods mostly applied to 2001/2). The only other methodology that attracted significant ratings was to approach colleagues or experts for information and a surprisingly large number picked up the required information serendipitously by browsing (the latter was incorporated in the *other* category; cf. Chapter 5.7.2.).

It was further clear that when the crystallographers encountered a work-related problem they most frequently approached a colleague in the work place or some other expert, and to a lesser extent they looked for a solution in the literature in the field, both in printed and electronic modes (the latter applied to the 2001/2 study). They obviously first tried to solve it themselves and often used a combination of these methods.

From the preceding it is very clear that the reason why information is required has a significant impact on the method, channels and modes used to gather information. It was further observed that preferred methods, channels and modes could vary considerably depending on the specific nature of the information required, the work environment, characteristics of the individual crystallographer and application of crystallography (these aspects will be discussed in greater detail in 6.5. below).

6.3.6. THE USE AND VALUE OF LIBRARIES IN THE COMMUNICATION PROCESS

A number of studies have indicated that the information facility serving a community can impact considerably (both positively and negatively) on the information communication process of that community (cf. Chapter 2.7.3.). The availability of efficient facilities may stimulate conscious

and unconscious information needs which then activate the communication process, while inadequate facilities tend to stifle information needs and the communication of information.

It was evident that in both studies, while the libraries were highly rated for the contribution they make to the information communication process, the use made of them and the rating given for the service provided was much lower (cf. Chapter 5.8.). The first seeming anomaly can be explained by the fact that many respondents stated during the interviews that they rarely personally used the library as they either sent a junior staff member or a student to find material in the library on their behalf, or they requested the library staff to search for the information they required. The low service rating can, in turn, be explained by the large number of university respondents who were dissatisfied with the services provided in the 1990/1 study (but which had improved by 2001/2) and the frustration that the respondents at the largest research institute had with their library in 2001/2. It was evident that the generalised view was that the main value of their libraries resided in the information resources offered rather than in the services provided. This view, however, varied considerably according to work environment and seniority of the respondents (cf. 6.5. below for more details).

6.4. RESEARCH OUTPUT

The research process reaches its culmination and is concluded when the results of the study are transferred into some or other output. It was clear from both studies that the nature of the output depended largely on the kind of research that was conducted and the type of work environment. This output, depending on the circumstances, was found to be either some or other written record of the project or a physical entity or process. Even when the latter was produced, it was found that some or other encoded output in the form of a technical report, and/or a patent accompanied the physical end-product. The crystallographers in the basic sciences generally produced some or other publication in the public domain, usually journal articles, usually in print format (even in the second study print was preferred over electronic) (cf. Chapter 5.9.1.).

In both studies formal publications constituted by far the greatest proportion of the recorded output, followed by internal reports (this category of output increased in 2001/2) and conference presentations, while patent specifications only represented a negligible component. The average annual encoded research of the respondents ranged from zero publications to 9.9 in 1990/1 and 12.1 in 2001/2 and the aggregate population output increased from 2.5 in 1990/1 to 3.2 in 2001/2

(i.e. by 28%). This growth in publication output was observed not only for the ten year period of the study, but also when the total publication output over the total period of publication activity for each respondent was examined. These increases may be attributed to a combination of three factors. The first is that during the last few decades all work environments have been under greater pressure to improve productivity and increase accountability, hence the increased encoded research outputs. The second might be that as each researcher matured and acquired enhanced skills and knowledge there was a growth in productivity with time, and thirdly the increase in collaboration practices that was observed also stimulated greater output.

The typical collaboration, and thus co-publication, pattern that emerged was that collaboration would predominantly occur among members of the same research group together with one or two scientists from the wider circle of South African and international scientists. It was further observed that the more prominent and well known a scientist became, the wider afield he/she would collaborate. It is clear that all the leading crystallographers within South Africa have worked with one another at some or other time and that the more eminent crystallographers collaborated extensively with scientists abroad. In this way the entire South African and international crystallographic fraternity was linked by means of their most eminent researchers.

A further interesting observation that was made was that there were decided peaks and troughs in the crystallographers' production patterns with periods of intensive research engagement stimulating research output and increased publication. The greatest proportion of the crystallographers published both in South Africa and abroad, or only internationally.

It is clear that the encoding and recording of research outcomes signals not only the final stage of the research process, but also the transfer of information generated during the research process into public knowledge and the scientists' interaction with the communication process converts finally to the formal domain (cf. also Chapter 2.1., 2.2. and 2.3.).

6.5. FACTORS AFFECTING THE COMMUNICATION PROCESS

It was stated in Chapter 2.7. that a fundamental prerequisite to understanding the communication of information among scientists would be to examine the variables that affect the information communication process. It was mentioned there that a wide diversity of factors have been listed in the literature that might affect information communication behaviour. The information

communication process is a complex social system and it should thus be acknowledged that an inter-meshed combination of variables could synergistically impact on the process. It is suggested that these could amongst others include

- the scientists' innate personality traits (both affective and cognitive domains), and demographic characteristics (e.g. age, position, qualifications, etc.);
- factors related to the work environment, such as structure, type of work (e.g. whether applied or theoretical by nature), specific task attributes, etc.;
- adherence to a discipline and/or profession;
- various external factors such as the socio-political environment of the scientists;
- information use and the consequences of such use;
- interaction with information systems (both formal and informal) and information communication channels.

The factors or variables that surfaced in this study as contributing most to differentiated communication patterns and behaviour were the scientist's work environment and work structure; whether they were basic or applied scientists and how they utilised crystallography; and finally the years of professional experience, and status within the organisation. This is fairly congruent with various studies as reported in the literature (cf. Chapter 2.7).

6.5.1. WORK ENVIRONMENT, ORGANISATIONAL STRUCTURE, AND APPLICATION OF CRYSTALLOGRAPHY

The study clearly indicated that the crystallographers' immediate work setting was the most important factor that influenced their information communication behaviour and the flow of information in their environment. The work setting's influence ranged from the direct and immediate impact of work-team structures and interactions, to overall organisational policies, to the individual's status or position, and the roles, and responsibilities they fulfil. Related to all these factors and intricately interwoven with it were the crystallographers' allegiance to, and position on, the basic to applied science continuum (i.e. whether on the one hand they utilised crystallography in its pure form or applied it in basic science, and on the other hand whether they applied it for more practical outcomes in their work environments). The three work environments that pertained to this study population thus each imposed their own inhibitors and stimulants to the information communication process.

The applied and very practical nature of the work environment in industry meant that these crystallographers' need for information was very utilitarian and their interaction with the information communication process was thus directly related to product and system development, and providing technical and problem solving support for their company. A specific feature of their work environment was that they operated within a very structured project management system which imposed clear lines of communication and this framework very clearly stimulated internal communication. They were not only compelled to hold regular progress meetings and produce written reports, but were also actively encouraged to regularly interact on an informal, person-to-person basis.

The competitive nature of their environment, however, restricted their communication with the outside world. This bound them to confidentiality and secrecy restrictions which severely impeded the free exchange of information and impinged on the transfer of their research findings to the public domain. The latter aspect meant that their final encoded research output was usually a report (with restricted distribution) or to a lesser extent a patent and, very rarely, conference presentations or formal publications. Report-writing was thus a fundamental component of the information communication process in industry.

All the industries, however, made a concerted effort to counter information isolation by actively supporting all initiatives to stay up-to-date with new scientific developments and innovations. This was mostly achieved by maintaining very strong interpersonal links with the local and international research community, usually by means of *gatekeepers* in their organisations. These *gatekeepers* were very active information communicators (cf. also 6.7.), they maintained direct contact with the other researchers in their divisions and they kept themselves informed of the information needs of their colleagues. It was very clear that within the crystallographic community the industry respondents (by means of their *gatekeepers*) were the most active in initiating and maintaining contacts outside their own environment.

The crystallographers who were attached to the academic institutions were, in direct contrast to the industry environment, all basic scientists that were either *pure* crystallographers or utilised crystallography as an analytical *tool* in a variety of subject fields. They operated in a far more open work environment and the forming of research teams was entirely voluntary. If these did evolve, it was because of the strong leadership of the more eminent academic crystallographers who attracted postgraduate students and colleagues who wished to work and collaborate with

them. Not all of the university crystallographers, however, operated in this way and three distinct work structures were thus observed that ranged from well-organised, cohesive research groups, to the less formal framework of unstructured groups, to the academics working on their own.

Members of the structured groups were very directed, focussed and were coalesced by strong inter-personal communication links that ranged from informal contact to formal meetings. These fairly close-knit groups were however far less structured and mission oriented than what was found with the research teams in industry. The unstructured groups usually consisted of members of the same department that collaborated with each other and regularly communicated, but the nature of the interaction was far less formalised. There was far less evidence of a group dynamic and individual members were less reliant on the group leader to drive the information communication process. The lone workers, although working outside a group structure, still maintained informal, unstructured, communication links with colleagues in their departments and outside the university environment.

The driving and motivating force for the academic researchers was to make their research known as widely as possible and to obtain peer acknowledgement in the broader science community. The major end-product of their research was thus some or other publication that could contribute to the body of knowledge in their field. They also produced project reports and promulgated patents, but to a far lesser extent than the other two environments. The latter two outputs however increased between the two studies in conjunction with the growth in contract work that was enforced by decreased budgets and the need to become more self-sustaining over the period of the study (cf. also 6.6.).

The distinguishing features of the academic respondents' interaction with the external environment related to whether they participated in collaborative research, whether their expertise was sought after by other researchers (often from a range of work environments), and whether they were attached to one of the universities that had their own diffractometers. The *pure* crystallographers who operated such diffractometers communicated actively with each and with those researchers who required a crystal structure analysis service. It was further clear that a close relationship existed between the academics and their former students. The latter kept contact with their former supervisors to tap into their expertise and/or to collaborate with them and/or to engage them to do contract research for them. The university crystallographers further interacted with the international research community by publishing in international journals, presenting

papers at international conferences and perusing the international literature.

The research institute environment emulated characteristics that were present in both the university and industry environments. Although most of the researchers in these institutes worked within a project team work environment, it was less formally structured than in industry (but more formal than in the universities). There was a greater tendency to devolve responsibility and this resulted in a fairly flat organisational structure and a more delegated working environment.

Research was applied by nature and originally this was driven by an inherent need to investigate and solve research problems to the benefit of South African society. Over the years this changed (once again because of financial reasons) to the prevalent situation where a large proportion of their research is conducted under contract (and for profit) for some or other external client (both private and public sector) and they, in turn, often further contracted their research out to various universities. This has resulted in a fairly complex information communication system which ranges from the more formal aspects of a typical project management environment to a more informal collegiate situation.

The free exchange of information outside the immediate research circle was, because of the high prevalence of contract work, thus also often affected by confidentiality restrictions. The respondents at the research institutes therefore consciously tried to maintain contact with other environments and a particular area of concern was the danger of not staying abreast with the latest international research developments. They therefore made a concerted effort to maintain close contact with research institutes across the world, to interact with scientists abroad and to keep up-to-date with international publications. The *gatekeeper* phenomena, although not as prevalent as in industry, was also present in this environment.

Although project reports and patents (to a lesser extent) represented a significant component of the research institutes' encoded research output, publications such as journal articles and the presentation of conference papers also played an important role in the dissemination of their research findings. Not all their research was confidential and it was part of their work ethos to share information with the wider research community and to transfer as much of their research output into the public domain as was possible.

The work environment clearly had a very distinctive impact on the use and value attributed by the

crystallographers to the various communication modes and channels that they used. It is clear that while all three work environments regarded interpersonal and particularly face-to-face interaction as an important factor in the information communication process, the crystallographers in industry, and to a slightly lesser extent at the research institutes, were far more dependent on this form of interaction than their university counterparts. The industry respondents often exerted considerable effort to achieve face-to-face interaction and if this was not possible they preferred telephone interaction, rather than less personal and less interactive communication modes. The university and research institute respondents clearly embraced electronic modes of communication to a far greater extent than their industry counterparts. A further feature of interpersonal communication was that while the university crystallographers were generally approached by the other two environments for information and advice, the converse rarely occurred. The university respondents, when they did contact an expert, mostly approached a colleague within the academic environment.

The university respondents awarded the highest rating of the three environments to print-based modes of communication and particularly journals and to a lesser extent monographs as channels of communication to both obtain information and as a publication vehicle. In the industry environment, reports and patent specifications were used the most extensively of the three work settings. The research institutes' position shifted from the situation in 1990/1 where they valued journals as a channel of communication to that in 2001/2 where, because of the increase in contract work, reports and patents grew in importance and equalled the role of journals.

Although it was clear that from the first to the second study all three environments had experienced considerable growth in the use of electronic modes, this was less evident in the industry environment. This can generally be ascribed to their wariness of security breaches in the electronic environment and their more conservative approach to new innovations and technology. As far as specific electronic channels were concerned, the only group of crystallographers that both extensively used and valued the Internet and CD-ROM databases was the university respondents (this is in line with the methods generally used by this group to search for information). Internally produced databases were used frequently and valued by the research institute respondents and to a slightly lesser extent by those in industry and this can be attributed to the more pro-active information services present in these environments.

It is not surprising that the respondents in industry gave the lowest use and value ratings to

electronic journals as they did not extensively engage with electronic modes or the journal literature in general. The research institute respondents, although awarding the highest value rating to the information content of electronic journals, did not use this journal mode more than moderately, both as a source of information and publication vehicle. Although the university respondents were the only category that made frequent use of electronic journals, and regarded their information value highly, they gave fairly low ratings to their publication value. The relatively low use of electronic journals at the time of the second study can generally be attributed to the fact that electronic journals of a specialised nature were not that readily available; that the respondents still doubted whether there was general acceptance of this mode within the science community and the effect this would have on peer acceptance of their research; and they were concerned that the archiving problems that pertained to electronic media would have serious long term effects on the science communication process (cf. also comments made in 6.6).

While conferences played a fairly insignificant role in the industry environment, they were highly valued by the other two environments, particularly the research institutes. This is a clear indication of the limited value that the predominantly theory orientated conferences have for industry as well as the fact that confidentiality restrictions generally prevented them from presenting papers. The high ratings given to conferences by the research institute respondents who are also generally engaged in research of a more applied nature, clearly indicates that they have been far more successful in bridging the divide between theory and practice. The university respondents valued conferences for the forum they provide to publicise their work and have it discussed and they, as well as the research institute respondents, particularly valued the opportunity conferences provided to network with experts working in similar fields.

