A cultural-historical activity theory based analysis of lecturer and student understanding of learning in the Department of Mathematics and Applied Mathematics at the University of Cape Town

Thomas van Heerden

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Abstract

Cultural-historical activity theory (CHAT) provides a framework for analysing activity systems. I use that framework to investigate teaching and learning in two first-year university mathematics courses at the University of Cape Town. The focus of this investigation is whether the different subjects of this activity system (i.e. the students and the lecturers) have different conceptions of learning, and what those possible differences mean for teaching and learning.

The CHAT framework is well-suited to this type of work. CHAT's theoretical roots are in Hegel's dialectics and Vygotsky's mediation. Teaching and learning are higher-order mental phenomena. Dialectics allow us to aggregate our data to draw conclusions about this type of higher-order phenomenon, and the notion of mediation (extended from Vygotsky's initial work by Leont'ev and others) provides a means to understand how learning happens.

Data are collected both through face-to-face interviews with a small group of subjects ($n = 6$) and more broadly through an online questionnaire ($n = 55$). The face-to-face interviews and the questionnaires make it clear that students and lecturers do have different conceptions of learning; in the language of CHAT, there are tensions in the system. These tensions can be categorised into two major themes: what students do and how they do it. These tensions will not be easily resolved; I suggest teaching some meta-cognitive skills rather than only mathematics as a first step.

This research was approved by the School of Education's Research Ethics Committee prior to its commencement.

Contents

Chapter 1

Introduction and background

Higher education in South Africa is changing. Over the last three years there have been a series of student protests at institutions across the country. These protests have affected change both at individual institutions (for example the University of Cape Town's insourcing of workers) and nationally. Despite the uncertainty that these protests and consequent changes bring, the core business of the country's universities proceeds. The faculty keeps researching and teaching; the students keep learning. For as long as teaching and learning continue, the everyday concerns of the classroom remain important. The recent events will undoubtedly influence the way I respond, but the types of questions I am asking as an educator remain the same: "What is my role as a teacher?", "How should I teach?", "What can I do to help my students learn?".

My emphasis on the everyday concerns of the classroom and the regular problems that universities face is not intended to downplay the importance of the protests. Business should not continue as usual, nor has it so far. These protests are precisely the realisation of "Learning III" (Bateson [6]) or "expansive learning" (Engeström [12, 13]) that may foreshadow a radical recontextualisation of the teaching and learning that happens at South African universities. Although my research question is not directly focused on the protests, the results of my research should be framed against this background and I will bookend this work with some concluding remarks in the final chapter.

The specific issues of interest to me in this study are the different student and lecturer conceptions of learning, the sometimes antagonistic behaviours that may follow from those differing conceptions, and the consequences these have for teaching and learning.

It has been long accepted [29, 31] that lecturers' conceptions of thinking and learning inform their practice. A recent study of lecturers in Science, Technology, Engineering and Mathematics (STEM) [33] highlighted the importance of lecturers' experience as students to their conceptions of learning, and ultimately to their practice. Mathematics lecturers' experience as students is unusual since very few students in any first-year university mathematics class eventually end up lecturing mathematics at university. The future lecturers enjoyed studying mathematics, probably more than they enjoyed studying any of their other subjects, and they must have been good at it too, good enough to complete their postgraduate studies and find a job in a competitive environment. As much as lecturers would like all their students to enjoy mathematics and easily understand the material, many struggle, both with motivation and comprehension. The students do not have the same benefit of years of discipline-specific learning at tertiary level either, another set of experiences that sharpens the way lecturers think about teaching and learning [33, 55]. Instead, they are likely to have their own notions of learning inherited from their experiences in a sometimes dysfunctional secondary schooling system. This difference in experiences, and difference in beliefs, along with empirical observations that "teachers' beliefs about mathematics and its teaching play a significant role in shaping the teachers' characteristic patterns of instructional behaviour" [55, p. 130-131] lead to situations where there may be

misalignment between teachers' instruction and students' behaviour.

When student behaviour doesn't satisfy lecturer expectations it leads to unhappiness on both sides. Students regard lecturers as unreasonable, and lecturers in turn regard students as deficient. Previous work (see Biggs [7] and Trigwell [57]) has investigated this "disconnect" between students and learners, i.e. the difference between students' behaviour and lecturers' expectations, some of the problems that may arise from this disconnect, the importance of identifying these problems, and of making changes to lecturers' practice to encourage better student learning.

I tackle this question: how does the learning context of first-year mathematics at the University of Cape Town (UCT) shape conceptions of teaching and learning among lecturers and students, using the framework of Cultural-Historical Activity Theory (henceforth CHAT)? There are a number of reasons why I use this particular framework to extend previous work. Students and lecturers at UCT have diverse backgrounds. Their social, economic and cultural circumstances differ, and this diversity, which all universities have to some extent, is particularly broad in South Africa as a result of its unique history. Compounding this problem is UCT's status as the premier university in the country; it attracts foreign students and lecturers with their own backgrounds. Among these differing circumstances are language, class, capital, schooling, belonging, and values. Many of these factors that influence conceptions of learning are interconnected and analysis that attempts to address each in isolation will neglect their interplay. I must adopt a broader, systemic analysis, and CHAT gives me the tools to consider the entire activity system surrounding the subjects.

Within the CHAT framework, this broader analysis is driven by the subjects, the lecturers and students (in what I will explain as a teacher|learner category pair). It is their experience of the teaching and learning activity within the system that is the keystone for understanding the learning context, and consequently the central pillar of my inquiry to which I will constantly return. CHAT has previously been systematised by Engeström [13] who provides some clear guidelines for the application of the theory to the real world, specifically in the context of learning. This, in turn, ensures a degree of rigour in its application and its methodological validity. The question of interpretive rigour does not have a short answer, but I argue below that the cultural-historical activity framework meets the standard of a "sufficiently authentic" representation of a real-world phenomenon described by Lincoln et. al. [27] and so I can be confident in my interpretations and consequent action.

In the section below I provide an outline of CHAT. I start with a general, decontextualised history that becomes increasingly specific as I focus on the parts of the learning context at UCT that interest me. This narrowing of focus allows me to map the theoretical constructs of CHAT to the real-world people, artifacts and activities that I can observe and understand.

1.1 Cultural-historical activity theory

Cultural-historical activity theory is the amalgamation of two distinct historical branches of thought. The first is the work of German philosophers, particularly Marx and Engels, who developed Hegel's ideas into the philosophy of dialectical materialism, the theoretical underpinning of Marxism. The second is the work of the Soviet psychologist Vygotsky (and later his student Leont'ev) on mediation, the zone of proximal development and activity. These two branches are discussed below. The exposition follows broadly the same historical routes offered by Roth, Roth and Lee, and Engeström [13, 39, 43].

1.1.1 Marx, Engels and dialectical materialism

I start with a discussion of dialectics and the three laws of dialectics proposed by Engels [11], then move to materialism, and finally dialectical materialism. Engel's laws of dialectics are:

1. The law of the conflict and the unity of opposites.
2. The law of qualitative change through quantitative change and vice versa.
3. The law of the negation of the negation.

The first law states that objects can be decomposed into complementary but contradictory constituent parts, or category pairs, and that these category pairs should form the basic unit of analysis. An individual element in a category pair presupposes the existence of its complement, for example, in this study one cannot speak of teachers without presupposing the existence of learners for them to teach.

Each of the elements in a category pair acts simultaneously on the other. A collective is constituted by individuals whose thoughts and actions are in turn influenced by the dominant discourse of the collective. This simultaneous action leaves the elements of the category pair in a state of tension. The two exist in equilibrium, the action of each on the other is balanced and the elements are unchanging. This notion of balance and unchanging elements presupposes the possibility of imbalance and change, a rearrangement of the current state of the category pair into a new equilibrium.

This simultaneous action and the consequent tension makes it impossible to analyse only a single element, for that element experiences reflexive change enacted on itself through the other element in the pair. They must be jointly considered or this relationship between the two elements will be neglected and the analysis impoverished to the point of failure.

Analysis therefore takes account of the entire category pair, of the unity of the opposites and the underlying tension that holds them in equilibrium. Change in the system is driven by a continuous cycle of building and releasing tension. Contradictions are surfaced and resolved, changing the relationship between the complementary elements but leaving them in tension for future contradictions to develop and so repeat the cycle.

In some recent publications these category pairs have been denoted using a vertical bar (Sheffer stroke [49]) or vertical arrow, i.e. teacher|learner or individual|collective. This notation is inherited from its use in Boolean logic to represent the NAND operation.

The subject of my research will be the teacher|learner category pair. I am interested in the underlying tension between these two constituent elements' conceptions of learning. The possibility of conflicting conceptions motivated this research, and as such it is the central pillar around which I will base the rest of my analysis. I hope to surface this tension in my current work and ultimately resolve it by moving to a new equilibrium where lecturer expectations and student behaviour are better understood.

The second law states that qualitative change can be effected through quantitative change. Consider a large jug of pure water from which a glass is poured. If a single molecule of table salt is added to the water which is thoroughly stirred before pouring, no-one who drinks that water will detect any change in taste. One can do the same with a second molecule, and a third, and a fourth and this definite, quantitative change will remain undetected. There is, nonetheless, some number of molecules that will be detected and there is another, greater number that will not only be detected, but will cause a drinker to spit out the water, rejecting it as "Too salty!" Although one cannot consider any particular molecule of salt as responsible for the change, the jug of water is no longer fresh; it is salty.

Qualitative changes arise as an emergent property of quantitative change. Local analysis, analysis which is too narrowly focused, be it in space, or time or on whatever else is changing,

will not be able to predict the outcomes that arise globally, over the entire domain of the problem. By looking at a narrow slice of a rainbow one may well conclude that the only colours that exist are various shades of green, but as one pulls away a dazzling array of alternatives reveal themselves. Higher order phenomena (the spectrum) have their roots in the lower orders (an individual colour), and the transition within and between orders is not a cleanly delineated one. There will be no agreement over the exact boundary between green and yellow, and then between yellow and orange. Likewise, there may be disagreement over whether a particular reddish-orange to blueish-indigo spectrum constitutes an entire rainbow, but there is no disagreement that it is a qualitatively distinct entity from the narrow slice of green.

In this study I am interested in student and lecturer conceptions of learning. People, and their thoughts, resist neat classification. It is highly unlikely that I am able to make a single observation that allows me to accurately categorise someone, or even that clearly delineated categories exist. Any analysis must be of a broad and aggregated set of observations. Just as no single molecule of salt is responsible for the saltiness of the water, no single observation can be responsible for my overall impression of a student or lecturer. They will all contribute to the *gestalt* judgement I make about how they think about learning.

Similarly to the way one might struggle to differentiate aquamarine from turquoise from teal, but be totally confident that none of them are red, I should expect some difficulty in distinguishing between similar people even after aggregating my observations. Using Biggs's terminology for this example: I may confidently identify someone as adopting a "surface" or "deep" approach to learning, and I could classify all my subjects into one of these two macro-clusters, but within these clusters it is harder to draw distinctions. There are no clear lines. My analysis is a matter of interpretation rather than rigid taxonomy.

The final law is that of the negation of the negation. This law was alluded to above when I spoke of the cycle of contradictions and resolutions that propel change within a system. More formally, the negation of the negation can be understood as a sublation of the conflict between the category pairs. The contradiction is overcome but in overcoming preserves the whole in an uncoiling spiral of thesis-antithesis-synthesis.

Thesis is an initial expression, which is in some sense deficient or contradictory. The antithesis, the first negation, is a reaction to the thesis, an alternative proposition which is itself unsatisfactory. Synthesis, the second negation, is the reconciliation of thesis and antithesis into a greater whole, from which a new thesis will develop. In this manner the spiral is propelled through contradictions and resolutions.

The chain of thesis, antithesis, synthesis that interests me is the consequence of the differing conceptions of learning that students and lecturers may hold. There are two mirrored chains. In the first, lecturers regard their students as underprepared, or in some sense deficient (thesis). They adopt a deficit model of the students, focusing on only their shortcomings (antithesis). In the second, students regard their lecturers as unreasonable, making demands that they are not equipped to meet (thesis). They enter into a survival mindset, focusing on the assessment, on what they need to do to pass the course (antithesis). Neither chain has a neat resolution. This work hopes to understand both students and lecturers, and in doing so take some initial steps toward a synthesis that completes both chains, resolves this underlying tension, and leads to a new and better equilibrium in the teacher|learner category pair.

Dialectical materialism is the union of dialectics with materialism. Materialism is a monist ontology that anchors the origin of all phenomena, both the physical and the mental, in the material world. All phenomena are the result of interactions between matter. The obvious consequence of the materialist position is that the primary focus of analysis must be the concrete world. Consciousness and thought are higher-order phenomena that emerge from interactions in the lower, more fundamental, material order of existence, in accordance with the dialectic principles outlined above. It is the aggregation of material interactions that produces the higher-

order phenomenon that interest me, and so observation, and interpretation, of interactions in the material world provide the explanation for seemingly abstract issues.

Marx's historical materialism was an explication of the sociopolitical through socioeconomic analysis based on the means of production. A high-order phenomenon, in this case the historical and future political arrangement of Europe and Russia, was explained through analysis firmly anchored in the concrete world – analysis of the instruments and subjects of labour, and labour itself. His historical materialism also demonstrates well the law of the negation of the negation. Capitalism is the first negation of feudalism, and the socialist revolution is the negation of capitalism.

Dialectical materialism, in contrast to earlier materialism and influenced by Darwin's theory of natural selection, understood that analysis must take account of man not as static, but as engaged with and in the world around him, both subject to change and driving change:

> *"The main defect of all hitherto-existing materialism – that of Feuerbach included – is that the Object [der Gegenstand], actuality, sensuousness, are conceived only in the form of the object [Objekts], or of contemplation [Anschauung], but not as human sensuous activity, practice [Praxis], not subjectively."* – Karl Marx [30]

Even though I am interested in conceptions of learning, which is clearly a high-order phenomenon, I should ground my analysis in the interaction of my research subjects, the teacher|learner pair, with the material world, with the "human sensuous activity" of teaching and learning. It is this emphasis on activity, on the material world as diachronic and not eternal, that leads me into the second historical branch of CHAT. I will demonstrate that CHAT not only emphasises ongoing activity, but also the interconnectedness of a larger material system in which all the laws of dialectic materialism are evident. It is the aggregation of interactions between the interconnected elements, and the underlying tensions between the different elements, that ultimately drives activity systems to change by resolving a chain of thesis, antithesis and synthesis.

1.1.2 Vygotsky, Leont'ev and activity theory

The second branch of CHAT starts with Lev Vygotsky, founder of the school of cultural-historical psychology. Vygotsky's central idea, upon which this school was built, was that of mediation. Vygotsky privileged semiotic mediation and focused on the individual. His student, Leont'ev, would broaden this to collective mediation, and later cultural-historical activity practitioners would emphasise the importance of tools and other artifacts in the process of mediation.

Mediation is social interaction that develops higher mental function. Simple organisms exhibit direct stimulus-response behaviour, for example a sea anemone will close its tentacles (response) around an object that is brought to its mouth (stimulus), or a sunflower will turn throughout the day (response) so that it is always facing the sun (stimulus). Human interactions are more sophisticated. A primary stimulus produces an auxiliary stimulus which is responsible for bringing about the response. This is often represented by the triangle schematic reproduced in figure 1.1.

Consider, by means of illustration, a child raised in a religious family which keeps the custom of prayer before a meal. A hungry child's direct response to the stimulus of a hot meal before them would be to start eating. They do not. They instead wait for the prayer to be made which evokes in them a sense of thankfulness. This ritual bestows a new meaning, a new significance, to the meal that transcends its material properties. This meaning, these higher mental functions, could not have been learnt through direct response, but must have been

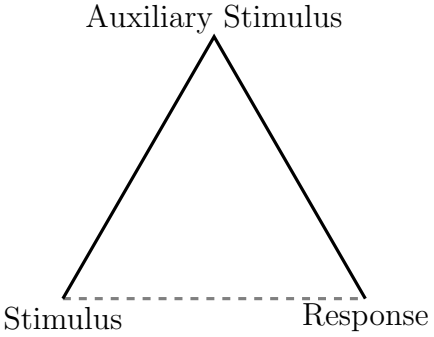

Figure 1.1: Vygotsky's model of mediation.

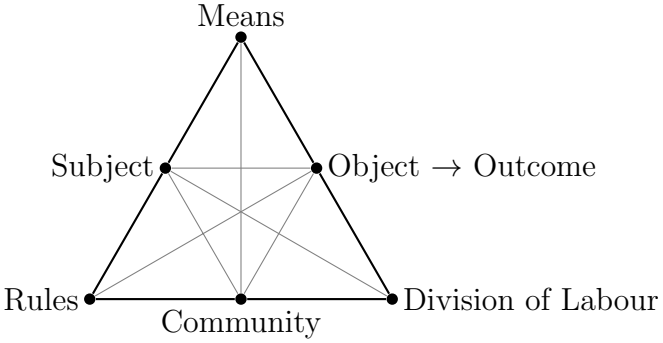

Figure 1.2: A generalised activity system with six elements and fifteen possible interactions.

developed through interactions with their family who provided appropriate auxiliary stimuli. Through these interactions meaning is internalised. In Vygotsky's words:

> *"Every function in the child's cultural development appears twice: first, on the social level, and later on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals."* – Lev Vygotsky [61]

The limitation of Vygotsky's first generation CHAT was that the unit of analysis remained the individual. Leont'ev expanded the unit of analysis to include collective activity. In second generation CHAT researchers are concerned with a far broader range, often modeled as an activity triangle as seen in figure 1.2.

With the introduction of community to the activity system come rules that regulate the behaviour of subjects within the community and the division of labour within the system. As these additional concepts are added, so are additional interactions between concepts. The complexity of the system and the resulting analysis grows superlinearly.

The 'activity' in these activity systems should be understood not as an isolated activity or task (in the original Russian, *aktivnost*) but rather in the sense of a culturally and historically motivated set of actions that meet a generalised need of society – productive activity (*deyatel'nost'*). These activity systems are therefore object orientated, and goal or motive directed.

The object of the activity is to be transformed by the subjects into an outcome. The object therefore exists twice. First in idealised form as the imagined outcome within the consciousness of the subjects, and secondly in the material world of activity. This pre-existence aligns the

activity through purpose, and gives motive to the individual actions that are undertaken to fulfil the activity. Actions cannot be separated from activity, since activity motivates action which realises activity.

Individual actions do not simply happen; they must be done. They are a willed series of operations, performed with unconscious competence, but deliberate. It may take very little effort for the reader to pick up a pen and copy the following sentence "The quick brown fox jumps over the lazy dog" but it will not happen spontaneously. Agency must be exercised.

Everyone has a set of bounded, unconscious competencies, and a complementary, unbounded set of non-competencies. Consequently there are actions one can take, and there are actions one can not. At the boundary between these sets lies Vygotsky's zone of proximal development. There are some actions that one may be unable to complete by themselves, but can complete when working with a peer, or a teacher, or following alongside a textbook or video. It is in this space that learning, which is regarded as an expansion of action possibilities, occurs.

This mediated learning process breaks the catch-22 that inhibits learning. The learner needs to perform an operation to understand it, but must understand an operation to perform it. This immobile internal process is pushed into action by an external force. As operations are internalised they become cognitive tools. A student must expend a great mental effort in MAM1021S[1] learning how and why to perform the elementary row operations to Gauss reduce a matrix, and will need guidance from their lecturer and tutors. The same student will in MAM2084S[2] effortlessly call on Gauss reduction as an intermediate step to solving more complex problems. Actions are moved from non-competencies to competencies through the zone of proximal development.

1.1.3 A general structure for analysing learning with CHAT

This section draws substantively on Yrjö Engeström's paper *Expansive Learning at Work: toward an activity theoretical reconceptualisation* [12]. In this paper he proposes a set of four questions and five principles that can be used to frame the analysis of learning. The elements of this framework have been discussed in the previous subsections 1.1.1 and 1.1.2 but are made explicit here. The framework presented in this section is context-free. In section 2.2 I apply these questions and principles to my research question.

Four questions

There are four central questions for any theory of learning. They can be read with reference to figure 1.2.

1. *Who is learning?* Any theory of learning must identify the learners. These are the subjects of the activity system, but they are located within a particular community.

2. *Why are they learning?* The motivation for learning, as in any activity system, must be to meet a generalised need of society. That need should be identified for it provides direction to the system and shapes its outcome.

3. *What are they learning?* The material to be learnt is the object of the activity system.

4. *How are they learning?* The means, rules and division of labour within the system govern learning.

[1] A first year mathematics course for engineering students.
[2] A second-year mathematics course for engineering students that follows MAM021S.

Five principles

The five guiding principles outlined by Engeström are to consider:

1. *The activity system as unit of analysis.* The entire system must be considered – individual components (people or actions or tools) cannot be analysed without considering their effect on the rest of the system, or the system's effect on them.

2. *The multi-voicedness of the activity system.* Activity systems are communities, and within those communities there are rules and a division of labour that afford to different constituencies, different perspectives. All of these voices should be considered.

3. *The historical context of the system.* There is no spontaneous generation. Activity systems developed over a long period of time and must be studied within the appropriate historical context.

4. *The inner contradictions that propel the system.* The historical development of activity systems has been driven by a series of contradictions, tensions within or between activity systems that cyclically swell and dissipate.

5. *The expansive learning cycles that transform the system.* My analysis thus far has been quiet on the subject of expansive learning. In short, expansive learning is the disruptive process of radical questioning that is currently well-exemplified by the movements and resulting protests across university campuses in South Africa. Although the current situation is undoubtedly of incredible importance to education in South Africa, and to the broader well-being of the country, it falls outside of the scope of the current research.

Putting it together

These four questions and four principles (for reasons discussed above I disregard the final principle of expansive learning) can be plotted on a 4 by 4 matrix to provide a basic framework for my analysis – see figure 1.3.

It is not the case that every subsquare in this matrix will be populated, but it does provide a useful set of prompts to encourage a thorough analysis of the activity system. I will return to this matrix and populate it with the issues relevant to my current study in section 2.2 below.

At this point I would also like to highlight how the historical foundation of CHAT in dialectical materialism is evident in its contemporary formulation, both with regards to the activity system and to the framework suggested by Engeström. This ties together a number of the notions that I have introduced in this chapter and makes explicit some of the links.

The contradictions that propel the activity system, the fourth column of Engeström's matrix, should be understood both in terms of the first law of dialectics, the conflict and unity of opposites, and the third, the negation of the negation. The continual process of surfacing and resolving tension within the activity system is the same process that has been described much earlier by Hegel, Engels and Marx. Although he does not make use of the same language, of a sublation of conflict and a resolution to the chain of thesis, antithesis and synthesis, the idea is the same. This idea also captures the essence of the expansive learning that he regards as important in transforming the activity system.

The interconnectedness of activity systems, and the relationships between the different constituent parts of those activity systems, also parallel the earlier dialectical work. These elements are never considered in isolation; they are analysed always as part of a pair, for example the relationship between subjects and the community, or between the means and the object. This echoes the first law of dialectics. It supposes a simultaneous action and reaction of

	System as unit of analysis	Multi-voicedness	Historicity	Contradictions
Who is learning?				
Why do they learn?				
What do they learn?				
How do they learn?				

Figure 1.3: Matrix for the analysis of my activity (teaching and learning) system.

two elements on each other, and that this simultaneous action makes analysis of a single piece impossible.

Activity systems are also obvious examples of the second law of dialectics; that qualitative changes arise from quantitative ones. Activity is an aggregation of action, which is itself an aggregation of operations. These individual operations can be well quantified. An individual makes a particular marking with a pen on a piece of paper, their eyes rest upon another set of markings, certain vibrations in the air are detected as disturbances of a fluid in their inner ear. The net result of thousands of these operations is that they learn something, a higher-level qualitative change which transcends the low-level nature of its components.