While all three environments valued print media highly to keep abreast with new developments in their fields, it was clear that there was considerable variation in the use and value attributed to the other methods used. The industry respondents were more prone to seek out experts; the research institute and university environments valued conferences; and the industry and the research institute respondents valued the electronic current awareness services provided by their institutional information services. This can be attributed to the industry and research institute crystallographers' more proactive library services; the greater value placed on conferences in general by the university and research institute respondents; and industry's general predilection to approach experts for information.

The three environments showed very similar search patterns when conducting an exhaustive search for information and the only distinctive differences were in the intensity of the use of the channels and methods. This varied from the slightly higher score awarded by the university respondents in 1990/1 for manual search methods to the higher scores given by the industry respondents in 2001/2 for electronic methods. The only other significant difference was that the university respondents rated colleagues and *other* search methods (mostly unsystematic browsing), far higher than the other two work environments. To find information to solve a problem the industry respondents relied almost exclusively on approaching colleagues and experts in the field; the research institute respondents also first approached an expert and then searched for a solution in print and electronic media; and the university respondents first searched in the print media and then approached colleagues or searched electronic media.

There was considerable variation with regard to the use and value attributed to organisational libraries. The industry respondents, although personally using their libraries infrequently, awarded the highest value ratings to their role in the information communication process and service provided. This can be explained by the proactive, value-added and user-oriented services that were generally provided by their libraries. The university respondents while personally using their libraries the most frequently, awarded the lowest estimates to its contribution to the communication process and service provision. The views of the respondents from the research institutes fell somewhat in between that of the other two environments with moderate use and service ratings, and high ratings for the value of libraries in the communication process.

It was further seen that working in a group structure appeared to often predicate information communication styles and have many beneficial outcomes; amongst others, it stimulated interpersonal communication, the flow and exchange of information and generally stimulated productivity. The respondents who thus worked in more structured and group-forming environments were collectively the more active communicators, and professionally more active. The more the respondents worked in a less group forming environment or on their own the less they initiated information communication acts and the fewer number of contacts they received and the less they were involved with all aspects of their profession.

It was specifically observed that the success of the group dynamics in all three work environments largely depended on good leadership and although all members participated, the group leader was generally the driving and motivating force. Strong leadership resulted in the

development of a good team spirit, vigorous inter- and intra-group communication of information and in maintaining active links with the external environment. Such leaders encouraged the cross fertilisation of ideas and new knowledge by ensuring that information was exchanged with colleagues outside the group and by filtering and disseminating the most relevant information into and out of the group; i.e. a typical *gatekeeper* role was adopted.

It was further evident that in the more structured work environments the junior members relied on the more senior members and particularly the group leaders to interact with the outside world on their behalf. The converse applied in that the less structured and greater the level of solitariness in which the crystallographers worked, the more the junior academics relied on their own devices to interact with the external environment and acquire the information they required. This interaction, however, still remained at a much lower level than that of the more structured groups.

The empirical studies clearly indicated that the crystallographers' alignment along the basic to applied science continuum (which was also related to their work environment) and the contingent application of crystallography had a significant impact on the information communication process. It was thus observed that while there were only slight differences between the information communication behaviour of the *pure* and *tool* categories, considerable variation pertained between them and the *applied* crystallographers. The respondents who applied crystallography generally emulated the combined information communication behaviour of the industry and research institute respondents (i.e. those who were on the applied science side of the basic/applied spectrum), while the respondents who were *pure* crystallographers or used it as a *tool* generally followed the behaviour pattern of the university respondents, i.e. on the basic side of the spectrum.

The *applied* crystallographers clearly followed the pattern referred to in Chapter 2.7, that applied scientists tend to transfer information vertically by exchanging information between researchers, practitioners, and others through several different levels of expertise. The *pure* and *tool* crystallographers, on the other hand, rather transferred information horizontally, by sharing information among like individuals who have the same levels of expertise (cf. the above paragraphs for verification of this statement). While the assertions made in Chapter 2.7 that there is a distinct difference in the way that applied fields of knowledge and the basic fields communicate information clearly came to the fore in this study, it is suggested by this researchers that these factors are closely intertwined with the work environment and that the latter is in fact

the primary variable that determines alignment along the disciplinary spectrum and information communication behaviour.

6.5.2. POSITION, AGE AND QUALIFICATION

The empirical studies clearly showed that there was generally a direct and strong correlation between information communication behaviour and the respondents' age, position and qualification levels. In most instances information communication activity intensified with increase in level of seniority, qualification and age. In the latter instance there was however a few exceptions where the most active respondents were in the middle age category (31-50 years). This finding correlates well with that reported in the literature (cf. Chapter 2.7.2.).

It was thus seen that of the older respondents (i.e. the middle and oldest age categories), the more senior and highly qualified the respondents were the more they initiated communication contacts, the more they were approached by other scientists and the further afield they communicated. These respondents thus also went abroad far more frequently to initiate and maintain communication links. It is suggested that information communication activity and networking capacity evolves and grows over time and the more mature, senior, highly qualified, and thus established, researchers have made a name for themselves in their professions and have therefore over the years built up a substantial circle of colleagues with whom they communicate, collaborate and generally interact. This verifies the assertions made that one of the most marked effects of a scientist's status on the communication process is related to informal communication networking. Such networks generally operate at a senior level with the more senior (and often also older) and experienced (and often more highly qualified) members of a profession communicating extensively on a personal basis at conferences, telephonically, electronically, etc.

The younger respondents thus generally had fewer external personal contacts and they relied fairly extensively on their seniors or on the literature to obtain external information inputs. It is once again suggested that the more senior members played a pivotal role in the communication process and in the crystallographic community in general. It would further appear that respondents who were in middle positions were generally less bound by the communication bonds of the groups they worked in and that they were thus less dependent on their group leaders than their more junior counterparts.

An analogous pattern was observed for the variation in use and value awarded to most channels

and modes of communication. The use and value awarded to print-based modes increased with level of seniority, and age and this could partially be attributed to the fact that research output activity generally reached its peak among the more senior respondents in the 40 to 60 year age bracket and that prestigious print-based publications provided the best vehicle to publish their research output (this was observed even in the latter study). This further explains why the use and value of specific print-based channels such as journals, reports and patents also increased with level of seniority, qualification and age.

It was similarly observed that the more senior and older crystallographers attended conferences more frequently and valued their information communication attributes considerably more than their younger and more junior colleagues. These senior respondents particularly valued specific features and opportunities that conferences provided, such as the interaction and discussions with other experts in the field and the platform to present their research outcomes. One assumption could be that these crystallographers' more advanced research standing ensures that their papers are more readily accepted at international conferences, that they are called on to officiate more frequently and also that they have a greater ability to secure funding. The younger and more junior respondents, however, did attend as many conferences as possible and they particularly valued the more formal presentations far more highly than their senior counterparts. In fact many of the institutions had a policy to award funding to expose as many junior members as possible to international gatherings.

The only instances where the younger and more junior respondents awarded higher ratings than their senior counterparts to an information communication channel, mode or system was to monographs, electronic modes, listening to papers at conferences, and using their libraries. It can be argued that in the instance of electronic modes this may be ascribed to the fact that younger people (and thus often those in a more junior position) generally adapt to and adopt modern technologies more readily than the older generations. The greater use of monographs could possibly be ascribed to the fact that the more junior and younger researchers, because they had not reached a sufficient level of research maturity, derived more value from secondary publications such as monographs that had already synthesised and interpreted the primary information. In a similar vein they would derive more value from conference presentations. The greater use of libraries, it is suggested, is because the more senior and older respondents often delegated library visits and literature searching to their more junior colleagues and possibly because they are usually linked to some or other *invisible college* where they easily obtain

information via personal contacts, moderating the need, in many instances, to use formal channels of communication. It should be noted, however, that the more senior and older respondents valued their libraries' role in the communication process, and the services they provided, far higher than the more junior and younger respondents. This can probably be explained by the fact that the libraries more readily provided proactive services to the more senior (and often older) respondents.

6.6. VARIATION BETWEEN THE TWO STUDIES

Although, as mentioned, the underlying information communication model remained fairly constant between the two studies, a number of significant changes were observed that mostly related to the impact of the escalating electronic information environment and structural and other changes primarily caused by decreased funding and the adoption of new organisational business models in the work environments. To a lesser extent the changed political dispensation since 1994 and the worldwide trend towards increased globalisation and collaboration in research also had an effect on the communication process.

In the industry environment there was a general downscaling of their R&D facilities and an increase in the research they contracted out to universities and research institutes. This meant increased levels of interaction with researchers outside their own environments and different information needs and interaction with primary information sources. The research institutes were subjected to drastic state subsidy cuts and they were thus forced to operate as self sufficient business units and adopt a profit-making model to drive their research endeavours. This resulted in the need to engage extensively in remunerative contract work, which in turn brought about the enforcement of confidentiality restrictions by their clients (usually in industry) and intellectual property rights issues.

This contract and profit driven environment had a considerable impact on the research institutes' information communication process. The project focus and a budget that was geared towards selling man-hours forced researchers to become less open and also generally prevented them from transferring research outputs into the public domain. The incentive was rather to patent innovations and produce profit-driven products and all these factors severely restricted the previously dynamic flow of information. Informal interpersonal interaction was particularly affected and informal networks struggled to exist. There were, however, glimmerings of yet

another change in the organisational structure of the research institutes. This was the growing move to adopt a knowledge management approach and once again emphasis being placed on the importance of collegiate interaction and knowledge sharing. The question, however, arises whether the transition into a knowledge intensive and sharing culture could effectively be synchronised and synergised with the profit motivation and emphasis on confidentiality that still prevails.

Government funding for universities had also been declining steadily over the period between the two studies and competition for external research funding was intense within and between universities. This has also forced the universities into the realm of profit-based contract research. This competition for funding and the need to secure contract work has increased the level of tension in the universities and two opposing views surfaced with regard to the effect this has had on the interaction with information in the academic environment. A few of the academics were of the opinion that competition is good and that it increases output, stimulates research and enforces a shift away from a predominantly theoretical research base to a more applied approach with greater relevancy and tangible benefits for South Africa. The opposing view, as voiced by the majority of the academic respondents, was that it countered open learning, the free and vigorous flow of information and that it had a detrimental effect on collegiate communication. An indicator of the effect of this shift in emphasis was the increase in patent and confidential research report outputs.

All these factors thus inevitably resulted in a greater shift from basic to applied research and confidentiality restrictions. This, in turn, while negatively affecting the open exchange of information and impinging on the transfer of information into the public domain had one major positive impact. A situation was now created where the three work environments maintained much closer links with each other and where research in general was more attuned to achieving practical outcomes and a greater utility factor which could have beneficial outcomes for South Africa.

The second major variation between the two studies related to the considerable impact brought about by the escalating growth in the use of electronic media, networks and systems. It had improved the ease, speed and accuracy of information communication, it was now possible to more easily maintain widely dispersed and a wider range of communication networks, and it further increased the propensity and feasibility of both national and international collaboration. It

was thus found that, although e-mail, online databases and the Internet were all used routinely, the channel that had the most significant impact on the information communication process was e-mail. The electronic environment also meant that the organisational libraries had extensively embraced the enhanced service opportunities provided by the electronic environment and the improved alerting and searching services were particularly valued by the respondents.

It was clear that while certain electronic innovations had considerable impact, others were not equally valued and used. It was found, for example, that electronic conferences and mailing lists were not extensively used, the former because they did not provide the right environment for collegiate interaction and the latter did not live up to the original expectations of providing a vibrant discussion forum. Although the Internet was used extensively, the general view was that the value and quality of the information was frequently of a dubious nature. Electronic journals, although considered to be very convenient, were not that extensively used as a source of information and even less so as a publication vehicle. The major reason was that, at the time of the second study, there were still too few journals in the electronic format in their specialised field, and of even greater concern were doubts about the permanency of the mode and the long-term impact this could have on the scholarly communication process in science. These findings correlate very well with many of those reported in the literature (cf. Chapter 2.6.).

A specific problem that was raised in the industry environment was the danger that security could be breached and confidential information accessed if electronic media are used. A further issue that surfaced recurrently was the tension between the ease of use and effectiveness of electronic communication modes and its dehumanising aspects. It was argued that it generalises the communication interaction and does away with the finer nuances of interpersonal relationships. The general view was that e-media are adequate for communicating unambiguous and clear information, but that they cannot supplant personal interaction, which generally creates few barriers and enhances interactive collegiate communication and lateral and innovative thinking.

The effect of the post-1994 political changes in South Africa, amongst others, resulted in a more open society, greater entrée into the international research community, which in turn meant that South African scientists could travel more extensively, have their work exposed for international scrutiny and evaluation and thus generally be integrated more seamlessly into the international research community. This clearly also opened more opportunities to engage in collaborative research, which again meant greater international interaction and exchange of information.

6.7. PROFESSIONAL ACTIVITY, SCIENTIFIC ELITES, AND INFORMATION COMMUNICATION

It was clear from the findings reported in Chapter 4.5. that there was a core nucleus of crystallographers who were not only approached far more frequently for information and advice than any of their colleagues, but who also frequently initiated interpersonal and formal information communication acts. The reasons given for making contact with these persons related mostly to their expertise and knowledge of crystallography as a basic science as well as its various applications. The respondents who were most frequently contacted indicated that they were approached, amongst others, to provide assistance in solving crystal structure problems, to help to solve combinatorial problems, to do analytical work on the diffractometer, to provide assistance with diffractometer problems, to assist with computer software problems, etc. Another important reason for interaction was their involvement with the South African Crystallographic Association as well as with the IUCr.

The high level of commonality between the two study populations, and particularly the more eminent crystallographers, meant that there was almost no variation between the central networks of the two studies and it was generally seen that the crystallographers who received the most contacts mostly worked in a group structure; they were attached to universities and to a far lesser extent to research institutes; they were predominantly *pure* crystallographers with only a few who applied crystallography or used it as a *tool*. All of these respondents were in senior positions, mostly in the 36-50 age category and they all held doctorates (the majority were obtained in South Africa). The majority worked in Gauteng.

When the profile of the core group of crystallographers who received the most contacts is compared with that of the respondents who initiated the most communication acts, a number of differences surface. The active communication initiators were far more equally distributed among the three work environments and as a consequence there was a shift away from a preponderance of respondents conducting *pure* crystallographic research to those who used it as an analytical tool and who applied crystallography in industry and the research institutes. Almost this entire category worked in a group structure and mostly held senior positions (with only a slight shift to the middle position) and all were in the 36-50 age category. There was further a shift from a small majority of respondents with South African doctorates to a large majority. The geographical distribution hardly varied between the core recipients and initiators.

Of these very active communicators, one crystallographer emerged as the person who was by far the most frequently approached for information, for assistance in solving problems and advice in general. A number of respondents referred to him as the “doyen or boss” crystallographer in South Africa. He was a senior academic, in the 51-70 age category, had a South African doctorate and was the leader of a structured group working in the field of chemistry as a *pure* crystallographer in Southern Gauteng (cf. also Map 4.1.).

These very active communicators, and particularly those who received the most contacts, were further also identified as being the most prominent members of the crystallography fraternity. They stimulated considerable interaction, not only because they were very active seekers and disseminators of information, but also because of their knowledge and personalities; the other scientists were encouraged and motivated to approach them for information. It was further observed that they generally served on a number of important boards, committees, and other high profile professional activities in crystallography and within the general field of science. They were actively involved and played a leading role in their professional associations, they published profusely, they served on editorial committees, were sought out to act as journal referees and for external examining purposes and generally emerged as the archetypal *sociometric stars* in their field.

From the above it is clear that high productivity, professional involvement and interpersonal information communication are intricately interwoven. It is thus submitted that this study indicated very clearly the presence of an *elite* group of scientists within the crystallography community who are in Price's (1971:74-5) words the *eminent men* of the crystallography community, who have achieved a standard of excellence in their work and are highly productive; who are very visible in their professional community and who generally have a distinct influence over the scientific communication process in crystallography. These findings are further also in line with the measures Amick (1973:318) suggested could be used to identify and circumscribe the positive relationship that generally exists between scientific elitism and the information communication system of science (cf. Chapter 2.2.1.).

It was further clear from the results of the two studies that Allen's (1968, 1977) *technological gatekeeper* phenomenon was a distinctive factor in the communication process within all the work environments. There was thus a clear indication of the presence of intermediaries in the various organisations who indirectly ensured the flow of outside information into the organisation

and the subsequent dissemination of that information within the organisation. This phenomenon was even more visible in the more applied environments where confidentiality created barriers in the flow of information and where because of the very applied and practical nature of the work environment many of these researchers required someone to transcend the divide between applied and basic science in an interpretive way. This study further verifies the assertions made in Chapter 2.3.1.1. that such informal *importation* of information provides an effective mechanism for these researchers to stay abreast with external innovations and probably explains the survival of the information communication process among applied scientists despite the unique constraining features that are imposed on them.

These *technological gatekeepers* were all outstanding contributors to the technical goals of their organisation and emerged as leaders in the crystallographic community. They were generally also more highly qualified, produced more reports (and, if possible, published articles) and held more patents than their colleagues. They enhanced their linking capabilities by attending more conferences, by having more extensive personal contact with colleagues outside the organisation, by engaging more actively with the technical literature than their less active colleagues. Such *gatekeepers* are clearly akin to *scientific elites* in the more basic fields of endeavour and although the *gatekeeper* phenomenon was not as conclusively indicated in the data that was collected as the *scientific elite* phenomenon, it very clearly came to the fore during the interviews. As was mentioned in the earlier sections of this and other chapters the group leaders of research teams in the both the industry research institute environments (and even in the structured groups in the academic environment) very evidently matched the typical *gatekeeper profile*.

From the above discussion and the results of the study it is clear that there is a direct relationship between a scientist's professional activities and interaction with the information communication process, i.e. the more prominent a role a person plays in her/his professional life, the more active she/he would be in the communication of information in her/his field. It was further evident that while the *sociometric stars or elites* in the crystallography community in South Africa mostly worked in a work environment that was more conducive to collegiate interaction where the profit motive and the concomitant restrictions were less evident, the *gatekeepers* were very successful in ensuring that work environments that were bound by confidentiality and other restrictions maintained contact with the external environment and new information. It was further clear that working together in formal or loosely structured groups stimulated information communication,

professional activity and productivity and that Gauteng provided a sufficiently large critical mass of scientists working in the same field to stimulate interaction and productivity.

6.8. CONCLUDING REMARKS

It clearly emerged from the above discussion that the crystallographers' information communication behaviour was largely determined by their work environment which again determined their alignment on the basic to applied science continuum. Other factors such as level of seniority and position also played a significant role in the process. It was further seen that informal communication networks and the *invisible college* phenomenon, scientific *elites* and *gatekeepers* were all important factors and often the motivational force behind the information communication process within the crystallographic community. The longitudinal study further indicated that the varying factors that impacted most in the intervening period were the changes brought about in the work environment, organisational structure, and work ethos as well as the impact of the significant growth and ubiquitous use of electronic media, networks and systems. To a lesser extent the changed political environment provided an overarching impact on the socio-political environment in South Africa and interaction on a global front. Information communication in this defined science community clearly constitutes a complex system of many communication pathways, information flow variables and a network of systems that drive the process.

In the next and final Chapter these findings will be utilised to derive a theoretical framework and model to explicate the information communication process within this circumscribed community of basic and applied scientists. This model will also be used to further explicate the findings, evaluate the research questions that motivated this study and derive hypothesis that can fruitfully be used as a basis for future research in the field.

CHAPTER 7

THEORETICAL FRAMEWORK AND CONCLUSION

7.1. INTRODUCTION

In this chapter the researcher will derive a conceptual model²¹ from the main results obtained in the study and synthesise these with salient aspects drawn from a study of the literature to provide a contextualised framework of the information communication process among the bounded group of crystallographers investigated. The research questions that underpinned this study will, in conclusion, be examined within this framework. It was stated in chapter three that a triangulated research approach was adopted and that both quantitative and qualitative paradigms informed the research process. In keeping with the objectives of a qualitative approach, the research process was thus not overly structured and set within predetermined theories, but rather a more holistic approach was followed where questions and answers evolved while the research was in progress and where the final outcome of the research process was the development of a framework that could serve as a basis for future research in the field.

Another reason for adopting this approach is that the researcher, after examining the literature in the field, was of the opinion that none of the existing theoretical frameworks or models satisfied all the parameters required for a study such as this one²². Having said this, the researcher however did examine a number of theoretical/conceptual models in the field and acquired useful guidelines from this perusal. The discussions that contributed most to the development of the proposed model were the works of Bathelt et al. (2004); Belkin (1978, 1980, 1984, 1990); Belkin et al. (1982a, 1995); Derr (1983); Dervin (1977, 1980, 1997); Dervin and Nilan (1986); Ellis (1989, 1993); Ellis et al. (1993); Ford et al. (1999); Fry (2006); Ingwersen (1984, 1995, 1996); Itoga (1992); Järvelin and Ingwersen (2004); Järvelin and Wilson (2003); Johnson (2003); Krikelas (1983); Kuhlthau (1988a,b, 1991); Kuhlthau et al. (1990); Levitan (1980); Maceviciute (2006); Menzel (1966b); Niedzwiedzka (2003); Paisley (1968); Shannon and Weaver (1949); Spink et al. (1999); Vakkari (1997); Wersig (1973); Wersig and Windel (1985); Yovits and Whittemore (1973); Wilson (1981, 1984, 1999, 2000); Wilson et al. (1999).

²¹ For operational purposes the researcher has viewed the concepts *conceptual models* and *theoretical frameworks* in much the same way.

²² Cf. also similar views expressed by Dervin, 1977; Dervin & Nilan, 1986; Järvelin & Wilson, 2003; Wilson, 1999;

Wilson (1999) and Järvelin and Wilson (2003) provide useful perspectives to differentiate between conceptual models and scientific theories and Wilson (1999: Introduction) suggests that “A model may be described as a framework for thinking about a problem and may evolve into a statement of the relationships among theoretical propositions”. Järvelin and Wilson (2003:3) in turn state that “Conceptual models are broader and more fundamental than scientific theories in that they set the preconditions of theory formulation ... they provide the conceptual and methodological tools for formulating hypotheses and theories. If they are also seen to represent schools of thought, chronological continuity, or principles, beliefs and values of the research community, they become paradigms”. Conceptual models thus provide an operational framework for any research project by assisting in organising major concepts and variables and showing their relationships. Following these definitions it is proposed to develop a theoretical framework or model that will as closely as possible follow the recommended structure proposed by Järvelin and Wilson (2003).

The underlying premise adopted for the development of a theoretical framework is that the communication of information in basic and applied science should be viewed as a holistic, human-centred activity where the knowledge and problem state of the individual scientist should be taken to be at the locus of the process. Specific attention will thus be given to the role and effect of the scientists’ cognitive and behavioural modality, as well as environmental and other factors that impact on their interaction with information communication systems. It is the intention that the theoretical framework will thus provide a basis to derive predictive measures of communication behaviour and assumptions about the role of information in the communication process of science.

From the previous chapters it clearly emerged that the communication of information among scientists constitutes a very complex social system with distinct communication and information flow patterns with many internal and external variables interacting synergistically. However, certain factors, such as the work and professional environments of the scientists, their research domains (whether basic or applied), their interaction with both formal and informal communication channels, and their integration into the global basic and applied science communication structure, appeared to have the greatest impact on the communication process.

7.2. INFORMATION AND THE COMMUNICATION PROCESS

As a point of departure towards the development of a theoretical framework, the researcher will re-examine the interrelationship between the concepts of information/knowledge and the communication process (cf. also Chapter 1.4.1.). Belkin and co-authors (Belkin, 1978, 1984, 1990; Belkin et al. 1982a; Belkin & Robertson, 1976) adopted a cognitive approach that focused on people in problematic situations²³ with views of the situation that were incomplete or limited in some way and which then becomes the motivating force behind any act to engage with the communication system, i.e. it emphasises the potential recipient's purposeful interaction with the information communication process to correct a perceived knowledge anomaly. Belkin (1978:82) thus refers to information as the message contained in the signals exchanged in the communication process which he suggests is instigated when humans react to internal or external stimuli to resolve an anomaly encountered in their knowledge structure. This is in direct contrast to the more positivist systems approach²⁴ that is based on the Shannon/Weaver model, which is sender controlled and which views information as "a measure of one's freedom of choice when one selects a message" (Shannon & Weaver, 1949:100).

The researcher would, however, like to adopt an approach that takes cognisance of the interactive forces of a scientist's need to generate and the need to gather information and the effect that both these needs have on the communication process in science. It is thus suggested that both the generator and recipient should be viewed as prime movers in, and instigators of, the information communication process and that they often interact synergistically to drive the process. The researcher therefore suggests that the concept of information should, for the purposes of this thesis, be circumscribed as

the message contained in the signals exchanged in the communication process by means of some or other mode and channel when scientists react to internal and/or external (environmental) stimuli

- to generate information by partitioning off a section of their knowledge structure, and/or
- to seek information to resolve a deficiency encountered in their knowledge structure.

Information is further viewed as a structural representation of knowledge (Belkin, 1978:82) which

²³ They refer to such a situation as one in which individuals are in an Anomalous State of Knowledge (ASK).

²⁴ Refer to the work of Wersig (1973); Wersig & Neveling (1975), Yovits & Whittemore (1973)

has no intrinsic meaning (Miller, 2002:Introduction). Meaning can only be construed and the state of knowledge attained when an individual assimilates information, makes sense of it and if that person's knowledge structure and reference framework is changed in some way. It is thus clear that human intervention is required to convert information into knowledge and that this is directly related to a person's cognitive ability to do so (Wilson, 2002:Knowledge and information). It is further argued that for this to happen effectively it is contingent that there is a level of common understanding, conceptual development and reference frameworks between the sender and recipient of the information (cf. also Chapter 1.4.1.).

It thus follows that humans are at the locus of the information communication process, and that this process is set in motion when some or other stimulus creates a need to impart a portion of their knowledge or makes them realise that they have a gap in their knowledge structure. The generators' partitioned knowledge, once it has been externalised and encoded, is contained as information in the signals exchanged, while at the other end of the communication system the recipient extracts relevant information, which, if used and internalised, becomes part of his/her knowledge structure. When information interacts with a recipient's knowledge structure, this can result in a number of consequences, most important of which are that the anomalous knowledge state can be corrected and the problem situation resolved, and or the role of the recipient can change and he/she can now become a potential generator of new information.

Another aspect of the information communication process that should not be neglected are the ancillary, but influential, communication channels and modes. They contain mechanisms or devices which operate on information, either physically or intellectually (or both), to transform it into a form suitable for further transmission, extraction or to assist in guiding it to the correct destination.

These aspects can be depicted as follows:

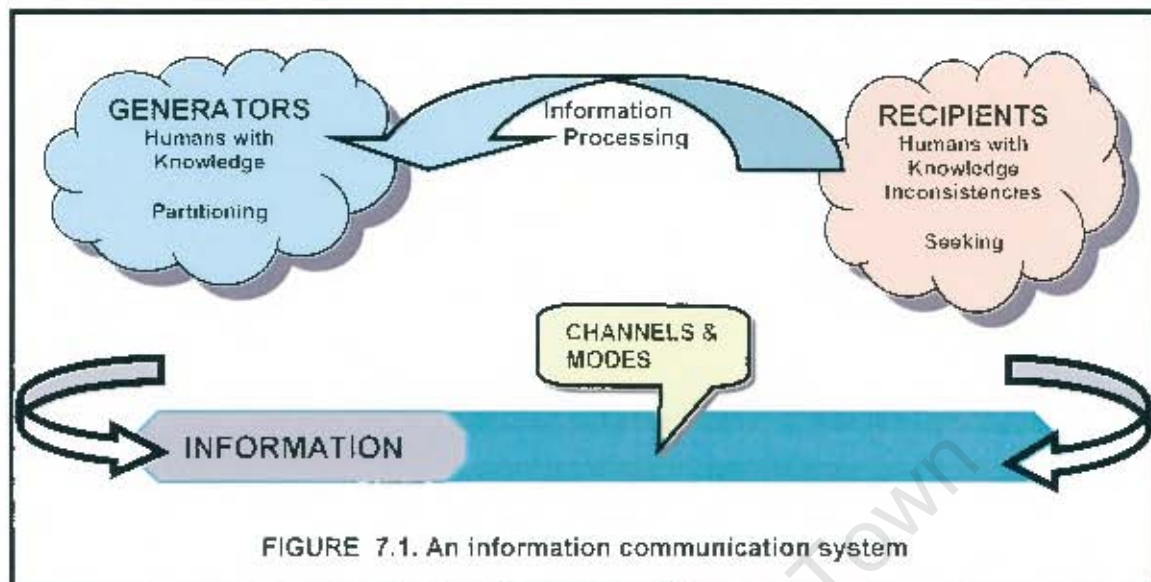


FIGURE 7.1. An information communication system

Such a communication model, however, has limited application as it has not taken cognisance of the scientist's personal characteristics, cognitive state, and the factors that relate to the situation that evoked the need to generate information and/or the knowledge inconsistency that provided the motivation to seek information. Further factors that should be addressed and which impact on the dynamics of the communication process are specific aspects relating to the environment of the scientists and the influence of environmental and situational variables on information communication behaviour, the factors that lead to the transfer of knowledge to the public domain, and the use to which information is put. It is further clear that the complexity and the interactive nature of the information communication process produce many feedback loops that constantly modify the system and that these aspects should also be reflected in a communication model.