None of these links should surprise. Marx conceived of dialectical materialism as an investigation of "human sensuous activity". Although contemporary CHAT is chronologically distant from his work, it remains close to its theoretical roots.

1.2 Previous literature

The present work is, to my knowledge, the first investigation into the teaching and learning of tertiary-level mathematics education using the CHAT framework in South Africa. Before I discuss my own work it would be appropriate for me to provide some outline of this previous work, what can be learnt from it, and how my own work differs. There are three strands that I will be drawing on. The first is outside of South Africa where CHAT has been used to understand mathematics education from primary to tertiary level. The second and third are inside South Africa, where much has been written about mathematics education without the CHAT framework, or where the CHAT framework has been used, but the focus of that work has been educational technology rather than mathematics education.

With regards to mathematics education and CHAT, I am following in the footsteps of Wolff-Michael Roth. He has (co-)authored a number of papers [35, 39, 40, 41, 42] that I discuss now. Common to these papers is the importance of three elements: activity as a minimal unit of analysis, dialectics and contradiction as a driver of change, and (in his later work) subjectification. Activity and dialectics have been discussed above. Subjectification is the process of reflexive change within the activity system between the subject and object. An individual may be part of many different activity systems, but within each system their actions are motivated by a particular object, and it is this motive that essentialises them as a teacher, or an engineer, or a doctor within that system; "participating in a different activity means that the person is differently constituted as a subject in each activity system" [40]. Just as an individual plays a different role in these different systems, each system plays a different role in the development of the individual, and their development should not be understood as a set of parallel, isolated streams, but rather "in terms of the *collective* object/motives that characterise the particular system and by the associated process of subjectification" [39].

In [40] contradictions surface when apprentice electricians experience an epistemological gap between their college and on-the-job training. They are constituted in two different roles within these two different activity systems, and the knowledge and practice that is valued in one is dismissed in the other. My work is not explicitly interested in this sort of boundary crossing, I will be restricting my research to a single activity system, but the teachers and learners I speak to are obviously members of many activity systems and some of these tensions may become evident in my interviews. There is also the meta-concern that their involvement in this project is itself part of a new activity system. The way they are in this system may differ from the way they are in the teaching and learning system so I must account for this. A more detailed discussion of this issue is included in the chapter below on methodology and research design.

In his more applied papers [35, 39, 42] Roth provides a fine-grained analysis of the particular artifacts or interactions within an activity system. A brief discussion, a few minutes, between

students and teacher is carefully discussed and subtle details are made retrospectively obvious through this work [35]. In another paper, a think-aloud exercise, again of only a few minutes, has been meticulously recorded and transcribed to make sense of a simultaneous double movement in the abstract—concrete category pair [42]. My work is not concerned with the process of learning itself but rather with the way the subjects think about learning. I am not going to have these sort of vignettes to deconstruct but I will still have to work carefully with the transcription and interpretation of my own interviews.

Much of the mathematics education work in the South African context has been focused at the primary and secondary school level. Although none of the work I discuss below uses the CHAT framework explicitly, it is nonetheless useful since it explains some of the appropriate cultural and historical background that belongs to the first-year students as they transition from secondary to tertiary education. South Africa's history has lead to a number of pedagogically interesting research areas, and I discuss two of them below.

The first of these areas is the investigation of multilingualism and its effect on on mathematics education. Here the work of Mamokgethi Phakeng et. al. [46, 47, 48] is important. In 1996 the University of the Witwatersrand introduced an in-service teacher development course and over the next three years some of those teachers formed part of a research study that included interviews, in-classroom observations, video recording of their teaching, examples of learners' work and so on. In these papers, language, and especially code switching, was discussed. In the CHAT framework of teaching and learning as an activity system these papers are excellent for their foregrounding of language. Language is inherently dialectic as it is a means of communication between teachers and learners. It is also a significant part of individual identity and so consideration of multilingualism is indirectly a consideration of multiculturalism (and this consideration is made more explicit in [47] where the "contextual diversity" of urban and rural schools is highlighted). In my study I must exhibit the same sensitivity to the diversity of cultural backgrounds among South African learners. One shortcoming of the research was its focus on teachers, and although student views on multilingualism were flagged as an avenue for further research, this should, in the CHAT framework, have been done at the same time to account for the reflexive nature of the interaction within the teacher|learner pair.

The second area that is of interest to me can be bluntly summarised by the question "Why are most South African schools bad?" Here I'd like to highlight the work of Nic Spaull [52, 60] and Brahm Fleisch [15]. Unfortunately there isn't a single, simple answer to that question. The current situation is the result of a number of factors, but the result, "Two nations and a bimodal distribution of achievement" [15, Chapter 1], is what interests me. As Spaull makes clear [52] the difference in quality of education provided by rich schools (quintile 5) and poor schools (quintile 1 to 4) is large, and grows larger throughout a student's school career. Although exceptional individuals at poor schools can still perform well enough to be admitted to university (and any students in my study from those schools are exceptional on the basis that they were admitted to UCT) they will still have had a significantly impoverished education relative to the students from top quintile schools. This difference emphasises the importance of the students' cultural and historical backgrounds. My interpretation of student responses should always take their high school contexts into account.

Finally, there has been some work done in South Africa, or by South Africans using the CHAT framework. The earliest work was by Joanne Hardman and investigated computer usage as a pedagogic tool in a primary school mathematics classroom [17, 18, 19]. This work is primarily about educational technology, not about mathematics education. Her conclusion that "there is a developing contradiction between the computer as a tool for creative student-centred learning and the computer as a tool for lower level drill and practice skills" [18, p. 110] is content-neutral and could just as easily have been made about a natural sciences classroom. Some of her later work [20, 50] still straddles these two fields of educational technology and

mathematics education but it certainly doesn't focus on mathematics education in the same way I will here.

In the ten years since her first set of papers other South African researchers have also started using CHAT, for example Geoff Lautenbach [24], Tabisa Mayisela [2] and Patient Rambe [37]. All of this work falls firmly into the field of educational technology research.

I intend to incorporate the two pedagogically interesting aspects of the South African context (multilingualism/multiculturalism and differential achievement at South African schools) into my analysis using the CHAT framework. CHAT is an appropriate framework to do this because it explicitly centers the importance of these sorts of cultural-historical factors, and because these factors can be directly linked to the various nodes in the activity system triangle.

For example, the bimodal distribution of achievement that Fleisch refers to, between a private school like Bishops in safe and affluent suburb of Rondebosch, and Oscar Mpetha Secondary School in Nyanga, which has one of the highest murder rate of any police precinct in South Africa and nearly 50% unemployment [44] might be reflected in the following way when learners from those respective schools arrive at UCT.

The means that those students have to mediate between themselves and the object, the mathematics that they have to learn, will be dramatically different. Mathematics is hierarchical, new ideas are developed from the ones that preceded them, and the better the preceding ideas are understood, the easier it is learn the new ones. The most important means for mediation between a student and new mathematics is the old mathematics they already know. In general, students from Bishops will have had more exposure to these foundational ideas, and they may find it easier to assimilate the new ones. Those students probably also have better access to educational technology like a personal laptop and a reliable internet connection at home, and may well be accustomed to using online resources like Khan Academy to help mediate their learning, a resource which is effectively denied to students from economically poorer backgrounds.

The division of labour for learning mathematics at school these two types of students experienced is also different. Students from Bishops would have been taught in a small class where their teacher could give them individual attention. Their parents may have employed a private tutor that helped when they were struggling. Their family's economic circumstances would be leveraged to make learning as easy as possible. Students from Oscar Mpetha will not have had that luxury. Their learning would have been their own. They would have had to take a great deal more responsibility for their performance, and would not have been able to rely on a great deal of outside help.

Similarly, the communities that they join once they arrive at UCT will depend on their backgrounds. Cultural alienation at universities [25, 28], not just in the South African context, can lead to student failure. It is my experience that the classes I teach at UCT are slowly becoming more diverse, and that students in my classes are mixing in more diverse groups, but the majority of the small groups I see working together in tutorials are still small groups of superficially similar people.

The issue of multilingualism and multiculturalism also feeds into the types of communities that student join once they are at UCT. It, and their school backgrounds, also affects how students interact with their tutors and lecturers, how they understand the rules of the activity system, and which resources, i.e. which means, they can comfortably access. There are links between these background issues and all the nodes of the activity system. I don't want to pre-empt the analysis that will come later, so I am going to finish with the final remark that the CHAT framework with its focus on the cultural-historical is well suited to this research and the issues that we want to surface.

In the following chapter I discuss the methodology and research design of this study. This discussion should be understood in terms of the theoretical background to CHAT that I have

provided in this chapter. The CHAT framework is the analytical scaffold that I will use to understand my interpretations of the student and lecturer conceptions of learning mathematics.

Chapter 2

Methodology and research design

There is no single right way to do research, but some research questions are more amenable to particular approaches. In this section I argue that my question will be best answered by qualitative, rather than quantitative, research. This distinction is not as stark as it sounds. As Niglas [32] points out the "paradigm wars" of the 1970's and 1980's have been succeeded by an era of research which mixes approaches, and even purely qualitative research may draw on some tools more commonly associated with quantitative research [10]. Denzin regards qualitative researchers as "bricoleurs", quiltmakers, that work "between and within competing and overlapping perspectives and paradigms" [10, p 6].

Within the field of qualitative research there are a number of different paradigms that I could adopt, each with their own strengths, and as Denzin points out the lines between these different paradigms are not always clear. I will use the CHAT framework. On the one hand it is understood by Luis Radford, Wolff-Michael Roth et. al. as an extension of critical theory. They stress the importance of praxis [36, 39] and the of historical and political factors – "Cultural-historical activity theory, which emphasises that the locus of all (mathematical) sense is historical and political praxis" [39, p. 88]. On the other, Postholm argues [34] that the similarities between CHAT and Dewey's social constructivism mean that "CHAT is thus regarded as a continuation of Dewey's theoretical stance" [34, p. 42]. Meaning, sense-making, is constructed rather than embodied in praxis.

Both of these approaches, these alternative positionings of CHAT within particular research paradigms, have their own strengths. I intend to adopt elements from both the critical and constructivist paradigms. There are two levels to my research. On the first level I speak to lecturers and students about their experience teaching and learning mathematics at UCT. They are simply reporting these experiences, and the interviews are a co-construction of meaning that I will later analyse and interpret. On the second level those interpretations are lifted out of the raw data and understood in terms of the CHAT framework. Here I adopt a more critical lens and consider some of the historical, social and political factors at play.

In this chapter I also discuss the particular research instruments that I use. I provide a description of my research context, and use it to concretise the general structure provided by Engeström. Finally I speak in some detail about the particular research instruments that I've used and discuss their validity.

2.1 Why qualitative research?

I am a lecturer in the Department of Mathematics and Applied Mathematics. I have a background in the natural sciences and my education, both undergraduate and postgraduate, was rooted in a positivist epistemological framework and heavily favoured quantitative research. Why then, is the current work a piece of qualitative research and not one of quantitative

research? Quantitative research imposes a number of demands. These demands are often tacit, left unstated and taken for granted, but they are real nonetheless. Quantitative research supposes the existence of a quantifiable, measurable object. If my study is of individuals' "conceptions of learning" it's not clear how those could be quantified. I could ask my research subjects to respond to a serious of Likert-type questions, and there is value in their responses (as I argue below), but it's not clear that there is a good way to map those responses onto the objective reality assumed by quantitative research. It's also unclear that there are underlying, generalisable laws that govern the formation of an individual's conception of learning, or that prescribe their behaviour given a particular conception of learning. Quantitative research is, for the purposes of answering this research question, deficient.

Qualitative research is a "situated activity that locates the observer in the world" and qualitative researchers "turn the world into a series of representations" [10, p1]. As a situated activity qualitative research is context sensitive. This sensitivity, as well as the notion of research as representations of reality rather than capturing an objective truth about reality, make the process subjective. This subjectivity is not just acceptable, but desirable. My research question is about individuals' experiences, their own, very subjective, conceptions of learning, as understood and presented through their point of view.