7.3. PERSONAL CHARACTERISTICS

If it is accepted that humans are at the locus of the information communication process then it should be recognised that a scientist's personal characteristics and attributes have an affect on information communication behaviour. Palmer (1991b;256-271) has proposed that scientists' learning and creative styles are important indicators of the cognitive model that each scientist has of the *world of information*. Using the Kirton Adaptation-Innovation Theory she stated that all scientists can be placed along a creative style continuum that indicates how individuals approach problem-solving and decision making. A scientist would thus operate somewhere between the *adaptor* end of the continuum, where individuals follow conventional procedures and adhere to

consensus opinion to solve problems, to the *innovator* end where they apply innovative and original approaches to problem solving. She further suggested that individuals can be categorised according to the learning style they prefer to use and which ranges from the *activists* who embrace new experiences, to the *reflectors* who are more cautious, to the *theorists* who adhere to rational objectivity, to the *pragmatists*. She found that these personality styles affected the intensity and originality of scientists' information communication behaviour.

Mahé (2004:4-6) proposes a typology of scientists as users of electronic journals based on the intersection of two axes that indicate how receptive the scientists' environment and their personalities are to electronic modes. She identifies four quadrants, indicating the levels of receptivity which she labels "high level surfers (high personal and environmental receptivity), basic level surfers (high personal and low environmental receptivity), traditionalists (low personal and high environmental receptivity) and bookworms (low personal and environmental receptivity)". She suggests that these factors play an important role in creating a culture that embraces electronic media. She further found in her investigations that affiliation to a discipline, the scientists' position and personal motivation all affected how readily electronic modes were accepted and used.

Both Ingwersen (1982, 1984, 1996) and Kuhlthau (1988a/b, 1991) have borrowed from De Mey's cognitive perspective of an information processors model of the world to serve as a basis for their views of information seeking behaviour. A person's mind set, prior experiences and education set the parameters for such a model of the world and all information processing is negotiated by means of systems of categories of concepts. These systems of categories of concepts are a person's individual knowledge structures or *cognitive maps* which change with time and conceptual growth. Individuals are seen to be purposeful learners, they are actively involved in sense-making and seek meaning in the information they encounter. They are in a continuous process of constructing and reconstructing a system of personally held constructs which have been built as a result of some or other experience.

Kuhlthau further also utilised the Personal Construct Theory (PCT) to explicate the interplay between affective and cognitive states when a person is interacting with new information and searching for meaning (Kuhlthau, 1988a/b; Kuhlthau et al, 1990). When an individual first encounters a new experience or idea, s/he enters a state of uncertainty and this feeling of confusion continues until the person takes the decision to choose between relinquishing the

search for meaning and either accepting or rejecting the new construct. The PCT theory, therefore, suggests that both a person's feelings (affective domain) and thoughts (cognitive domain) would influence as well as be influenced by his/her decisions and actions during the information communication process.

Psychological and personality factors, such as motivation, extraversion, introversion and emotional stability, may further also affect the communication process. Hewins explored the synergistic relationship that exists between cognitive attributes, which are used to explore or solve problems, motivational attributes, which prompt a person to tackle the unknown, and a person's need for, search and use of information. She suggests that a person "may possess the cognitive processes for resolving" an information need, but might not have the "motivation to seek novel information" to resolve the need. Likewise, a person "who is motivated to seek out novel information to resolve problems" may be unable to process the new information without the required cognitive ability (Hewins, 1990:160-161).

Wilson referred to Schutz's characterisation of types of people, ranging from the expert whose knowledge is clear, distinct, but restricted to a specialised field and whose opinions are based on verified facts; to the man on the street who depends on *recipe knowledge* to resolve problems and whose decision-making is as much affected by emotion and passion as by knowledge; to the well-informed citizen who is not an expert, but who also does not rely on *recipe knowledge* and irrational emotions to arrive at decisions and who rather "arrives at reasonably founded opinions" (Schutz in Wilson, 1984:199-200). Thus different categories of person have different frames of reference and world views and as a consequence they have different information seeking and generating needs and interact in different ways with information when engaged in the communication process.

Drawing on the aspects discussed above it is suggested that personality and cognitive factors impact in a number of ways on the information communication process. Cognisance should be taken of the variety of cognitive processes that affect both the search for information and the need to generate new information. Scientists, while engaging with the information communication process, are constantly forming new constructs that interact with their internal cognitive maps and which affect and are affected by their reference frameworks and the nature of the original situation that stimulated the process. It should further be noted that the scientists are constantly

engaged with sense-making and creating meaning and that their knowledge structures thus also change over time as they mature cognitively.

It is not only a person's cognitive domain, but also his/her affective domain and motivational attributes that can influence as well as be influenced by an encounter with the information communication process. While a scientist may have a cognitive need to seek or generate information, the motivation may be lacking, or the reverse could apply. Overlaying all these factors would also be the scientists' predilection towards a certain creative and learning style (e.g. how innovative, methodical, etc. they are) and their emotional state at the time. It is thus clear that each scientist is an individual with unique frames of reference, personalities, cognitive states and world views and each would thus react and be influenced in different ways by an engagement with the information communication process²⁵.

7.4. ENVIRONMENTAL INFLUENCES

As was seen in Chapter 6.5. (and in Chapter 2.7.) the various environments that scientists interacted with have a distinct influence on their information communication behaviour. It is generally accepted that scientists operate within a series of many converging environments, or systems that influence their information communication behaviour (cf. the reference to Paisley's model in Chapter 2.7.1.). These systems range from the focal system of a *scientist within his own head* to a number of external systems with varying levels of interaction and influence on the information communication process. Contained in the focal system is the cognitive function of the scientist who is seeking, evaluating, utilising and/or generating information and this in turn cognitively creates, motivates and directs the engagement with the information communication process.

It was further suggested in Chapter 6.5. (and in Chapter 2.2 and 2.3) that each major orientation in science, i.e. basic or applied, has its own unique information communication patterns and a scientist's affiliation to one or other of these disciplinary groupings would thus directly influence his/her information communication behaviour. A further factor that adds complexity to the situation is a scientist's association with and incorporation in a circumscribed research area with

²⁵ A typical example from the study that illustrates these factors was the divergent views that two academics from the same department held on the benefits/demerits of greater engagement with industry and contract work. The one saw it as a threat to academic endeavours, the other as an opportunity to conduct research that has greater practical and beneficial outcomes (cf. Chapter 4.2.3.).

its structures that can range from informal but very important associations (e.g. *invisible colleges*) to formal professional organisations. Such organisations are very influential as they collectively control most formal and many informal channels of communication in a discipline (cf. references to the IUCr and the SA Crystallographic Association in Chapter 6.2.2.).

An environment that, this researcher suggests, exerts one of the greatest influences on the communication behaviour of scientists is their immediate work environment (cf. Chapters 6.5. and 2.5.1.2.). Such a system consists of a number of hierarchically related subsystems ranging from the specific work team with which the scientist narrowly associates to the overall employing organisation to which s/he belongs. The work team, consisting of the group of people working on the same project, has the most direct impact as it is directly attuned to the scientist's research area. The organisational structure of the employing organisation with its unique aims and objectives further strongly affects information communication behaviour. It can either impede the flow of information by regulating roles, establishing rigid communication structures, etc. or it can facilitate the communication of information by creating an open collegiate environment (cf. also references to this factor in Chapter 6.5.).

The information communication behaviour of any community in science is influenced, furthermore, by all-encompassing systems, such as the formal information-system and the socio-political and cultural environment. Although, the influences of the latter two systems are less personal they often create barriers to the flow of information. Libraries and other formal and less formal information dissemination structures further have an obvious and very direct affect on the communication of information (cf. also 2.5.3.).

A very complex structure emerges if one, further, takes into consideration that most scientists have more than one work-related, and professional role to fulfil. This results in the generation of a set of closely related and interacting problems requiring information to facilitate the decision-making process and/or the need to transfer information into both the public and private domain. Information communication behaviour should thus, it is suggested, be examined in the context of how individuals view their constantly changing environments, and how their information communication activities correspond with those changes.

A theoretical framework should, therefore, embody, first an individual's information behaviour at a personal level, taking into consideration all influencing variables emanating from personal

attitudes and cognitive states, as well as professional tasks, roles and functions within a given organisational structure and circumscribed research area. Second, these individual-dependent and situation-specific variables should be placed in a more generic setting, due cognisance being taken of socio-political and cultural environmental influences. The factors influencing information behaviour in the basic and applied sciences can thus be seen in terms of a concentric structure ranging from the most concrete individual and personal level of influences to the more abstract and general environmental levels of influence.

7.5. INFORMATION SEEKING AND INFORMATION GENERATING NEEDS

The discussion in 7.2. and 7.3. clearly suggests that personal attitudes, cognitive states and various environmental influences of the individual scientist set the communication process in motion. On the one end of the communication cycle a need to generate information arises within an individual scientist which has usually been triggered by internal cognitive, affective and other personality factors and which are usually also related to the accomplishment of some or other task, e.g. the completion of a research project, which requires that the outcomes (that can range from intangible theories to tangible products, processes, etc.) are made known in encoded format, either within the confines of the immediate organisation (by means of a report or if priority claims are made as a patent), or to the science community and the public domain in general (usually by means of a publication in a reputable journal or conference presentation). Alternatively the scientist may have been triggered by other factors (e.g. a personal need to share knowledge; the intake and internalisation of new information that changed his/her knowledge structure; or an invitation to contribute to a publication, conference, etc.) to partition a section of his/her knowledge and transmit that as a communicable structure (information) by means of the communication process.

On the other end of the cycle some or other problem or decision or situational inadequacy, generally in a work-related situation, sensitises scientists to the fact that they have reached a state where they have insufficient internal knowledge to continue with whatever they were involved with (cf. the reference in 7.1. to the anomalous state of knowledge [ASK] situation identified by Belkin). It is at this stage that they realise that they should try to find the right information to overcome their knowledge inconsistency and a need for information is established. The scientists would then generally be prompted into some form of activity to try and acquire information to resolve the need. A need for information, however, may also be latent and may only become

apparent after information has passively or accidentally been assimilated (this, however, could only have had an effect if there was an inherent anomaly in the knowledge structure of the individual).

Information need, i.e. both the need to generate and to search for information, is a subjective, abstract concept existing cognitively in the mind of the scientists who are experiencing some or other professional or work-related stimulus (either as a knowledge inconsistency, or the drive to convey knowledge). Scientists, in their daily work environment, are constantly in some or other incongruous situation where they require a knowledge input to resolve the situation, but in many instances this need is not consciously recognised and it remains latent, or it is suppressed for various reasons or the scientists, because they are not aware of how to resolve the situation, leave it unattended, or they might be aware of the situation but unsure of how to negotiate a resolution with an information system. To compound the situation, at different stages different needs arise, each requiring different information inputs which vary according to the level of knowledge of the topic and the nature of a person's situation. In much the same vein scientists are either consciously or sub-consciously motivated to partition off a section of their knowledge and convey it to others as information.

Dervin's (1977; 1980) sense-making model, which she labelled SITUATION-GAP-USE, depicts users in unique time-space contexts with fundamental gaps regarding their immediate world that instigate a need for, and motivation to seek, information. These discontinuities sensitise individuals to the fact that their internal sense has run out and they then stop movement until bridges are built to cross these gaps (i.e. an information need situation arises, strategies are created and information is acquired to resolve the situation). Information communication is thus depicted as a sense-making process where individuals engage with information to create meaning in order to bridge a situation caused by an information gap.

Dervin and Nilan (1986:13-14) state that within the sense-making approach information needs are situationally determined, and information seeking and communication is a process of movement over time where information assists people to move more effectively through life's time-space continuum. It is further suggested by the researcher that knowledge is created by the user of information when he/she processes it to create sense that is unique to his/her situation (no message means the same thing to different people). In the process the information user, therefore, becomes an active participant of the communication process rather than a passive recipient who

mechanically accepts information. It is further clear that the individual's problem state changes and evolves as information is encountered and assimilated. Derr (1983:274-277) has further argued that value judgements play an inextricable role in determining a valid need to search for information and the search would only commence and focus on obtaining information if the potential use of that information has been judged to contribute directly to achieving specific objectives. In the same, it could be argued that value judgements and the perceived benefits of sharing their knowledge would have a direct influence on any scientist's decision to generate information.

In brief, it may be summarised that information seeking need is viewed in this thesis as a cognitive state that is intricately related to the scientists' awareness of a problematical situation they are in and which they cannot resolve themselves and which causes them to realise that there are gaps in their knowledge structure and further that they can possibly alleviate the situation by obtaining and assimilating relevant information pertaining to the problem. Information generating need is also seen as a cognitive state that relates to the various personal and external situations that generate a need to transmit information and engage with the communication process. The experience of information need and its resolution is situation specific and changes as information is processed and a value judgement regarding the situation is made.

To obtain a more complete understanding of information need and its impact on the information communication process, the various situations that cause a need for information should be further explored²⁶. It is suggested by this researcher that in the environment in which basic and applied scientists operate, information need can be categorised according to whether there is a need to

Seek current information (i.e. a need to stay up-to-date with new research and work-related developments and to maintain a certain level of competence, stimulation and feedback);

Seek specific information (i.e. a need related to finding information for clearly demarcated applications, such as finding solutions to specific problems or responding to questions generated by professional tasks solutions);

Search for exhaustive information (i.e. the need to scrutinise all extant information of relevance to a subject);

²⁶ A detailed exposition of many of these factors have been provided amongst others by Brittain (1975), Cronin (1981), Line (1974); Lor (1979); Krikelas (1983); Menzel (1964), Orr (1970), and Rohde (1986)

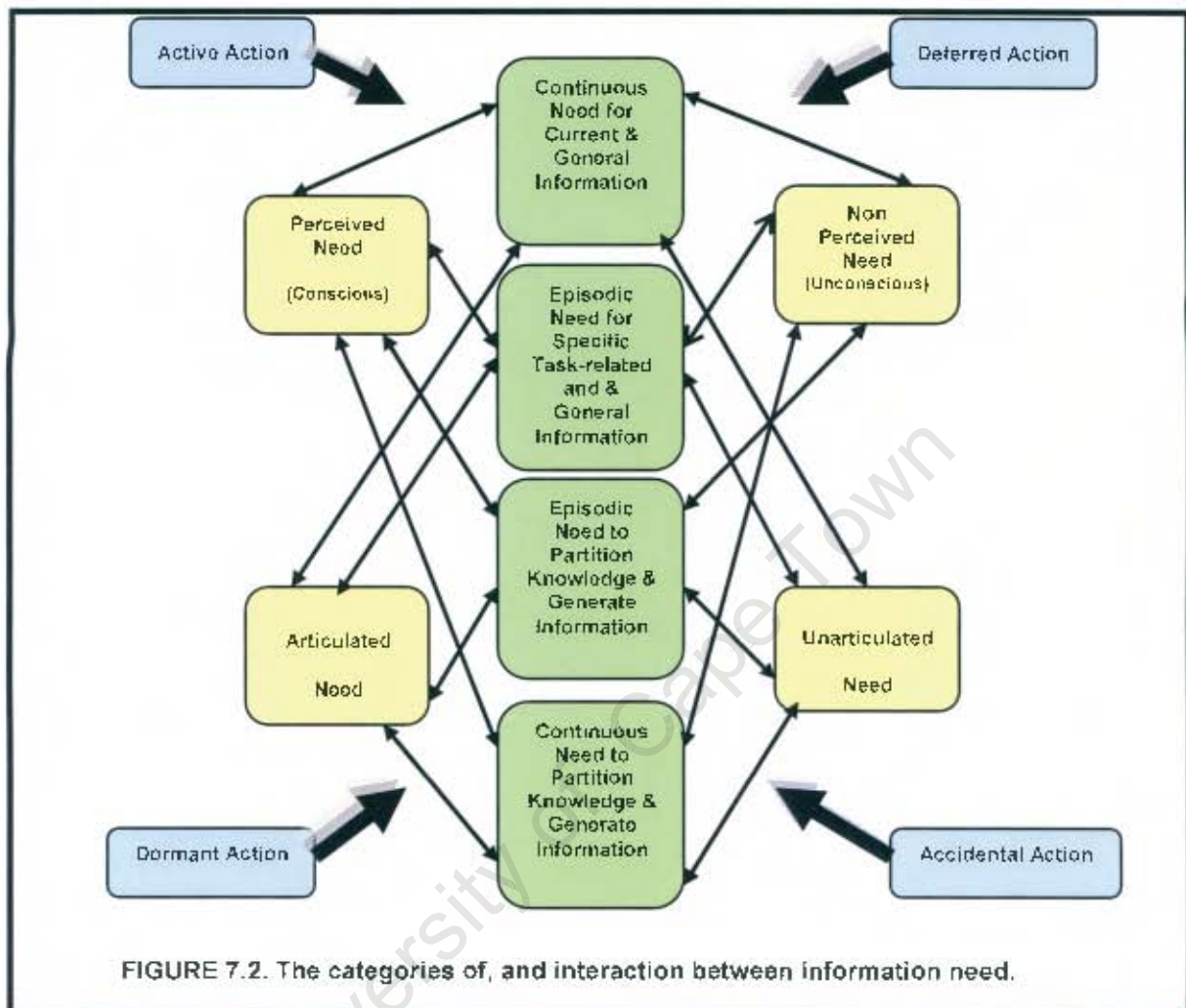
Generate information in the formal domain (i.e. the need to impart knowledge by encoding a section of the knowledge they wish to impart and transferring it as recorded information or delivering formal lectures;

Generate information in the informal domain (i.e. to participating in informal meetings, discussions and oral person-to-person information exchange).

Both of these information generating needs might apply to an inherent need to share information or it may constitute a work-related output requirement..

It is also clear that the above information need categories could be further classified according to whether they are continuous and spread over time or whether they are episodic and have a short-lived time-span; and whether the information that is required or generated is specific and specialised by nature or if it relates to the broader fields of science and other cognate knowledge areas that a scientist engages with. Three restraining factors, however, relate to all categories of need. First they can manifest themselves in either conscious or unconscious modes and in the latter instance, because the need situation is masked, overt action will not be taken to resolve it. Secondly the need may not be sufficiently urgent and of immediate importance and a conscious decision is taken to defer action. Third, people often do not, or are unable to, articulate and verbalise what they need to seek or wish to generate and this factor also might inhibit action to resolve the situation. An additional factor to consider is that the information need situation may continuously change as a person assimilates information and transforms it according to the requirements of that person's knowledge structure. This process will lead to changes in the original knowledge structure which in turn might trigger a new need to either seek or generate information. Furthermore, because information need is situation specific it will further change as the individual's situation and problem states change. It is thus clear that both the information recipient and generator's knowledge and need situation are in a constant state of flux.

The aspects discussed above have been summarised and graphically depicted in the following diagram:



It may further be queried whether the need to seek or impart information is in any way amenable to precise categorisation and whether humans should not rather be viewed as having a range of needs, including basic needs (as depicted by Maslow in his hierarchy of human needs), which constantly interact with and impact on each other. Such human needs, various environmental factors as well as the various roles a person fills in life may instigate a variety of needs at differing levels of intensity, each of which may set the communication process in motion.

7.6. USE OF INFORMATION

It is suggested that the process of information use occurs when a specific sub-set of information is internalised, processed and actually used or applied to satisfy some or other need for information.

to resolve an incongruity or to generate new information. This may be the result of purposeful information seeking, browsing, the accidental acquirement of information, or the partitioning and use of internal knowledge. Use, however, may or may not result in the resolution of the original need that set the information communication process in motion.

Paisley (1980:121-154) had proposed that information use and its value are related to various inherent information attributes and the settings in which information is used. Information attributes that he identified that affect use include relevance, timeliness, comprehensiveness, authoritativeness, ease with which the information may be represented, ease of location, ease of acquisition, and the suitability of the form and content for intended use. Various other factors further also have an effect on use and include, amongst others

- the reason why information is used, including its use to generate new information, for learning, decision-making, problem-solving, keeping up-to-date, etc.;
- the individual's cognitive approach to information, including their preference for cognitive complexity or simplicity;
- the theories and principles by which the field of enquiry is structured;
- the various social and organisational structures that impact on the individual, such as the characteristics of the work team, work organisation, and professional disciplinary groups to which an individual belongs; and
- the nature of the individual's tasks, including whether the problems encountered in a task are recurring or episodic, and its effect on information requirements.

Westbrook (1993: 542) was of the opinion that information users who are interacting with new information assimilate it into their own internal reality in terms of "what is comfortable and acceptable to the individual" and not what "best fits with external reality". People create personal constructs to represent the universe which they test against external reality to establish how well it matches. New constructs are accepted on the basis of how well they fit in with a person's existing system of constructs. Such an approach suggests a framework according to which we may understand how information users relate to the availability of information, how the choice of information is determined by the frames of reference, and how information may change or affect the frames of reference. The process of forming meaning from information is seen primarily as a creation of the information user.

As mentioned in Chapter 2.5, a further factor that impacts on information use is the medium through which information is communicated. Messages may be communicated by means of various combinations of modes and channels and as stated it has been suggested that although channels and modes are initially selected based on the principle of least effort, time and cost, there is evidence that quality and credibility considerations determine whether the information will be adopted and used. It was also mentioned that information derived from more than one source is perceived to have greater validity and thus increases the probability that it will be accepted and processed.

7.7. PROPOSED THEORETICAL FRAMEWORK

Based on the preceding discussions a theoretical model will be developed which will encapsulate the findings of the empirical study and incorporate the main points derived from the literature (cf. the relevant sections in Chapters 1, 2, 4, 5 and 6). Such a model it is suggested could in future be used as a framework to study the communication of scientific information within a specific science community.

The focus of the framework is on individual scientists who are at the locus of the information communication process in science, i.e. it is based on a human- and not on a system-driven paradigm. The researcher contends that the communication process is set in motion by human intervention when there is a need to create and disseminate new information and/or to acquire information to resolve an incongruous situation.

Thus, at the one end of the communication cycle a stimulus, which has been generated within the context of a particular task-orientated situation (an enactment), and which is further impacted on by cognitive, personality and other environmental factors, prompts potential generators of information to impart some aspect of their knowledge and to engage with the communication process. To actualise this need to contribute knowledge they isolate the units with which they wish to communicate and modify them to create communicable structures that are transmitted to the science community by means of various channels, modes and either or both formal or informal communication systems. These communicable structures then become part of the body of scientific information and knowledge.

At the other end of the communication cycle a stimulus, which has been generated within the context of a particular task-orientated situation (an enactment), or the need to maintain a certain level of competence in a field, prompts a scientist to realise that he/she is in an incongruous position that requires an information input to resolve the situation. It is at this stage that there is a conscious or subconscious awareness of the information need situation which can further be influenced by the scientist's own cognitive states and the various environments that they interact with.

If a positive decision is taken to resolve the information need, the scientist then actively sets the communication process in motion by seeking information. The required information can either be found from within, or from the external body of knowledge accumulated by mankind. The latter possibility results in engagement with a variety of information channels, modes and systems that can range from the informal and personal to the formal and recorded. This enactment is achieved by converting the information need into some communicable structure that can effectively be used to select from the required channels and modes of communication the appropriate information to resolve the situation. If a negative decision is taken, the scientist disengages with the system.

If the information seeker is successful in finding information it is then interpreted and evaluated in terms of the original situation that evoked a need for information. If satisfactory this might lead to complete or partial resolution of the situation, and/or feedback to need, and/or input into the communication cycle of new information. If not satisfactory there could be re-engagement with the information communication cycle using different strategies, or a decision can be taken to abandon the search for information. It is thus clear that the information communication system and the scientists' interaction with it is a dynamic, interactive and cyclical process which undergoes constant adaptations and feedback into the system.

The following is a graphic outline of the concepts discussed above:

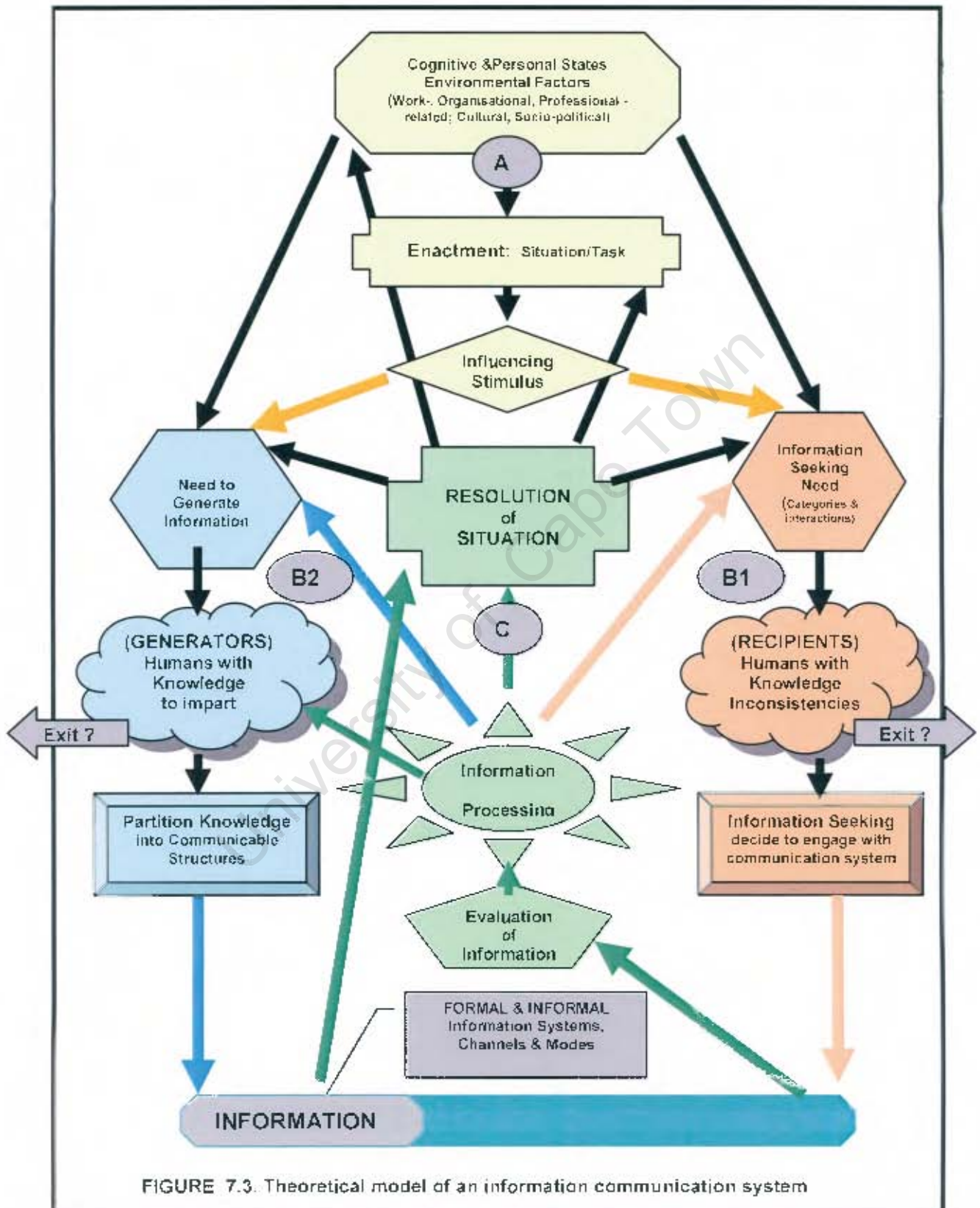


FIGURE 7.3. Theoretical model of an information communication system

The theoretical model clearly may be categorised into the following main components (cf. Figure 7.3. above) and they each suggest a categorisation in terms of which variables can be grouped and hypotheses derived for the purpose of future empirical investigation:

A. The enactment component relates to the enactment of a work- and/or professional-related situation in which the scientists are prompted to realise that they have a need to impart an area of their knowledge structure and/or are in an incongruous situation and that they lack the knowledge/information to resolve it. This component of the model takes into account all factors which affect the need to impart and/or seek information such as the individual characteristics of the scientists, situation specific and environmental factors, professional role requirements which may be task specific, related to the general maintenance and generation of knowledge, uses to which information will be put, previous interaction with information communication systems, engagement with channels and modes, etc.