Qualitative research is egalitarian with respect to research practice. It does not privilege or exclude particular practices. Nor does it limit itself to using a single method at a time. Multiple complementary methods can be used when gathering data to answer a single research question. There must be some care given to the reconciliation of different data as new representations of the world are produced, but these representations are enriched when this is done properly. In this study I conduct interviews and gather additional quantitative-like data from Likert-type questionnaires. Unlike a piece of quantitative research I do not give primacy to this data, nor am I interested in simply measuring some causal relationship, nor do I assume that there is an objective reality that is being quantified by these responses. The underlying processes and subjective experiences are important, and remain the focus of my study. The quantitative data collection is nonetheless important, and I explain why in section 2.1.2 below.

Within qualitative research there are a number of paradigms, epistemological, ontological and methodological frameworks, that I could adopt. These frameworks are linked strongly to the researcher's motivation for their work, values, beliefs about the foundations of knowledge, validity and so on. Broadly speaking these paradigms are positivism (and postpositivism), constructivist-interpretive and critical.

2.1.1 Why the critical and constructivist-interpretive paradigms?

Although mathematics lends itself to positivist ontological and epistemological worldviews, it is not the mathematics itself that is my research subject. I am interested in the teaching and learning of mathematics. This is an unavoidably human activity with all the repercussions that entails. The activity is not neatly divisible, there are no underlying natural laws that govern it, and it is not deterministic. What is observable are teachers and learners jointly constructing mathematical knowledge, and so a positivist approach to this research would be inappropriate.

Postholm has pointed out a number of similarities with Dewey's work that root CHAT in the constructivist-interpretivist paradigm [34]. I add that the dialectical foundations of CHAT root also suggest a constructivist-interpretive paradigm. The aggregation of observations to produce a *gestalt* judgement, especially when the distinctions between different conceptions of learning are not clear, is linked back to the second law of dialectics and to the need for interpretation rather than rigid taxonomy. Similarly, the process of resolving the underlying contradictions within the teacher|learner pair, and of completing the chain of thesis, antithesis and synthesis, requires that I first understand individuals' conceptions and then jointly con-

struct a new understanding of learning. The cultural-historical psychological roots also locate my study within the same approach. Mediation, which will be central to my analysis, must be understood as a social interaction that constructs meaning.

The constructivist-interpretivist paradigm is not the only lens that I use. The CHAT framework requires that I consider the cultural and historical factors of a particular context. These factors arise from particular political decisions and structures, and are manifestations of power that have accumulated over many years. Although I am not directly addressing these issues they will inform the conclusions I draw from my data. It would not be inappropriate to adopt a more critical approach than what I undertake here. The protests on campus over the last few years reinforce that the academy and academic power should be interrogated, however I choose not to explicitly center power in my research. The production of emancipatory scholarship should be done, and is being done elsewhere, but is not being done here for two reasons. First, I acknowledge my own limitations – I have neither the academic or lived personal experience to do the issue justice. Second, I believe that there is academic capacity to work on multiple different issues. The current situation, however acute, does not demand that all other work stops. We can all still produce work that is inherently valuable and worthwhile even though it may not be addressing the most urgent problems.

2.1.2 Why a questionnaire and interviews?

The question that interests me is difficult to investigate because it cannot be directly observed. I am interested in the ways teachers and learners think about learning, and their conception of learning is an inherently internal process. Naturally their conceptions of learning will inform the way they act, the way they teach and study, and these behaviours can be observed, by this observation is only an indirect account of their thoughts. The simplest approach is to ask the teachers and learners what they think learning is, and in this way strip as many layers as possible from around the object of my study. Instead of observing behaviour in the real world and interpreting this to create an image of their thoughts, I ask directly about the thoughts themself.

One might worry that what they say they think, and what they actually think are different. It may be that their responses to my questions are not faithful representations of their true thoughts, either because they aren't sure what their true thoughts are, or because they are deliberately mischaracterising their thoughts. If they haven't explicitly thought about learning before it's likely that their thoughts on learning are not easily accessible. I can work to surface their thoughts through dialogue, through a dialectic process of questioning, clarifying, explaining and so on. This type of first-hand, collaborative inquiry is preferable to the *post hoc* imposition of meaning onto actions by a researcher who does not, and can not, understand the internal cognitive context of the actor. As for deliberate mischaracterisation of thoughts, perhaps to represent an idealised version of themselves, or to fulfill the perceived expectations of the researcher, these are considerations that can be, and are, taken into account when designing the research instruments. I discuss the technical details a little later.

The interviews were not the only research instruments that I used. A small number of subjects were interviewed face-to-face, and a larger number simply completed a questionnaire online. I must try to capture the diversity of backgrounds at UCT, so the online questionnaire cannot be discarded as it allows me to sample broadly. Alone it is insufficient to capture the full experience of learning at UCT. The face-to-face interviews, and the rich detail that is evident in even a short conversation, is vital in producing faithful representations rather than simply caricatures of student and lecturer thinking. These two methods are complementary, I enjoy the depth afforded by interviews, and the breadth offered by the questionnaire.

The data produced by these two different methods is compatible. All of the interviewees

also completed the questionnaire, and the discussion in the face-to-face interviews was led by their responses to those questionnaires. Many of the face-to-face questions were simply requests to elaborate on responses they had already made. I can use these longer explanations as a lens through which I can better understand their responses, and to check my interpretations of the Likert-type data. Different viewpoints of the same object allow me to make holistic judgements that can incorporate seemingly incompatible initial interpretations (Figure 2.1).

The quantitative data collected by the questionnaire, in addition to providing a starting point for the qualitative data collection, i.e. the interview, is useful in other ways too. The first is simply as a check on the consistency of the research subjects' responses to questions. If their answers to the same question on the questionnaire and in the interview are different, it provides a cue for the interviewer to interrogate those responses more carefully than they would otherwise, and possibly to ask follow-up questions to resolve this inconsistency. The quantitative data is also useful in clarifying the ambiguity that arises in the course of a conversation. This clarification can happen retroactively if necessary, by referring to quantitative data as the qualitative data is transcribed and interpreted. For example, if an interviewed student says they worked "a lot" for mathematics, their understanding of what constitutes "a lot" may differ significantly from what a lecturer, or the interviewer understand to be "a lot", especially in a research study that is explicitly interested in how individuals' conceptions may differ. Having a concrete value like two hours of work each week in addition to the lectures resolves this ambiguity. It also allows me to draw conclusions that could not have been made from either set of data in isolation, in this case that a particular student thinks an additional two hours of work is "a lot".

The quantitative data collected from the students that were not interviewed is also useful. That data may allow me to identify loosely clustered sets of students and in turn decide if the interviewed students are representative or not. If there is a large overlap in the responses of the majority of the students, but the interviewed students answered the questionnaire differently, I should be cautious about treating their experience as representative. Obviously any single individual's experience will be highly idiosyncratic, but there will be some elements in their experience that are shared with other students.

In addition to the questionnaire and interviews I also considered observations of students during the week(s) leading up to the first class test. The problem with this sort of research is that it introduces an additional layer that would have to be interpreted before the data could be used. I am not interested in how students go about learning, or how lecturers go about teaching. I am interested in how students and lecturer's think about the learning and about their teaching. Observations of students working in the library, or in class, do not provide directly the information that I want. Inferences would have to be drawn, and those inferences may be right or wrong. The simplest way to check that my inferences, and hence my understanding of their behaviour and what it means about how they think about learning, are correct, would simply be to ask them.

This is worse than just asking them without making the observations. Most people do not consciously and constantly interrogate their actions. If I present them with plausible but incorrect interpretations of their behaviour they may simply accept them. If they are not primed by my interpretation of a particular event, or series of actions, they are forced to engage with the questions I ask and present an account of their understanding that is not influenced by me[1].

[1]Beyond, of course, the obvious fact that they are talking about learning and understanding mathematics when they would instead have been sitting outside in the sun or enjoying their afternoon in some other fashion.

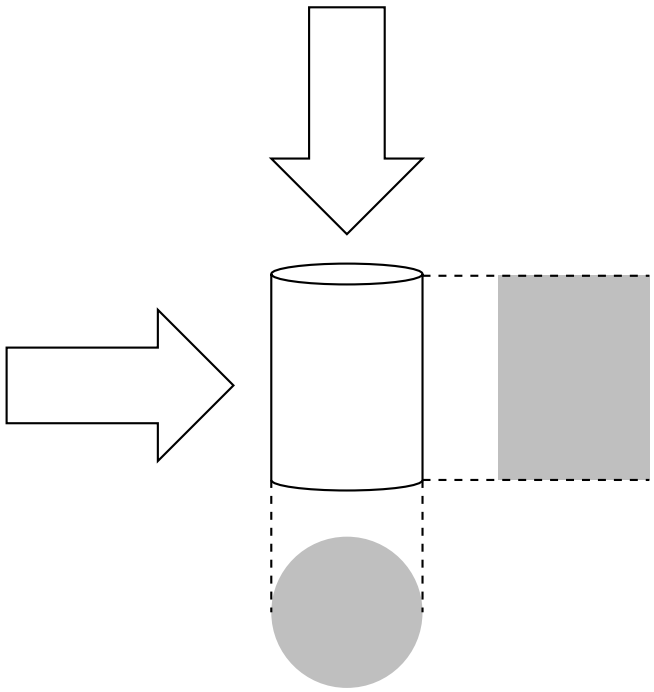

Figure 2.1: Different viewpoints lead to different interpretations.

2.2 Teaching and learning

I focus on two first-year courses in the Department, MAM1020F, the first-semester course for engineering students and MAM1004F, the first-semester course for science students who are not majoring in mathematics. There is a great deal of overlap between the material taught in the two courses (both are introductory calculus courses covering differential and integral calculus) as well as in the cognitive demands made of the students. In comparison to MAM1000W, the first-year course for mathematics majors, MAM1020F and MAM1004F are less rigorous and have a reduced emphasis on the importance of proof to mathematics. The formal teaching and learning activities in the two courses are identical: five weekly lectures of 45 minutes each and a weekly tutorial of 105 minutes. The short reason for considering two different courses is that I teach MAM1004F but not MAM1020F, and for some of the data collection (specifically face-to-face interviews) it would have been an inappropriate blurring of the teacher-researcher boundary. I discuss this in more detail in section 2.3 on data collection below.

For both courses there are some boundaries to the related activity system which are simultaneously natural and artificial. The boundaries I mean are the boundaries imposed by the university on its teaching activities. Temporally, the courses start in February and end in June. Pedagogically, the courses are delineated by the entries in the respective faculty handbooks. The people in the courses, the lecturers, tutors, students, are those who have registered for the course, or been assigned to the course. These are natural boundaries in that they are pre-existing boundaries that are not imposed by the researchers and that have a material impact on the activity. They are artificial in that each of these courses is part of a much larger system that could be more easily understood as meeting a generalised need of society. Educating new engineers and new scientists makes sense as *deyatel'nost'*, productive activity, a semester of calculus does not. Nonetheless, there are still interesting questions that can be asked within these boundaries.

2.2.1 The activity system

The generalised activity triangle has been contextualised in figure 2.2. The subjects of this system are the students as well as the lecturers and tutors. Together they comprise a teacher|learner category pair. The object of the activity is the mathematics that the students must learn. I make the natural association between the intended learning outcomes of the course and the outcome of the activity system. The generalised need of society served by this outcome is ultimately the need for qualified engineers and scientists, although there are intermediate steps that should be considered. One can conceptualise the outcomes of this activity system as the means of other systems, like the one modelling the second-year civil engineering course on structures, or a third-year Bioinformatics course. All these smaller interconnected activity systems constitute the larger Undergraduate Engineering Teaching and Undergraduate Science Teaching activity systems that directly meet these generalised needs.

The means of this activity system include the mediating tools needed for the teacher|learner pair to realise the intended learning outcomes as actual learning. These means include the textbook, the lecture and recordings of the lecture, videos on YouTube or Khan Academy, computer algebra systems like Wolfram|Alpha[2], but the most important of these tools is their previous mathematical knowledge. It is against this background that any new material must be understood. I note that only some of the subjects, the learners, need mediation to understand the object of the system. The object already lies within the teachers domain of competency, and so their responsibility is to facilitate the mediation that happens between the learners and the object.