B 1. The information seeking component which is precipitated by the enactment of a work- and/or professional-related situation and which results in the scientists realising that they require a knowledge input in the form of a communicable structure (information) and that they need information to reduce their states of uncertainty. This component of the model takes into account all factors which affect information seeking need, and types of information need (e.g. whether or not conscious and articulated, etc.). It further relates to the decision by the potential recipient/user to resolve his/her need by interfacing with an informal and/or formal information communication system to obtain information. It takes into account the interaction with systems channels and modes by means of which information is transferred (whether of a personal, impersonal, formal or informal nature). The recipient, or user, of information is the focus and serves as the point of departure in this component.

B 2. The generation of new information component. This component relates to all factors that lead to the generation and dissemination of new information. It addresses all aspects that stimulated the need to impart a subsection of the generator's knowledge base, such as the intake of new information and the consequences of information use: the completion of an empirical investigation; problem solving; other work requirements; interaction with other scientists; or merely the wish to partition existing knowledge. Factors that impact on information generation such as the individual's personality and cognitive attributes; other

environmental factors such as the scientist's work environment, membership of a discipline, profession, reference groups and informal networks, specific work activity, and the wider socio-political and cultural environment are further also considered here. It also takes into account the interaction with systems, channels and modes by means of which information is transferred (whether of a personal, impersonal, formal or informal nature). The generator of information is the focus and serves as the point of departure in this component.

C. The resolution of the situation component addresses information processing, the evaluation and subsequent use, or non-use of information in relation to activity (such as whether task specific, or for current awareness purposes, or to generate new information, etc.); the analysis of information behaviour in specific situations; indications of preference for modes and channels for both generation and use; the relationship with formal and informal communication systems for both generation and use; the relevance, timeliness, comprehensiveness, credibility, and usability of information and success in finding information; the success in transferring knowledge-structures into the information communication system, measures of success (e.g. impact factors). It further addresses the success in resolving the original situation that lead to engaging with the information communication process and all feedback loops back into the system. The most important of these are the impact on information generation and creating new needs (both from information use and generation), on the generation of new information seeking needs; and the effect of the engagement with the information communication process on cognitive and personal states, environmental situations, enactment and the creation of new stimuli.

It is proposed that this theoretical model could provide a perspective from which to view the factors that determine individual information behaviour in the communication process and that it could suggest useful hypotheses that could serve as an impetus for future research. It further provides a framework to identify interrelated variables that impact on the communication process. It is clear that the relationships among predictive variables are highly situation specific and that while certain variables are affected by environmental factors, others are influenced by personal attitudes and professional and work-related functions. These, in turn, influence the need to generate information, and/or the need to seek information, thus creating a basic causal element in information communication behaviour.

7.8. CONCLUSIONS IN RELATION TO THE THEORETICAL FRAMEWORK AND THE RESEARCH QUESTIONS, RECOMMENDATIONS, AND FUTURE RESEARCH

Using the model as a framework the main research results of the longitudinal study may be briefly recapitulated and then related to the research questions that served as the basis and motivation for this study (cf. Chapter 1.7).

The framework evolved out of the findings of the study that clearly suggested that the information communication process should be based on a human-centric paradigm that regards the crystallographers' interaction with the communication process either as contributors of information or as seekers and subsequent users of information which in turn may lead to feedback into the process. The researcher will thus first relate the model to the crystallographers as proactive seekers, recipients and users of information who set one end of the information communication cycle in motion when they react to a stimulus, which has been generated within the context of a particular task-orientated situation such as when a new research project is initiated, or an ad hoc problem arises in the work situation, or when the need arises to keep up to date in their field of endeavour. This stimulus sensitises them to the fact that they are in an incongruous position as they have insufficient internal knowledge and information to proceed effectively with their tasks and that they should remedy the situation.

A number of other causal factors may further also reinforce or prevent the crystallographers from acting on the situation. These causal variables all interact synergistically (once again positively and /or negatively) and may be viewed as radiating from a nucleus of the most immediate and personal influences to more general environmental factors. A scientist's personal view of life, mental attitudes, affective and cognitive states all in varying ways will influence a decision to take action to remedy a knowledge incongruity. The external environment that has the most direct influence on the situation is the professional and/or work-related tasks, roles and functions that the crystallographers have to fulfil within a given organisational structure (e.g. an academic institution, research institution, or industrial organisation). This is followed by a commitment to research programmes which could be either inter- or intra-institutional; incorporation in, interaction with, and role played in an invisible college; and affiliation to various professional associations. These situation-specific influences should, however, be placed in a more generic setting, cognisance being taken of the global communication structure of the specific discipline the crystallographers belong to with its distinct information flow and behaviour patterns; the

research domain (whether pure, tool or applied); all-encompassing systems, such as the socio-political and cultural environment in South Africa and worldwide; and interactions with both formal and informal communication channels and information systems.

These factors may thus, collectively, or individually influence the crystallographers either to react, or not react to the fact that there is a gap in their knowledge structure which prevents them from effectively continuing with their activities. A further factor that should be noted is that two persons in the same work environment and even the same person at different times might react in widely divergent ways as specific interests and other factors may vary with time, place and situation.

If the crystallographers decide to remedy the situation a need for information is awakened and the information communication process is set in motion. They might, however, for a variety of reasons not react at this stage, e.g. if the stimulus was not sufficiently imperative; if it is not very crucial to satisfy the need and the consequence of not having the information is not severe; information and/or sources of information may not be available and the cost to search for information might be too high. This then may result in a decision not to act at all, or to defer action; or neither the need nor its satisfaction might be consciously recognised (i.e. it will remain dormant), or less important needs may be solved by chance long after the time they were recognised. In the event of a negative decision being taken, the hitherto potential recipients/users of information make their exit from the system.

Information need may be resolved in three different ways if a positive decision is taken to react to the situation. The first possibility is for the crystallographers to find the required information from within themselves i.e. from their own store of knowledge (which may or may not have momentarily been forgotten), or to personally produce the required information empirically, or to acquire it by means of observation. The second is to try and find the required information externally amongst the body of scientific knowledge. The latter possibility results in the seekers of information going directly to individuals who they think may have the knowledge, and/or to a record of that knowledge (generally the published literature, both in print and electronic modes). The third possibility is to utilise more than one option.

If the crystallographers decide to find external information they activate the communication process by converting their need into some communicable structure, for example a request, which

is used to select and/or extract from the universe of knowledge in basic and applied science such information as is likely to satisfy their need, reduce their states of uncertainty and remedy the situation (e.g. solve a problem). An information contact, however, may satisfy only some of the crystallographers' needs but is not likely to satisfy all of them and a large proportion of information needs may thus remain unfulfilled, inadequately fulfilled or inefficiently fulfilled. Alternatively such an information contact may generate new needs which once again set the information communication process in motion.

Once the crystallographers have created a communicable structure they interact with one or more communication modes and channels by means of either an informal communication system (for example, direct personal contact with another scientists who has the required knowledge) or a formal communication system (for example, a library or information centre). The sources of information may have an organisational, or a research related relationship with the recipient crystallographers, they may have been suggested by a colleague, by circumstantial conditions (including a serendipitous incident) or by some other indirect channel.

After a successful interaction with the information communication process, the crystallographers analyse and interpret the information received, and evaluate whether or not the original information need has been reduced or resolved. The evaluation process is influenced by the nature of the information need prerequisites (such as timelines, environmental aspects and task requirements) and the crystallographers' inherent cognitive and affective states which not only determine the conceptual requirements of an appropriate answer, but the situational requirements and enactments as well. If the evaluation leads to a negative result or, initially no information is found, the system is either re-instigated, or the system is closed on the basis of a negative accomplishment. If, however, the results of the evaluation are positive one or more of the following will occur: 1) the problem will be resolved, a decision will be taken, or some or other task related activity will come about 2) the crystallographers will keep up-to-date and maintain a certain level of competence in a field; 3) there will be feedback to personal attitudes and cognitive states; 4) new information will be generated; 5) there will be feedback to need, or 6) as stated a combination of the above will happen. A further aspect that should be noted is that the crystallographers' perception of the situation and the need for information will probably change with each encounter between them and information. Furthermore, information assimilation, processing, interpretation, and its use may trigger an awareness of an information need hitherto unrecognised.

At the other end of the communication cycle potential generators of information decide, or are stimulated, to communicate some aspect of their knowledge in the fields of basic and applied science (or any other field for that matter) (it should be noted that all personal, internal and external environmental factors that impacted on the need to search for information would likewise affect the need to generate information). The generation process is set in motion when the crystallographers isolate the units they wish to communicate and modify them to create communicable structures. During this process the senders adapt the knowledge they wish to communicate, taking into account, first, the various personal and external environmental factors that stimulated and motivated them to communicate the knowledge (i.e. created a need to communicate information), and second, their understanding of the likely states of knowledge of the potential recipients. These communicable structures then become the communicable texts, i.e. *information* that is transmitted in the communication process by means of a combination of modes and channels and systems which may be formal, informal, personal, impersonal, direct or indirect, or a combination of these. This information is then evaluated in various ways by the community of science and if accepted it is assimilated into the storehouse of knowledge in science and it then becomes accessible to potential recipients.

The model outlined above clearly indicates that the crystallographers', and by analogy any scientist's, information communication behaviour is by no means a simply explainable phenomenon. The communication of information constitutes a very complex social system with distinct communication and information flow patterns with many internal and external variables interacting synergistically. Information travels through diffuse paths, and individual information generating and seeking behaviour is the result of a network of interactions, involving personal attitudes and backgrounds, work-related roles and functions, specific tasks, situations, environment, as well as the scientist's active role in the information communication system of basic and applied science and includes factors such as their place on the activity continuum (which can range from that of a sociometric star or gatekeeper role to that of quiescence).

In conclusion the research questions that motivated this project will be examined in relation to the outcomes of this research project (cf. Chapter 1.7). The primary question related to

What constitutes the information communication process among a bounded community of basic and applied scientists in South Africa?

It is suggested that the crystallographers' (i.e. the bounded community of scientists) information communication process and behaviour, including all impacting factors and variables have

been outlined in terms of the model in the previous paragraphs.

With reference to the subsidiary questions, it is further suggested the model has also addressed the

Cognitive, behavioural and environmental factors that drive the communication process in science in South Africa;

and that

The factors that impacted most on the communication process were the immediate work environment, overall organisational and work structure, utilisation of crystallography, whether they were basic or applied scientist, position, age, and qualification;

and that

The environmental and other changes that had occurred during the intervening years of the longitudinal study and which affected the communication process in South Africa were mostly the changing funding structures, organisational models, the effect of the escalating electronic environment and to a lesser extent political changes since 1994. While changes towards more structured and profit orientated organisational models and decreased funding appeared to mostly have a negative impact (other than greater interaction between industry and the other environments) the change to a democratic government opened many communication channels that were previously closed to South Africans. The significant increase in the use of electronic modes and systems while not affecting the inherent structure of the communication process did create a far wider range of modes of communication and did have a positive influence on the ease of communicating and cooperating with particularly the international research community;

and that

Clear evidence exists that informal communication of information plays an important role in the science communication process in South Africa and in many circumstances face-to-face interpersonal communication is the preferred mode of communication. It was clear that this applied for example where reciprocal interaction and feedback was important. However, it was also clear that when it was required to ensure that a permanent knowledge record be created and transferred into the communication cycle it was far more important to utilise reputable, permanent and formal channels of communication. It was further evident that the invisible college, scientific elite and gatekeeper phenomena played

an important role in the crystallography environment;

Finally it is suggested that the theoretical framework that has been developed and the main results that evolved from the research project may be used as a basis for future studies on information communication in other areas of science. The researcher further suggests that the following research statements that she has derived from the theoretical framework could fruitfully be used to derive hypotheses to serve as foundation for such future research:

- Variation in work environment has a distinct impact on the information communication process of basic and applied science;
- The level of structure in the work environment impacts on information communication, too much as well as too little structure can have a negative impact;
- The more involved scientists are in the information communication process, the more active they are in their profession and the more productive they become;
- Informal, particularly face-to-face, communication of information is an important factor that enhances scientific activity and output;
- The more senior a scientist, the more she/he is integrated into informal information communication systems and the greater the influence she/he has on the system;
- Productivity grows with seniority and age to a certain cut-off point beyond which it declines again;
- The electronic environment does not affect the inherent structure of the information communication process;
- Greater use of electronic media and systems facilitate the ease with which information is communicated, particularly if distance is a factor;
- Although the use of electronic media and systems will continue to escalate and in many instances supplant print modes in science, face-to-face interaction will continue to be one of the most important modes of communication;
- The more open and democratic the political environment the more the information communication process is promoted;
- In most scientific communities evidence will be found of the presence of the *invisible college* and *gatekeeper* phenomena and these are driven by the most eminent scientists in the community.

This has by no means been a definitive research project on this topic and it is clear that further research is required to investigate specific aspects of the information communication process and

the effect thereof on scientific endeavour in South Africa. In this way a more unified view would be obtained of the communication of information in science on the African continent. It is this researcher's conviction that the African continent is in urgent need of developing its science and technology endeavours if it wishes to compete and even survive in the prevailing competitive and technologically orientated global economy. Specifically, if South Africa is to fulfil its full potential as a nation in the new millennium, concerted efforts should be made to develop an environment that promotes scientific and technological research and this can only be achieved by promoting the effective exchange of scientific and technical information and active and collegiate interaction among its science communities. One input into such an endeavour would be to systematically study the information process and identify lacunae that require remedial intervention.