As it is the role of the teachers to facilitate mediation, so it is the role of the learners to engage with the means made accessible by their teachers for mediation. The expectations and responsibilities of the teachers and learners are different, and this division of labour within the activity system is seldom explicitly described. Some of the rules of the activity system are also never made explicit. Although the curriculum may formally describe some of these rules, especially rules regarding assessment, there is much left tacit. Teachers, who have been part of an academic in-group for many years, acquire a particular set of dispositions and behaviours, and expect their interactions to be informed by a mutual understanding of an invisible etiquette. Learners, and especially learners from social backgrounds with no link to higher education, have no notion of academic discourse and must acquire it (or fake it) through slow enculturation.

Within the activity system, the subjects interact in different communities. In principle they are all part of one large community when they attend lectures, but in large classes this may be split into two or more sections, and not all students attend lectures anyway. They also interact during tutorials and lecturer consultation hours, as well as in tests or as peer groups studying together in residence or at the library. The composition of each community is different, and within each of these communities individuals may take on different roles. The same student who teaches their friends during a study session may ask their tutor questions in a tutorial and sit passively in a lecture.

2.2.2 Engeström's matrix

Engeström's 4 by 4 matrix reminds me to consider four questions: who learns, and why, what and how do they learn? Although I am chiefly interested in the fourth question (How do they learn?) the other three provide important context.

1. *Who is learning?*

   The subjects of my activity system are the lecturers, tutors and students that comprise a teacher|learner category pair. Although it is nominally the learners (i.e. the students)

[2]The vertical slash in Wolfram|Alpha is part of its name, not an indication that it forms a category pair.

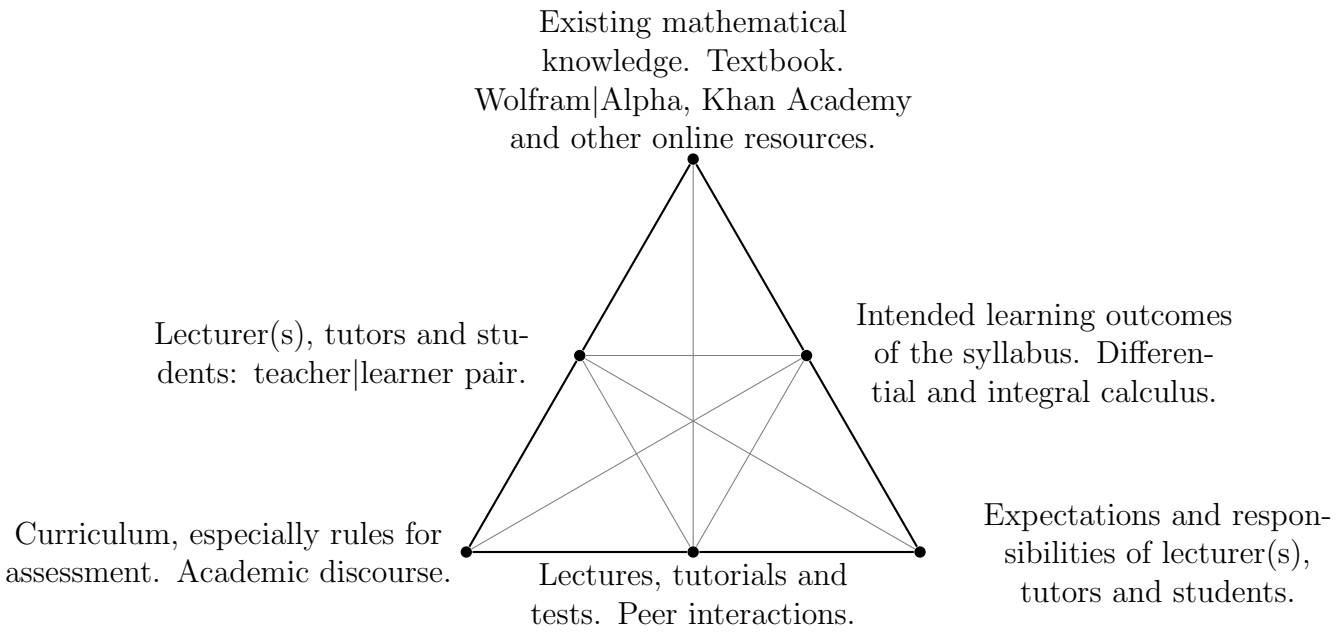

Figure 2.2: The activity system of MAM1020F/MAM1004F.

that learn I must be aware of the feedback between teachers and learners. Any interaction on the part of the lecturers and tutors with their students, any teaching that goes beyond a monotone recitation of a static text, is an opportunity for the teachers to learn. This learning is, at least formally, of secondary importance. The curriculum for a course lists intended learning outcomes for students, but not for the lecturer and tutors, although there may be some notions of academic development that informed their appointment to a particular course.

I cannot divorce the teacher|learner pair from the broader South African context. Although I may not be able to make causal claims about any particular individual, in the aggregate, the historical legacy of apartheid is still the single biggest influence on which individuals are in a position to constitute this pair. If I want to understand teaching and learning in first-year mathematics I must take into account the voices of all of its subjects. I must ensure that not only do I look at teachers and learners, but I also look within teachers and learners. I must work to surface opinions from a broad range of backgrounds.

Finally, I should acknowledge the demographic contradiction in the makeup of the teachers compared to the learners, and also the learners compared to the South African public. It is, in part, these contradictions that drove the cycle of expansive learning currently playing out across campuses.

2. *Why do they learn?*

The motivation for student learning is twofold. From the outside, there is a generalised societal need for engineers and scientists that one hopes this learning will eventually address. From the inside, I hope that the students are learning because they want to learn, because they want to build things, they want to be engineers; or because they want to understand their world, they want to be scientists. This internal motivation is undoubtedly multifaceted. Some learners may be motivated entirely by curiosity or by a desire to build things. Others may have far simpler motivations – they need a well-paying job and they were good at science at school so they signed up for engineering. Many may

be motivated by some combination of these two, or by something else entirely. There may be some tension when pragmatic concerns (instead of academic preference) forces students into a particular degree.

Although student (learner) learning is purposeful, learning by the lecturers and tutors (the teachers) is not. Apart from the first few courses at the start of an academic's career, it is incidental.

3. *What do they learn?*

   The material in MAM1020F and MAM1004F is aligned with the proposed outcomes of the course. It prepares prospective engineers and scientists for their future courses, and ultimately to practice as an engineer or scientist. The exact selection of material is a compromise between a number of different departments in the Engineering and Science Faculties whose students all have slightly different needs, and the Department of Mathematics and Applied Mathematics which is responsible for the teaching and has its own opinions about how the material should be taught, and what should be emphasised.

   There is also a large amount of 'pedagogic-inertia'. From year to year and lecturer to lecturer tutorials and lesson plans are inherited and slightly modified. Although the previous year's plan may not be exactly the way the current lecturer would set it up from scratch, it already exists and (in most cases) was 'successful', i.e. implemented without objections from either the students or the Engineering Faculty.

   These various forces mean that the exact syllabus of MAM1020F (and of the entire Engineering Mathematics sequence) is not entirely coherent. This was discussed in some detail in a previous assignment [58]. The same is true to a lesser extent in MAM1004F.

4. *How do they learn?*

   Most importantly for my proposed study, different individuals may have different conceptions of learning, and how to learn. All the issues discussed below should be understood through at least two different viewpoints, the students' and the lecturers'.

   Learning in first-year mathematics at UCT takes place in many ways, and in different communities. All of the department-led teaching and learning suffers from the same sort of pedagogic-inertia described above. Lectures and tutorials are run in a certain way because they have always been run that way.

   The primary site of learning is ostensibly the daily lecture. Students and lecturers engage with the material, but that engagement may differ from lecturer to lecturer. Some lecturers may adopt a transmission model of teaching and learning, others may regard themselves less as gatekeepers and more as facilitators. In different lectures the expectations and responsibilities of the teacher|learner pair may be very different, as are the tacit social norms that govern their interactions.

   Weekly tutorials are compulsory for all students. They work in small groups and the tutor's role is not to teach, but to facilitate peer-to-peer interactions. They do this by encouraging students to explain the work to each other, by confirming that students correctly understand the material, and by providing prompts in the form of questions when necessary. The learning that occurs here is very different from the learning that occurs in the lecture.

   Although all the class tests for MAM1020F are summative (i.e. the scores will be used for calculating the final mark) they may be variably weighted in the calculation depending on the student's exam performance. A good exam can count for up to 80% of the final mark, diminishing the role of the tests as summative assessment and for many students

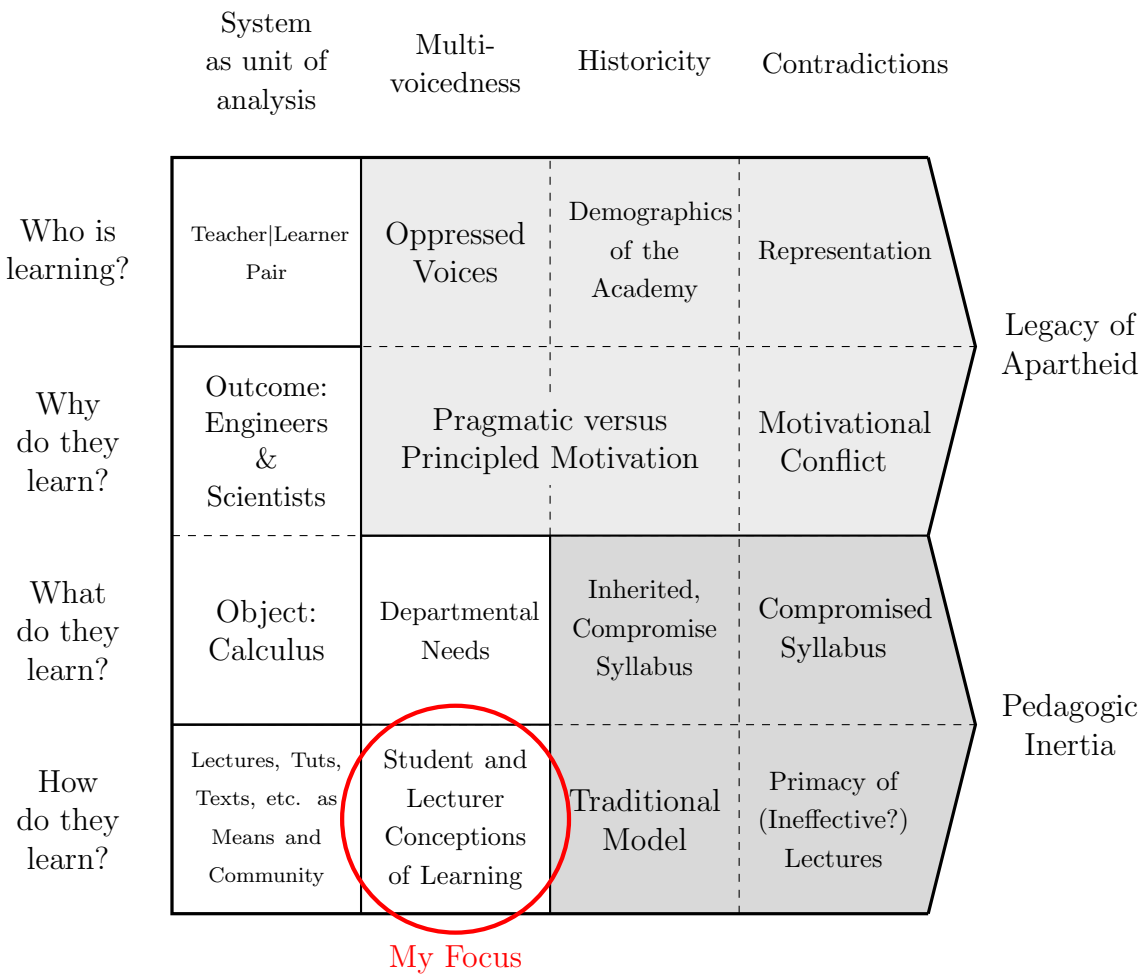

Figure 2.3: Matrix for the analysis of teaching and learning in MAM1020F and MAM1004F.

turning them into primarily formative assessments. Performance in the class tests may not help a student learn that material directly, but it is often an important part of the student's meta-learning, i.e learning about learning, and whether their current approach is working.

In this regard MAM1004F is materially different. There is no option for variable weighting of the tests scores in the calculation of the final exam, although the very first class test serves as a diagnostic test as well as a summative assessment. On the basis of scores for the first test, in mathematics and all their other subjects, some of the first-year science students will elect to extend their degree over an additional year.

Most learning in mathematics occurs outside of the university-arranged communities, away from lectures and tutorials, and in small (or singular) study groups. Here students engage with the material, and the mediation provided by the lecturer is indirect. It happens through the memory of the lecture, or by reading posted lecture notes, or by watching a recorded lecture. Alternatively, the lecturer plays no role and students use other tools they find effective, like the textbook, or Khan Academy, Wolfram|Alpha or each other.

Engeström's matrix, populated with the issues above, is reproduced in figure 2.3.

My research focuses on one piece of the entire picture suggested by Engeström's matrix. I am interested in the different conceptions of learning students and lecturers at UCT have, and

how those conceptions have been shaped by their backgrounds and by the learning context at UCT. Although these conceptions have been located at the intersection of the question "How do they learn?" and the principle "Multivoicedness", the lines in the real world are not as clear as the ones in the figure.

Naturally the different student and lecturer conceptions of learning are influenced by historical factors, and certainly I am interested in contradictions. This research is motivated by the possibility that student and lecturer conceptions are different, and that this difference, and consequent tension, is responsible for problems in the learning environment. Different questions, as well as different principles, play a role. I explain in the analysis below that in at least one case (Student Delta) what they learn has a large impact on how they learn it. I locate my research initially at one point in the matrix, but there are links across the entire range of possibilities suggested by Engeström.

The interconnectedness of the system also means that it is possible to build up a representation of the entire system by observations of just one element, the subject, i.e. the teacher|learner pair. This is especially true since the observations I make are fundamentally about students' and teachers' interactions with other elements of the activity system. In my interviews I do not expect abstract, decontextualised discussions but rather ones that are closely linked to concrete artifacts and practices. Other elements of the system for example the means, or the division of labour, are not explicitly centered as the subject of my research, but teaching and learning as an ongoing human activity will obviously be influenced by, and must be understood in terms of, the rest of the system. These discussion can be aggregated and interpreted to provide a broad representation.

2.3 Data collection – the details

Data collection from students was through an online questionnaire, and for a subset of those respondents, a face-to-face interview. Students were solicited to participate in the research study through Vula, the university's online learning environment built on the Sakai platform. The respondents selected for interviews were all in MAM1020F, not MAM1004F, since the interviewer lectures MAM1004F. The power dynamics make it inappropriate to interview one's own students. Lecturers have enormous power over their students. They are responsible for assessing their students and ultimately allowing them to proceed or forcing them to repeat a course. A face-to-face interview could unconsciously bias a lecturer either in favour of, or against their student and should thus be avoided. Even when a lecturer is not affected by the interview, the student may be. They may feel pressure to give the answers they believe the lecturer is expecting, or wants, and could feel by the end of the interview that the lecturer has developed a bias against them, whether or not this is the case.

The questionnaire is attached in the appendix of this document. The questionnaire includes only closed questions. Students interviewed face-to-face were asked additional open-ended questions based on their responses to the questionnaire. These open-ended questions are also included in the appendix.

The first thirteen questions are four-point Likert scale questions. Four points were chosen to force participants to make a choice in support of or against the presented statement. Respondents have a tendency to agree with presented statements when they are unsure of their feelings [38]. To combat this acquiesance bias the statements were worded so that the researchers agreed or strongly agreed with half of them and disagreed or strongly disagreed with half of them. When a respondent is unsure, their response is equally likely to be biased toward or away from the researcher's preconceived ideas on the subject.

What exactly, should I ask my subjects, and how should I ask them? The CHAT framework provides a strong set of guidelines for my questioning. I should ask my subjects how

they conceive of learning in relation to the other elements of the activity system. Of primary importance is the relationship internal to the teacher|learner category pair. I need to know how and what the students think of their lecturers and vice versa. Next are the various relationships between the subjects and other elements. What are the means that students use to mediate learning? What communities do they work in? Do they understand what is expected of them, do they understand the division of labour within the system? Why do they study, what is their relationship to the object of the system?

The first six questions deal with student motivation and general conceptions of learning, although there are links to other parts of the activity system as well. The two most important ideas that are being tested here are of responsibility and of the difference between studying and learning. Responsibility for learning is linked to the division of labour within the activity system; what are the subjects supposed to do? The difference between studying and learning is not linked to another element in the system, but it strongly influences how I interpret the other questions and is a starting point for the face-to-face discussions.

Questions seven to nine investigate the subject's relationship to the object of study and to the division of labour in the system. I've already tested this with the notion of responsibility above, but this investigates the linkage in more detail. These three questions are about how subjects, especially students, understand their place within the system, and whether that understanding is consonant with the assumptions of their lecturer.

Questions ten and eleven address previous conceptions of learning. This speaks both to the H in CHAT and to their relationship with the means of the system. A first-year student's mathematical history is their school history, so I should get some indication from them how they feel about school. This history has also (hopefully) equipped them with some knowledge of mathematics. This pre-existing knowledge is the most important of the means they have to understand the new mathematics, the object of the system. This knowledge, and their set of competencies, also controls their zone of proximal development, and consequently the mediation they undergo as they learn.

Questions twelve and thirteen test the student's relationship to assessment, the rules of the system. This is particularly important given the timing of the data collection in the weeks before the first test. I speak below about the importance of assessment in more detail.

The second set of questions measure student engagement with different learning resources or means in the activity system. The final closed question is for the student to predict their mark in the first assessment – effectively self-reflection on the effectiveness of their learning and their understanding of the entire activity system.

Prior to the start of the interview and the open-ended questions, the students were reminded that their responses would remain anonymous, that there are many different ways to study and to learn, and that consequently there were no right or wrong answers to any of the questions. This was done to encourage honest responses and minimise acquiesence bias. The first four open-ended questions are conditional on responses to the earlier closed questions and unpack some of the relationships between different parts of the activity system in more detail. The final open ended questions directly address student conceptions of learning. I hope that the previous questions will have stimulated the participant's thinking and thus encourage more detailed responses to the open-ended question than had they been asked it without preamble.

Data collection from lecturers on the course was exclusively through face-to-face interviews. The first part of these interviews was to ask the lecturers to complete the student questionnaires twice, firstly answering in the way they expected their students to answer, and then in the way they wished their students would answer. Once this was completed I proceeded to an open-ended discussion of teaching and learning in their courses.

For both student and lecturer interviews the work of Engeström is again useful. In addition to the matrix he has proposed, and that I considered earlier, he has also given some guidelines for

identifying "discursive manifestations of contradictions" [14] that can be used when analysing the interviews.

I ran my data collection in the first weeks of the semester, in the lead up to the first assessment. The primacy of assessment in contemporary education forces students and lecturers into a focused state of attention. The material valued by lecturers, their intended learning outcomes, are manifested in a physical text. The production of a test forces lecturers to give some thought to their teaching practice. Conversely, students who may otherwise be occupied with extracurricular pursuits are forced to engage with their academic work.

The first assessment is particularly useful because it allows me to understand students as they arrive at university. Over the course of an undergraduate degree student's understanding of learning will change as the academic environment of UCT acts on them. It is at the start of this process, when students straddle their old high school learning context and this new one, that the biggest changes will occur, and the greatest differences in student and lecturer conceptions of learning will be evident.

2.4 Validity

An assessment of the validity of a piece of research must always be an assessment of validity for a particular purpose and through a particular lens. A piece of research done through a critical lens may be a valid interrogation of power differentials across different racial groups, but might fail to reach positivist standards for replicability, objectivity and so on. It is appropriate to start my discussion of validity with a discussion of the purpose of this research.

The ultimate motivation for this research is to improve first-year mathematics teaching and learning at UCT. The proximate purpose is to understand a small part of the current teaching and learning that goes on in the course, namely the ways that students and lecturers in the course think about learning. I hope to produce a representation that is "sufficiently authentic" [27] so that any future decision made on the basis of conclusions here can be confidently justified.

The question of validity is really a question of authenticity, of how closely the model produced by my research describes some reality. It's not, however, a question of objectivity, because the objects of my research are the individual conceptions of learning that students and lecturers have. These are necessarily subjective, they are internal processes coloured by personal experience. This is not to say that there is no way of reconciling the notions of validity and replicability with subjective inquiry, but rather that I should focus on replicability and accuracy of interpretation. In this respect CHAT is a useful framework because it provides a systemic outline of the various factors that should be considered in my analysis, and has been previously systematically operationalised. There are guidelines for the interpretation and consideration of data that provide some guarantee of replicability of interpretation.

Replicability of research procedure and interpretation is the most I can hope for. Replicability of the produced data is impossible. People are not controlled experiments like swinging pendulums, or carefully heated chemical reactions. Even if I repeated the interviews with the same research subjects I should not expect to produce exactly the same data. It is possible, however, that similar themes may arise across a number of interviews. Where there are commonalities, and where these commonalities can be mapped onto specific elements of my activity system, I can have greater confidence in my interpretation.

When investigating such subjective issues, validity also requires that I consider fairness. There should be a balanced representation of views; I should sample broadly. This is also a feature of cultural-historical activity systems. They are explicitly multi-voiced and dialectical. It's impossible to make sense of a single voice in isolation, I must understand these voices as constituent parts of a category pair in constant internal tension. If I am constrained by time or resources, and cannot sample as broadly as I would like, this damages the validity of the

research. I will not be able to act as confidently on my analysis unless I qualify my actions. I cannot act to improve teaching and learning generally, but I may be able to improve it for a specific subgroup where I do understand it.

The limitations to this type of qualitative research are obvious. It is not easily scaled. Interviews take time to conduct, time to transcribe, and time to interpret. It's not feasible to interview everyone in the class, or even to interview a tenth of the class. As a result, the study remains idiographic, and not nomothetic. I can not generalise my findings, I can not claim any sort of statistical significance or objective truth.

The choice of short interviews and questionnaire rather than a long-term ethnography or continued observation of teaching and learning activities has some shortcomings. As much as I can encourage honest responses through careful instrument design there is still a possibility that the subjects misrepresent their thoughts, intentionally or otherwise. A particular behaviour consistently observed over a longer period of time is probably authentic, even if observation introduces new problems of interpretation. Whether or not the subjects' responses are honest, this once-off interview cannot capture changing conceptions. It is a static snapshot, rather than an ongoing investigation.

2.5 Some contestation within CHAT

The description that I provided of CHAT (in chapter 1), and the contextualisation of some of its principles to the present research problem (in the current chapter) have been presented so far as a relatively uncontroversial application of theory to investigate an interesting question. In truth, there is an ongoing debate about the development of CHAT. In this section I discuss some of the contestations within the school, primarily critiques of Engeström's work by some other practitioners in the field, for example Bakhurst [3, 4], Langemeyer and Roth [23], and Levant [26].

The objections to Engeström's work can be broadly classified into two groups. There are objections made to his work on philosophical or conceptual grounds, that he is using a psychological theory originally intended to understanding the nature of thought and of the mind to analyse "fairly mundane pursuits, such as organic pest management in Swedish apple production" [26, p. 106]. The second set of objections are pragmatic, and focus on some of the more specific details of Engeström's formulation of activity theory, like the activity triangle reproduced in Figure 1.2. The objections here are that the particular framework he has developed impede the dialectic thinking that should underpin CHAT and lend it its critical viewpoint on the world.

The philosophical objections are grounded in CHAT's roots in activity theory [3, 4, 26]. For Bakhurst and Levant the activity theory of Engeström is a radical departure from the roots of the theory as a psychological tool developed for understanding thought and the mind. To those writers, the notion of people as social beings, constituted in part through their interactions with others, is the central way of understanding them. It is only when people relate to each other, and their world, through some directed, engaged activity that meaning can be ascribed to their actions, and that they can ascribe meaning to their own lives. It seems strange that a theory with such lofty foundations should find purchase as a tool for analysing organic Swedish apple farming [53], and Bakhurst's critiques are cautionary: "It would be a shame if contemporary activity theory lost touch with that sentiment... their tradition's philosophical roots" [3, p. 92].