APPENDIX A.

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²⁷ Section headings are used as reference indicators for resources in electronic format that do not indicate page numbers.

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APPENDIX B

INTERVIEW SCHEDULE: 1990/1

SECTION A: Personal Details

Verify personal details (*Particularly for unlisted members*)

1. Name
2. Department and organization
3. Position
4. Highest qualification; which university obtained; what year obtained
5. Describe major research interests
6. Date of birth

SECTION B: Communication of information

Discuss the communication of information within your immediate work environment, within your institution, in South Africa in general, and beyond the borders of South Africa.

2. Discuss the role of inter-personal communication of information. Indicate for what purposes you mostly maintain contact, e.g. information exchange in general, collaborative research, routine matters, maintain friendships, etc. and please name the people with whom you exchange information within your work and research environment (give names and organisation).
 - a. In your organization
 - b. Elsewhere in SA
 - c. Worldwide

Discuss any other aspects that relate to the communication of information within your profession.

SECTION C: Information Communication Modes and Channels

General

4. Discuss the role that the following four general methods of communicating information play in your field and work environment. Rate their relative importance on a scale of 10 very important to 0 not important/not used:
 - a. Person-to-person communication
 - b. Recorded information:
 - i. Print-based e.g. journals, books, patents, etc.
 - ii. Electronic media and modes
 - c. Information communication at conferences

Interpersonal

5. Discuss information communication on an interpersonal basis and please rate your preferred method of interpersonal communication when interacting with
 - a. colleagues at work
 - b. persons elsewhere in South Africa
 - c. persons outside South Africa
 (apply a scale of 10 very important to 0 not important/not used)

Print-based modes

6. Discuss your use of print-based information communication channels. (e.g. journals, monographs, reports, patents, etc). Rate the usefulness of each source to you. (apply a rating scale of 0 - not

used/useful to 10 - very useful)

Impact of electronic modes/media

7. Discuss the role of electronic media e.g. electronic communication networks, electronic journals, etc. and the impact they have had on the information communication process.

Conferences

8. Discuss the role of conferences, symposia, etc. in the information communication process. Rate the value of conferences on rating scale of 0 - not used/useful to 10 - frequently used/very useful.
9. What was the reason for attending the above listed conferences, (e.g. as organiser, to present a paper or poster, to listen to papers, to obtain specific information, for informal interaction, etc.). Indicate how important each of the reasons given are on a rating scale of 0 - not important to 10 - very important.
10. Do you engage in 'electronic' conferences? If yes, do you, i. prefer electronic conferences to personal attendance of conferences, ii. prefer personal attendance of conferences to electronic conferences, iii. have no preference ?

Information gathering

11. How do you keep up to date in your field? Do you Browse in the library, trace citations in journals, etc., regularly communicate with colleagues, regularly attend conferences, Other. For each method rate its usefulness (apply a rating scale from 0, not at all useful / never used to 10 Very useful)
12. How do you go about it to find information for a new research project, or investigation into an unknown field. For each method given rate its usefulness (apply a rating scale from: 0 - not at all useful/ never used to 10- very useful)
13. How do you go about it to find information to solve a problem encountered in your current work environment. For each method given rate its usefulness (apply a rating scale from: 0, not at all useful/never used to 10 very useful)

Library interaction

14. Discuss the role of the library in the information communication process. by
 - a. rating its importance to you,
 - b. the frequency that you personally visit the library, and
 - c. your satisfaction with the service provided.
 (apply a rating scale from: 0 - not at all important/frequented/satisfied to 10 -very important/very frequently visited/ very satisfied)

SECTION D: Professional Activity & Research Output

15. Discuss your involvement in professional activities such as editorships, refereeing, professional institutions, etc.
16. Discuss your main research and/or development output: e.g. published papers, papers read at conferences, reports, patents, products, procedures, etc. Please provide full details such as whether you generally co-publish, and with whom, and where do you mostly publish (in SA or overseas)? Could I please also have a list of your publications, reports, patents, conference papers, etc.

SECTION E: Conclusion

17. Please provide any other comments with regard to
 - a. the way that you find information
 - b. exchange information with colleagues / other scientists
 - c. interact with colleagues, other scientists

APPENDIX C

INTERVIEW SCHEDULE: 2001/2

SECTION A: Personal Details

Verify personal details (*Particularly for unlisted members*)

1. Name
2. Department and organization
3. Position
4. Highest qualification; which university obtained; what year obtained
5. Describe major research interests
6. Date of birth

SECTION B: Communication of information

Discuss the communication of information within your immediate work environment, within your institution, in South Africa in general, and beyond the borders of South Africa.

2. Discuss the role of inter-personal communication of information. Indicate for what purposes you mostly maintain contact, e.g. information exchange in general, collaborative research, routine matters, maintain friendships, etc. and please name the people with whom you exchange information within your work and research environment (give names and organisation).
 - a. In your organization
 - b. Elsewhere in SA
 - c. Worldwide

Discuss any other aspects that relate to the communication of information within your profession.

Specifically refer to any changes that have taken place over the last 10 years

SECTION C: Information Communication Modes and Channels

General

4. Discuss the role that the following four general methods of communicating information play in your field and work environment. Rate their relative importance on a scale of 10 very important to 0 not important/not used:
 - a. Person-to-person communication
 - b. Recorded information:
 - i. Print-based e.g. journals, books, patents, etc.
 - ii. Electronic media and modes
 - c. Information communication at conferences

Interpersonal

5. Discuss information communication on an interpersonal basis and please rate your preferred method of interpersonal communication when interacting with
 - a. colleagues at work
 - b. persons elsewhere in South Africa
 - c. persons outside South Africa
 (apply a scale of 10 very important to 0 not important/not used)

Print-based modes

6. Discuss your use of print-based information communication channels. (e.g. journals, monographs, reports, patents, etc). Rate the usefulness of each source to you. (apply a rating scale of 0 - not used/useful to 10 - very useful)

Impact of electronic modes/media

7. Discuss the role of electronic media e.g. electronic communication networks, electronic journals, etc. and the impact they have had on the information communication process.

Specifically relate your discussion to:

- a. The impact that the use of electronic media has had on the communication of information in your field.
Please comment with reference to each of the categories below and rate the impact on a scale of 0 – no impact to 10 – very positive impact:
 - i. at work
 - ii. elsewhere in SA
 - iii. worldwide
- b. The effect that the use of electronic communication media has had on interpersonal interaction with colleagues, etc. For example has it facilitated/inhibited 'group associations, collaborative research', etc.? Rate the effect on a scale of 0 – no effect to 10 – very positive effect.
- c. List the electronic sources such as the Internet, CD-ROM databases, etc. you use when looking for work-related information. Rate the frequency of use and value of each sources on a scale of: 10 (used very frequently / very highly rated) to 0 (not used / of no value)
- d. Do you use electronic journals, and if yes, indicate
 - i. how frequently you use them on a scale of 0, never used to 10 used very frequently.
 - ii. their value as a source of information using a scale of 0, not useful to 10 very highly rated
 - iii. their value as a publication vehicle using a scale of 0, not useful to 10 very highly rated
 - iv. their relative importance in relation to printed journals
 1. electronic journals more important
 2. printed journals more important
 3. equally important
 4. no comment

Conferences

8. Discuss the role of conferences, symposia, etc. in the information communication process. Rate the value of conferences on rating scale of 0 - not used/useful to 10 - frequently used/very useful.
9. What was the reason for attending the above listed conferences, (e.g. as organiser, to present a paper or poster, to listen to papers, to obtain specific information, for informal interaction, etc.). Indicate how important each of the reasons given are on a rating scale of 0 - not important to 10 - very important.
10. Do you engage in 'electronic' conferences? If yes, do you, i prefer electronic conferences to personal attendance of conferences, ii prefer personal attendance of conferences to electronic conferences, iii have no preference ?

Information gathering

11. How do you keep up to date in your field? Do you Browse in the library, trace citations in journals, etc., regularly communicate with colleagues, regularly attend conferences, Other. For each method rate its usefulness (apply a rating scale from 0, not at all useful / never used to 10 Very useful)
12. How do you go about it to find information for a new research project, or investigation into an unknown field. For each method given rate its usefulness (apply a rating scale from: 0 - not at all useful/ never used to 10-very useful)
13. How do you go about it to find information to solve a problem encountered in your current work environment. For each method given rate its usefulness (apply a rating scale from: 0, not at all useful/never used to 10 very useful)

Library interaction

14. Discuss the role of the library in the information communication process. by
 - a. rating its importance to you,
 - b. the frequency that you personally visit the library, and
 - c. your satisfaction with the service provided.

(apply a rating scale from: 0 - not at all important/frequented/satisfied to 10 -very important/very frequently visited/ very satisfied)

SECTION D: Professional Activity & Research Output

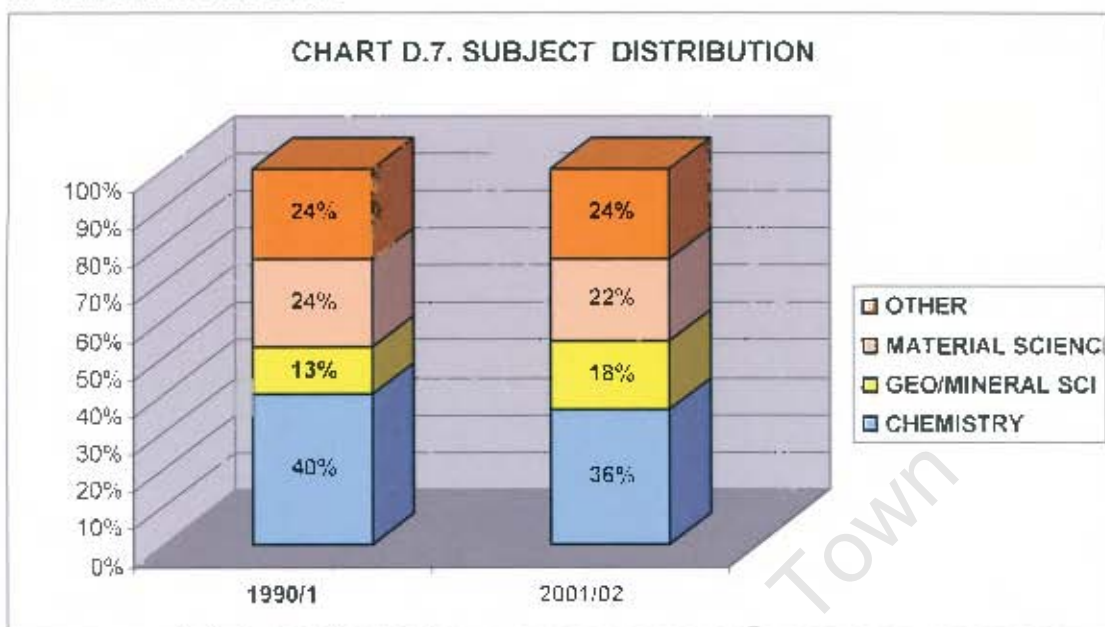
15. Discuss your involvement in professional activities such as editorships, refereeing, professional institutions, etc.
17. Discuss your main research and/or development output: e.g. published papers, papers read at conferences, reports, patents, products, procedures, etc. Please provide full details such as whether you generally co-publish, and with whom, and where do you mostly publish (in SA or overseas)? Could I please also have a list of your publications, reports, patents, conference papers, etc.

SECTION E: Conclusion

17. Please provide any other comments with regard to
 - a. the way that you find information
 - b. exchange information with colleagues / other scientists
 - c. interact with colleagues, other scientists

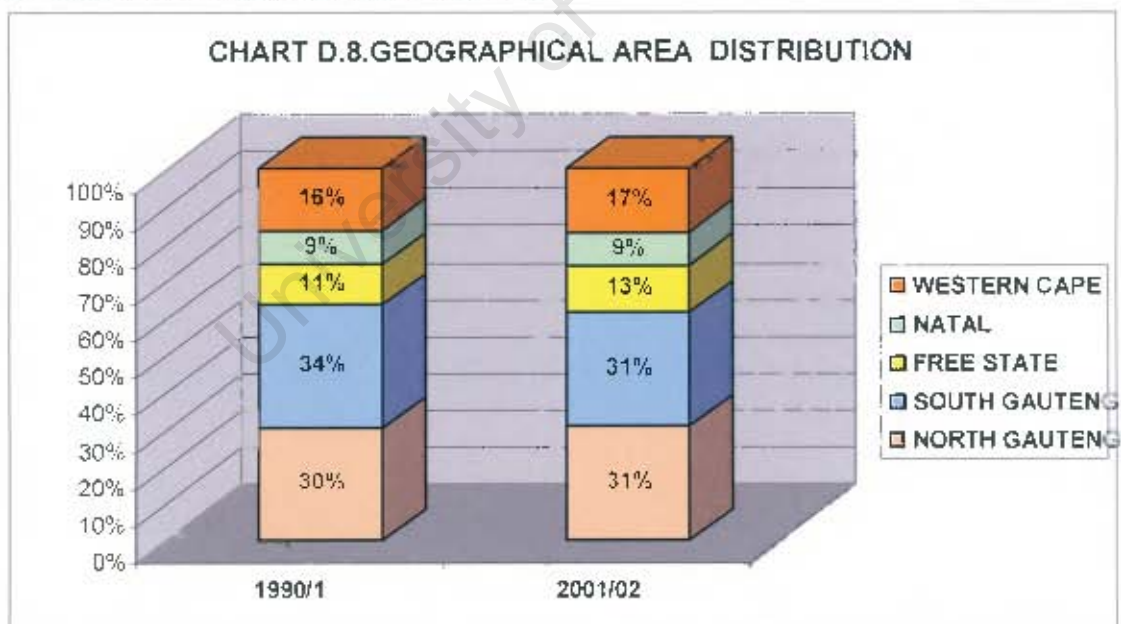
University of Cape Town

7. SUBJECT PROFILE



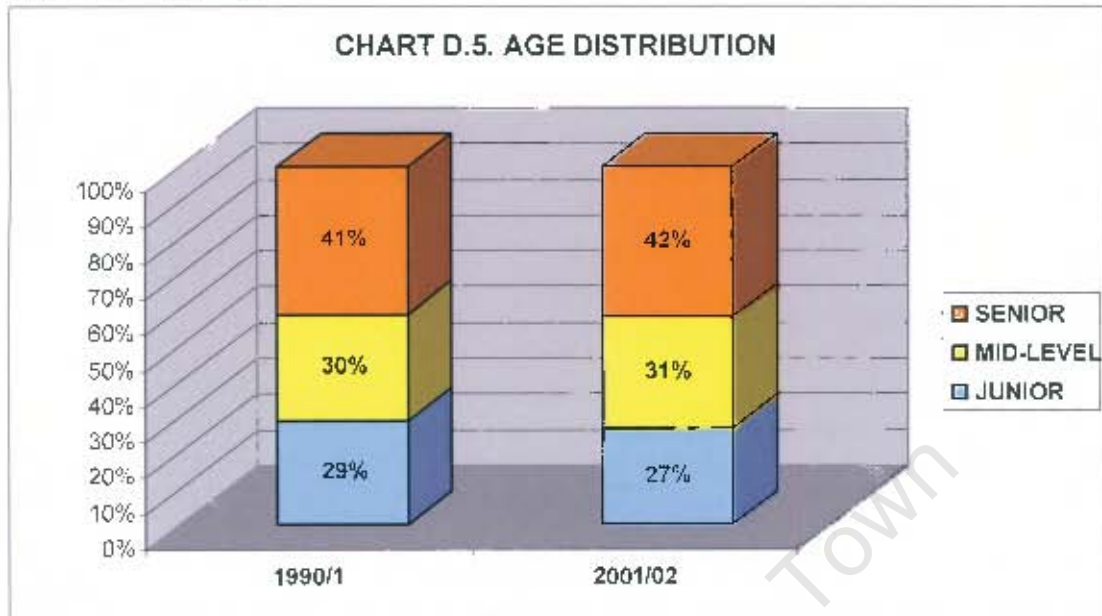
Distribution according to subject for 1990/1 and 2001/2 was as follows: Chemistry 40% and 36%; geological and mineralogical sciences 13% and 18%; material science 24% and 22%; other 24% and 24% (this was mostly physics).