Langestrom and Roth's position is that Engeström's framework impedes dialectic thinking. They point out that the activity triangle conceptualisation first provided by Engeström suffers from the following problems: it gives the false impression that the activity system is synchronic, not diachronic; the interactions within individual components is rendered invisible; the listed components (subject, object, means, etc.) are not necessarily important in every system, and

that there may be other components that should be considered; the model itself presupposes a third-person view of the system, that the system is to be analysed and explained by an external researcher and not one of the participants within the system; the various subjects of a system are heterogenous and bundling them all under the single heading of "Subject" neglects this diversity.

These critiques are all valid, but I think they should again be understood as cautionary, as advice to other researchers in the field, rather than an outright rejection of Engeström's work. Indeed, the activity triangle appears in some of Roth's papers [39, p. 88] [43, p. 198] albeit with qualification that it should be treated as a useful heuristic rather than an ironclad set of rules. Some of the criticisms above are also mitigated against by Engeström's matrix which reminds us to consider the multi-voicedness of the system, its historicity, its internal contradictions and so on.

In aggregate we should take these critiques simply as a reminder that CHAT is a theoretical framework, and like any framework it should not, and can not, be used to answer a research question without first giving some thought to how it can be contextualised. It is precisely this sort of contextualisation that I have done in this chapter. Having done this I proceed to the analysis of my data.

Chapter 3

Analysis

In this chapter I analyse both the face-to-face interviews with four students and two lecturers, and the online questionnaire completed by 55 other students. The analysis is done on two levels, as I indicated in the previous chapter. The first step is to make sense of the data. The data, particularly the face-to-face interviews, needs to be interpreted since it is not an objective description but subjective reporting of individual experiences. The interview itself may also form part of the research subjects' understanding of learning, and learning mathematics, since they may not previously have thought about these issues explicitly. The interview is a collaborative construction of meaning.

Once the data have been interpreted through a constructivist lens, it will then be understood within the CHAT framework. The research subjects (probably) have no understanding of activity systems, mediation, the zone of proximal development and all the other theoretical tools that have been developed in the literature. This linkage between the initial interpretation and the CHAT framework occurs therefore on a second, higher level, and the work here is done more critically, with the aim of understanding how problems may arise from differing conceptions of learning, and ultimately how those problems could be fixed by changing the way academic structures operate, and academic power is exercised.

The analysis in this chapter should be understood as descriptive. It is not meant as an affirmation that a particular way of thinking about learning is right, or a condemnation of another way of thinking about learning as wrong. It is simply meant to surface possible differences between how lecturers and students think about what is happening in their courses with the eventual aim of closing the gap, if there is one, and ultimately improving the quality of teaching in learning in their courses. The analysis in this chapter considers both students and lecturers, but is weighted slightly toward the students since the student data are richer. I want to avoid ungrounded speculation about the lecturers' contexts and conceptions.

3.1 Interviews

The first analysis is of the four interviews with students and two with lecturers. The analysis follows a pattern of excerpts drawn from the interview, my interpretation of those excerpts through a constructivist lens, and the linking between that interpretation and the various elements of the CHAT framework.

I start with the four students who will be referred to as Student Alfa to student Delta. Students Alfa and Bravo are both white Afrikaans South Africans who attended public schools. As white South Africans they would likely have attended one of the relatively "high-achieving" public schools that previously served only white students rather than one of the "low-achieving" schools that previously served black students, or were only established post-apartheid to address the massive underservicing of those communities. Despite the relatively good education (and

university preparation) those types of schools provide it will become clear in the analysis that there are still problems with the absolute level of Student Alfa and Bravo's preparation.

Students Charlie and Delta are Africans from outside South Africa who attended private schools. These countries were previously British colonies, and the private schools in those countries consequently follow the guidelines laid out by the United Kingdom for their General Certificate of Education A-levels, as examined and assessed by a private body like Cambridge Assessment International Education. Schooling took place in English, but it is not their home language. Although I do not have the ideal diversity of backgrounds there are still interesting points of similarity and difference in their backgrounds and responses to the online questionnaire and interviews.

I start by identifying broadly a few points that were common to all four students. After this I focus on Students Alfa and Bravo, who exhibit a number of commonalities, and then proceed to Students Charlie and Delta.

There were two points where the responses from all four of the students agreed: what learning is, and how learning happens. The exact language naturally differed between students, but all four regard learning as the ability to generalise beyond their immediate contexts and solve problems in a broader domain[1], for example

> *"If I learn something I know how to apply it and how to use it in different subjects."* – Student Bravo

> *"I think I've learnt something... if I can use it to solve different types of problems and different like scenarios.* – Student Charlie

This is good. The objects of the tightly constrained and somewhat artificial MAM1020F activity system are the intended learning outcomes of that course. This activity system naturally interlocks with other equally artificial activity systems, first-year drawing, first-year physics and so on, and together these systems constitute the more natural activity systems of educating engineers, or engineering itself. A conception of learning as an ability to generalise beyond the immediate needs of the course, or the assessments of the course, indicates that all the students are capable of unpacking these layers and understand their position within the larger system.

The second point of agreement was on how learning happens. Their answers differed, but all shared a core element. They all learn mathematics by doing mathematics.

> *"Examples and time... because you need to practise."* – Student Bravo

> *"Hmm, with like a lot of corrections."* – Student Charlie

These two sets of observations are consonant with Roth and Hwang's papers on mathematical learning and whether development goes from concrete to abstract or vice versa [41, 42]. There is a "double ascension" here just as they theorised. Students' generalisation beyond their mathematics courses is a move toward the abstract, while the acknowledgement that this happens through practise, through practical action, is a simultaneous move toward the concrete.

The details of this double ascension, and the mediation between Subject (students), Means (books, videos, tutorials etc.) and Object (the mathematics) is different for each of the students, but all of them stress the primacy of doing mathematics. This is also good. I hope to understand learning as part of a larger ongoing activity and it's clear that the students conceive of their own learning in the same way – although they obviously don't have the language of CHAT to make this description explicit. The inherent catch-22 of learning by doing and knowing before doing is resolved by each student slightly differently, but in all cases the students are aware of this contradiction and resolve it through purposeful action.

[1] Although Student Delta gave this characterisation explicitly for non-mathematics subjects. See section 3.1.3 for a more detailed discussion.

3.1.1 Students Alfa and Bravo

The common theme for students Alfa and Bravo is that they realise that (public) school and university are different, that they have made a conscious effort to change the way they learn mathematics, and (subsequent to the interviews) that they were nonetheless relatively unsuccessful in the first class test. The rules (of assessment) and division of labour (a division of responsibility for learning) that they are used to at school have changed. Although they were aware of this, they were unable to adapt.

That these two students exhibit strong commonalities is an indication of the importance of their historical backgrounds. Alfa and Bravo belong to different engineering streams (Geomatics and Electrical Engineering), i.e. they belong to different communities within the activity system. The contemporaneous differences in experience – different courses, different lecturers and tutors within the courses that are common to the two streams, different peer groups inside those streams and so on – are not nearly as evident in their interviews as their similar understandings of learning, and the similar historical behaviour they describe that produced those understandings.

These two students strongly disagreed (Alfa) and disagreed (Bravo) with the statement "I study at university the same way I studied at school". When asked about the way they studied at school they both described a shallow approach to learning – minimal effort aimed at a purely instrumental understanding of the material that would suffice to pass tests and exams.

> *"Well at school I crammed basically everything."* – Student Alfa

> *"I got through school just by reading through my work and paying attention in lectures... at school they teach you this is the thinking method, how you need to think to get to a certain answer."* – Student Bravo

There is very little sense of Students Alfa and Bravo as active participants in their own learning at school. They accept what is presented by their teachers and, bar the assessment-driven "cramming", they spend no time outside of the classroom learning mathematics. The division of labour at school does not make consistent demands of their time outside of the classroom. Nonetheless, I know that they, as engineering students at UCT, would have performed excellently in formal assessments at school and must have finished with an A for mathematics.

The most important relationship in any activity system is between the subjects and object of the system. Although Students Alfa and Bravo were nominally "successful" students with excellent marks, there are serious substantive problems with their education. The root of these problems is the superficial subject|object relationship that is accepted at school. The assessments at school, the rules of that activity system, have been established in a manner that cannot distinguish between surface and deep learning, or at least cannot be used as a predictor of future mathematical success [45, 59].

At university things are different. They are active participants and although they have only been at UCT for a few weeks they are already developing a sense for the course. They are building relationships with their lecturers, they understand, to some degree, what is expected of them, i.e. what the division of labour is inside this activity system. They are looking for additional means to mediate between themselves and the course material and all of this is being done deliberately and consciously.

> *"I made a conscious decision because I know this isn't a school. I need to actually put in a lot of effort to get results.* – Student Alfa

This extra effort is evident in both students' responses to the questionnaire. They attend lectures and tutorials as expected, but they also spend extra time completing those tutorials,

reviewing material that they didn't understand, preparing for upcoming lectures and solving extra problems. Some of this is done strategically, with an appreciation of the rules of the system.

> *"All my stuff that counts for marks are finished prior [to when it's due]. All my stuff for this week is already finished... I keep ahead of schedule."* – Student Bravo

This sort of strategic work is necessary at university; the engineers have many courses all making demands on their time. I want to focus on the notion of keeping ahead of schedule. Keeping to a schedule, or ahead of a schedule, implies the possibility of falling behind schedule. This phrasing indicates that Student Bravo really is an active participant. There is a division between work that belongs to the lecturer and work that belongs to the students and they are working to meet that expectation. Student Alfa is working as well.

> *"They expect me to take the work they give us and further elaborate on that... and not to just use the work that's given in class."* – Student Alfa

This is a far cry from the description of school that the students gave earlier. It's clear that Students Alfa and Bravo know they need to work and they are working. What remains is the question of how they are working, indeed, how they are learning. All the students in MAM1020F are, at minimum, equipped with the following means: their own school background, the online textbook, access to tutors each week, and daily lectures. Students Alfa and Bravo both also use YouTube.

> *"They go into all the detail. They start from the basics and escalate more ... I just have better access to YouTube. So I live in a res off-campus, so I can't, if I have a problem that I just discovered now I can't really [speak to my lecturer]."* – Student Alfa

> *"When I have a problem I address it. I sit on Youtube..."* – Student Bravo

Both students speak of problems. They are trying to learn some mathematics, perhaps they are working through an exercise or reviewing their notes, and reach the boundary of their competencies. There is an idealised form of the imagined outcome in the minds of these students. They wish to complete the exercise or understand a concept discussed in the lecture. They are taking actions but cannot make progress without some form of mediation. They are stuck in the learn by doing, know to do catch-22 and they break it by looking for video explanations on YouTube.

YouTube is not just important as a means of mediation between the subject and object of this activity system. It also provides an alternative community for these students. This community exhibits some similarities with the more traditional learning communities of university. Most obviously the primary interactions in this community are one-sided. Students watch the videos but they cannot ask the content creator questions. This is substantively no different to the majority of students in regular classrooms that have the opportunity to ask questions but never do. Unlike a regular classroom there are secondary, asynchronous interactions that occur among all the students/viewers who can leave comments on the video, or respond to those comments with answers or further questions of their own.

As with regular lectures there is a possibility with videos on YouTube that the students are simply passive participants; they might watch the videos without necessarily absorbing the information. I think that this is unlikely. Students in lectures may be attending out habit. Student watching videos on YouTube has deliberately sought out that specific video to watch

at a specific time because they are trying to address a specific problem that they have identified. The very act of finding the video marks them as active participants in the learning process.

These online learning communities are independent of the formal structures that have been put in place by the lecturers. The articulation between these two communities is therefore the responsibility of the students. They need to assess the relative importance of each to their own learning, the amount of work and time that they should invest in the respective communities, the relevance of these communities to the object of the formal activity system (and, if they are thinking strategically, to the rules of assessment in the formal system). It is worth remarking that none of this, in my experience, is ever made explicit to the students. At most they may be told that they can find additional resources online but there is no guidance on how best to use those, or other resources.