8. GEOGRAPHICAL AREA PROFILE



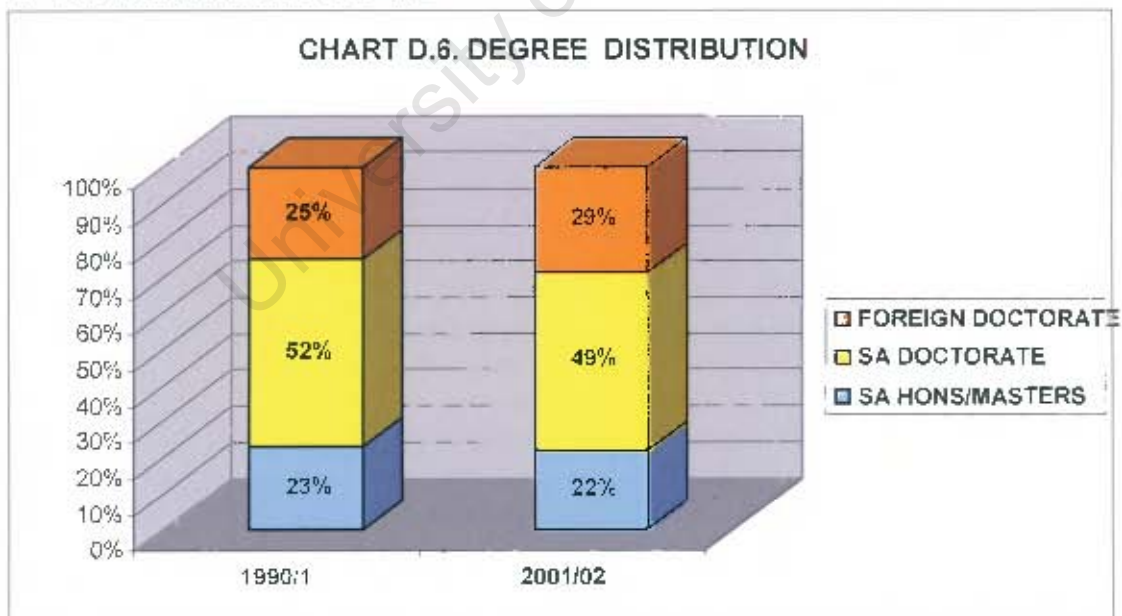
The distribution by geographical area clearly indicates that this had hardly changed between 1990/1 and 2001/2 and that the majority of the crystallographers worked either in North (30%; 31%) or South Gauteng (34%, 31%), followed by the Western Cape (16%; 17%), the Free State (11%; 13%) and Natal (9%).

5. AGE PROFILE



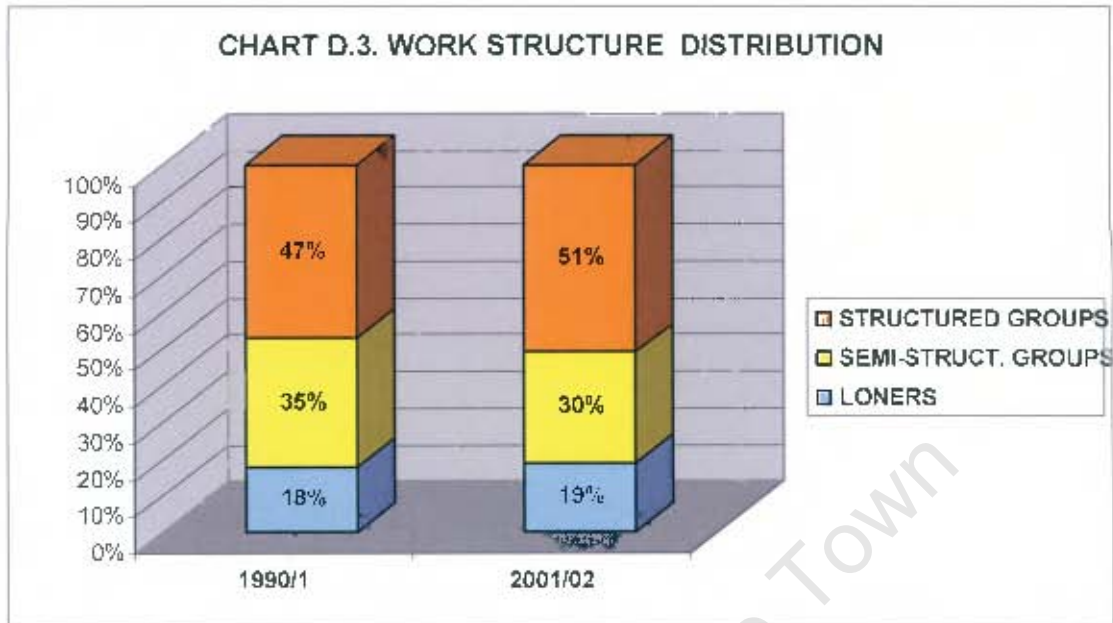
The age distribution showed an increase in age distribution from 1990/1 to 2001/2 and was respectively for the two studies 30% and 28% for the youngest, 46% and 38% for the middle and 24% and 33% for the oldest age categories.

6. QUALIFICATION PROFILE



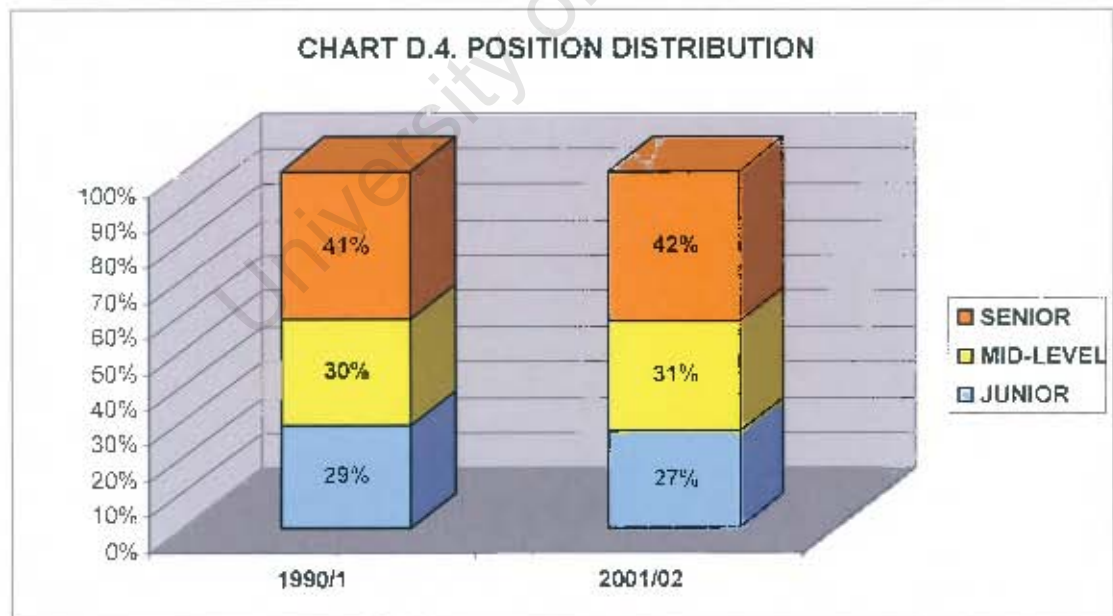
The distribution according to qualification indicated that respectively for 1990/1 and 2001/2: 23% and 22% held honours or masters degrees (all South African); 52% and 49% held South African doctorates; 25% and 29% held foreign doctorates.

3. WORK STRUCTURE PROFILE



The distribution according to group forming indicated that respectively for 1990/91 and 2001/2 47%; 51% worked in structured groups; 35% and 30 % in semi-structured groups; and 18% and 19 on their own.

4. POSITION

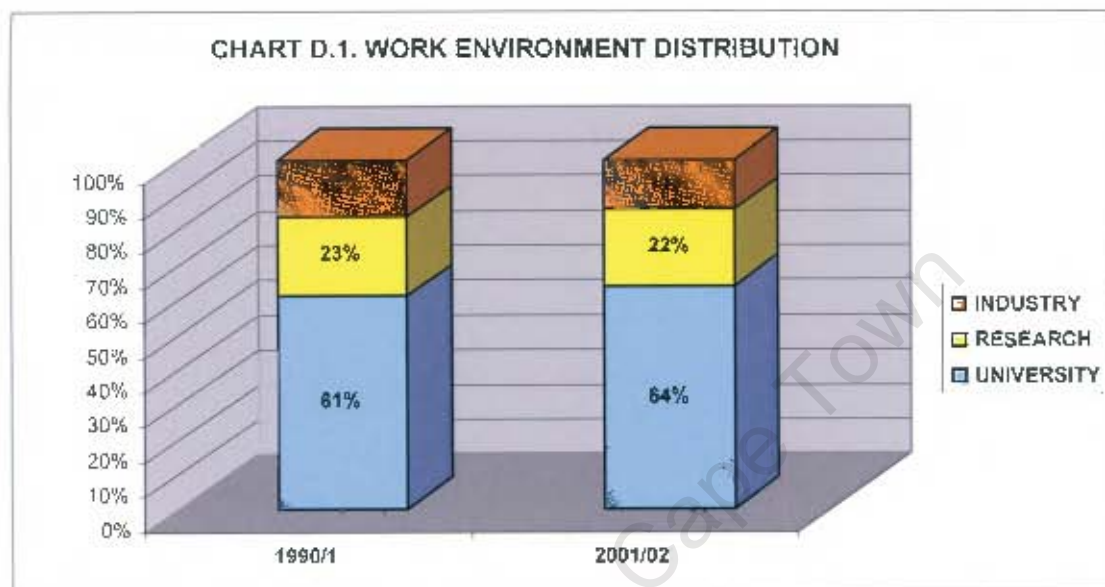


As far as position was concerned there was a fairly equitable distribution among the senior levels with for 1990/1 and 2001/2 respectively 41% and 42% at the senior level, 310 and 31% at the middle level; and 29% and 27% at the junior level.

APPENDIX D

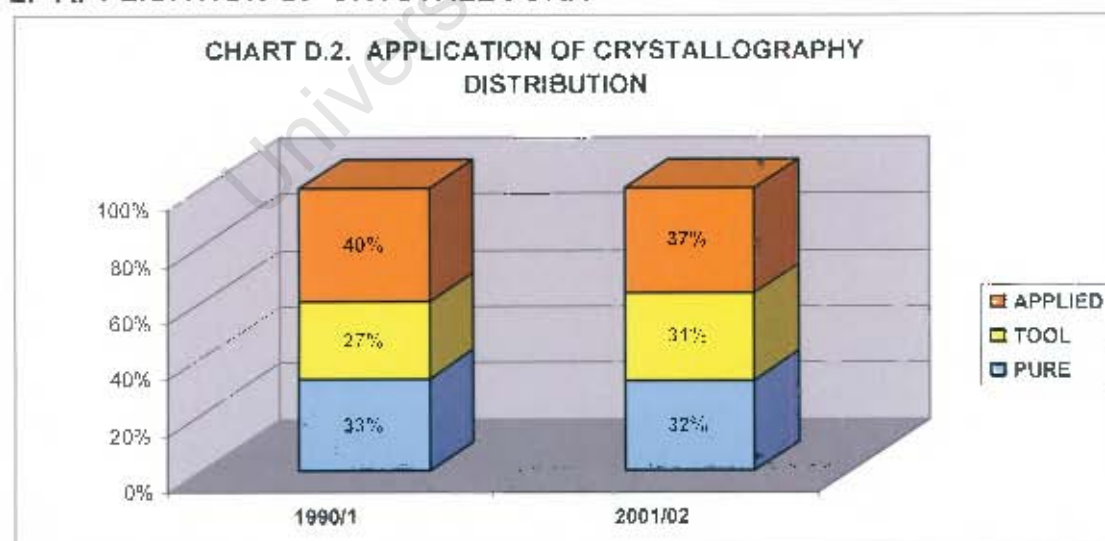
PROFILE OF THE STUDY POPULATION

1. WORK ENVIRONMENT



The work environment distribution indicated that respectively for 1990/1 and 2001/02, 16% and 14% of the respondents were in the industry sector; 23% and 22% were working at research institutes; and 61% and 64% at universities.

2. APPLICATION OF CRYSTALLOGRAPHY PROFILE



The distribution according to application of crystallography was respectively for 1990/1 and 2001/2: 40% and 37% applied; 27% and 31% tool and 33% and 32% pure.