As mentioned earlier all the students believe that learning happens when they do mathematics, and these videos are sought out while they are doing mathematics. The problems that they speak of here are problems they encounter in doing mathematics, in working through examples, in "further elaborating" what was discussed in class. This mediation within the zone of proximal development is described by Student Alfa when he speaks about the scaffolding of more complex examples on top of simpler ones.

> *"Do examples because they start off from a basic principle that everyone has and then they slowly but surely start incorporating new things."* – Student Alfa

The students expand their action possibilities through action itself. They consciously seek out additional means to resolve the learning catch-22. In both cases their independent learning is mediated by directed Youtube videos. Neither of these two students spoke about belonging to any study group for mathematics. Their physical communities in this system are restricted to the university imposed lecture and tutorial groups.

Student Bravo also shows some understanding that he needs to adjust to the new rules within this activity system, particularly the rules of assessment. (As we will see, this is something they share with Student Charlie). When asked about his study process for the upcoming test he indicated that he had reviewed their notes, and gone through the examples in the tutorials and textbook and was now ready to look at the tests from previous years.

> *"The upcoming weekend I want to work through the test ... in the test you can see what they expect of you and what you must know"* – Student Bravo

Student Bravo was clear that the test should not be looked at before he had a chance to learn the material himself, that he was not simply learning (or trying to learn) by reproducing solutions to previous assessments. This is a mature approach, and stands in contrast to the sort of repetitive drill that many high schools impose open their grade twelve students.

I summarise their current situation as follows. Two students have performed well at school despite their shallow approach to learning. They arrive at university and realise that their old approach will not work, and seem to have a good grasp of what is now expected of them, and how they learn mathematics. One may well feel quite sanguine about their prospects of success.

Unfortunately, both students were relatively unsuccessful in the first test. When prompted to predict their mark in the upcoming test they both said they expected to score a first (75% or higher). They didn't score firsts. They both scored thirds (in the band of 50% to 60%). Student Alfa eventually failed the course, and Student Bravo improved slightly but still finished with a third-class pass.

It is not clear why they were unsuccessful, or why they so badly misjudged their performance on the first test. It is interesting that Students Charlie and Delta, who went to private schools, were not as confident about their prospects, but in Student Charlie's case performed excellently nonetheless. I discuss their interviews below.

3.1.2 Student Charlie

Student Charlie attended a private school in a previously British-colonised country. This obviously has many cultural-historical consequences, but perhaps the most relevant to my current work is that the language of instruction would have been English, rather than her home language, and that she did the Cambridge IGCSE and then EdExcel A-levels. These are recognised as equivalent to the GCE and GCE Advanced qualifications offered in the United Kingdom, and "the educational level attained is likely to be higher than that of the NSC" [16] (NSC stands for the National Senior Certificate, the South African school-leaving qualification). She strongly agreed with both the statements "I study at university the same way I studied at school" and "The mathematics I learnt at school was good preparation for university".

At the time of the interview Student Charlie hadn't seen any new material. She regarded the first three weeks of lectures as revision of what was covered in A-levels. The single biggest component of the means that students have to mediate between themselves (as subjects) and the mathematics (as object) in MAM1020F is their pre-existing knowledge, and in this respect Student Charlie is far better equipped than Students Alfa and Bravo.

Her A-level schooling has not only provided them with an excellent mathematical background, but has also inculcated in them good learning habits, personal responsibility, and strategic thinking:

> *"In A-levels you kind of had to decide this is important, this isn't really important."*

This same strategic thinking, and an appreciation for the rules that govern MAM1020F, was evident in her preparation for the first class test. In the context of the increased workload at UCT she said that she wasn't able to study as thoroughly as she liked.

> *"You are picking your battles – like okay I'm strong on this part so I won't do the exercises on this, but I will do the exercise on this part that's quite weak."*

This strategic thinking goes further than just preparing for the test. Like all the students, she said that she learns by doing. More specifically she emphasised that it was by trying to doing things that she cannot currently do, and in correcting her subsequent errors, that she made the most progress. She realised that depth is more important than breadth, and wanted to adapt her learning strategy.

> *"That's kind of what I want to try [to] change. I don't need to do as many examples [as] before."*

We should contrast Student Charlie's experiences with those of Student Alfa and Bravo, particularly their experiences at high school. As before, it is the relationship between the subject and object of the system that is of primary importance, and it is clear that Student Charlie is making a conscious and reflective effort to engage with the material that is being taught. This is a clear difference from the shallow approach that Alfa and Bravo described at high school, and particularly from the passivity that was evident in those descriptions.

After arriving at UCT, Students Alfa and Bravo both explicitly espoused personal responsibility. They said that UCT was different from school, and that they had to change their approach away from the shallow one they adopted at school. For Student Charlie, responsibility for her own learning has been internalised to the point that it is no longer remarkable. Student Charlie has not explicitly taken responsibility for her learning but her considered responses about how she can best spend her time clearly indicate that she understands the rules and division of labour within this system. She look for extra problems in areas where she is weak and pores over the questions from the tutorial that she got wrong. She understands what

work will be done by the lecturers and tutors, and what work she has to do herself, and it is this understanding that allows her to take an active role and engage meaningfully as part of the subject|object pair.

Like Students Alfa and Bravo, Student Charlie also seeks out additional means for mediation when she has difficulty understanding. In her case she draws on her old A-level textbooks and `www.physicsandmathstutor.com`, a website for A-level study; the same resources she drew on previously.

Student Charlie was less confident than Students Alfa and Bravo about the first class test.

> *"I just hope to pass. I don't even know what passing is!"*
>
> *"Fifty percent."* – Interviewer
>
> *"No, I aim for something more: sixty-five and above."*

When she were asked why she were aiming so low (relative to her performance in her A-level exams) she responded that she was nervous about her new environment, and was afraid that she hadn't been able to prepare as thoroughly as she would have liked given the workload for all her courses. Student Charlie was the best-performing of the four interviewees. She scored above 95% for the first test and finished the course with an upper-second-class pass.

3.1.3 Student Delta

Like Student Charlie, Student Delta attended a private high school in a former British colony where he did Cambridge A-levels. Despite their similar backgrounds there are big differences in their conceptions of learning and responsibility. These differences become apparent when Student Delta exhibits a clear distinction in the way he thinks about learning mathematics and learning anything else.

> *"For me I treat maths differently from other subjects."*

His approach to learning mathematics can be best described as rote learning. Mathematics is learnt by brute force – repetition of examples and memorisation of rules and procedures.

Throughout the interview he emphasises a disconnect between the rules of the system (as they govern assessment) and the object of the system (the intended understanding of some mathematics). At a number of points he makes the distinction between understanding mathematics and passing a mathematics course.

> *"Maths is just practice... to get that passing grade, to get that A, we memorise those rules."*
>
> *"It doesn't matter if you understand [what] that concept is about. If you are able to just do it then you score a grade."*

This has a lot in common with the shallow approach to learning that Students Alfa and Bravo used at school, but breaks completely from their approach, and Charlie's approach, to learning at university. To try to understand this I want to highlight three places in the questionnaire where Student Delta gave answers that differed from the other interviewees.

Student Delta strongly agreed with the statement "My lecturer is responsible for how much I learn". The others strongly disagreed (Bravo), or disagreed (Alfa, Charlie).

Student Delta agreed with the statement "There is no difference between studying mathematics and learning mathematics". All the others disagreed.

Student Delta agreed with the statement "I don't understand what I need to learn in each lecture and tutorial". All the others disagreed.

In addition to these answers there is one final piece of salient information – his personal history. Student Delta's parents didn't go to university, in fact he is the first person on his father's side of the family to do so. He also had a poor record in mathematics until his final exams and doesn't believe he would have been accepted to UCT with his predicted grades. Finally, English is not his home language and at one point in the interview he complains about the terminology of mathematics and his difficulty in following the lecturer.

This information, taken in aggregate, paints the following picture of Student Delta. He is disconnected from the material he is supposed to learn. It's not only that he don't understand what he is supposed to be learning, or why he should learn it, but he also has to deal with linguistic alienation. Mathematics does not appear useful or interesting. If anything, it is an obstacle to be overcome as it was overcome in his exams at school. It can be overcome only through study, and that study takes the form of memorisation; rote learning and repetition of rules.

It comes as no surprise that Student Delta spends less additional[2] time (three hours each week) on mathematics than any of the other interviewees. His conception of learning mathematics as boring work and the relatively diminished personal responsibility he feels for his own learning would naturally reduce the time he allocates to mathematics.

Student Delta belongs to a strong two person learning community. His roommate in residence is also doing engineering and came from the same school in the same home country. On the one hand, the feelings of alienation that many foreign students feel upon arrival at a university must be somewhat alleviated by a familiar face, but on the other it does mean that Student Delta, who works with his roommate using the same study process, may stick with their study patterns from high school.

His approach to mathematics should be contrasted to his approach to learning any other subject.

> *"I read my textbooks, I try to understand the concept or I try to understand what it's trying to mean. Like for a certain reaction why does it occur like that? So it's more of an inquiry, figuring out how it works."*

Understanding mathematics is regarded as unnecessary, but understanding seems to be the central aim of learning in other subjects. He has a natural curiosity that drives his learning. Unfortunately Student Delta can't offer a neat explanation for the difference. He suggests that the language barrier is larger in mathematics, and that his mathematics textbooks are not as coherently put together as his physics and chemistry books, but neither of these would explain the enormous gulf in his approach to learning different subjects.

Despite his approach to learning mathematics, Student Delta had the best sense of how he would perform. He expected to fall in the band from 60% to 70% for the first class test, and he did (it was at the lower end of the band). His marks slipped slightly through the semester and he finished with a third-class pass, a few percent short of 60%.

Student Bravo, who failed the course, opted not to repeat it. The other three students all proceeded to MAM1021S. The performance of Students Alfa and Charlie was comparable to their performance in MAM1020F, but Student Delta made a dramatic improvement and finished with an upper-second-class pass. It would be interesting to know if he adapted his approach to learning mathematics.

I move now from the students to the two lecturers that I interviewed. Their thoughts about teaching and learning, and about their students were similar despite their different backgrounds. Lecturer Echo is a more experienced, foreign lecturer and Lecturer Foxtrot is a younger, local

[2]In addition to lectures and tutorials.

lecturer just starting his career. These interviews are important because I must understand the teacher|learner pair. I cannot look at the learners in isolation. As I analyse their interviews and compare to the students' a number of tensions within the teacher|learner pair become evident.

3.1.4 Lecturers Echo and Foxtrot

Lecturer Echo is one of the senior faculty members in the department. He is not South African, but was appointed to his position at UCT a few years before the start of the study. He has a strong research record and supervises a number of postgraduate students. Despite the demands on his time, he still does undergraduate teaching in the department. Lecturer Foxtrot is younger, and local. At the time of the study he was completing his PhD and had just started lecturing. His undergraduate degree was at UCT, so he is well acquainted with the department and its activities. As discussed in the introduction both lecturers will draw on their own experiences as students when they think about teaching and learning, but Lecturer Foxtrot, because he is younger, closer to his own undergraduate, and has less experience as an academic, will draw more heavily on his experience as a student.

Both lecturers have low expectations of their students, borne of their pessimistic view of the South African schooling system (which, as previously discussed, faces great challenges). They don't think their students were adequately prepared by high school, they don't think their students are responsible or have learnt how to manage their time, and they both worry that their students consequently adopt a shallow approach to learning. They both also try to spend some time in lectures speaking about metacognitive skills, about how the students should be learning, but feel like they don't have enough time to do it properly given the constraints imposed by the curriculum.

> *"They are still thinking as high school students... and they think that the minimum effort is enough in order to pass. Not many of them are eager to learn in depth... This is a responsibility that they are not prepared [for]."* – Lecturer Echo
>
> *"So they are doing the bare minimum just to get by, because they don't manage their time."* – Lecturer Foxtrot

The lecturers use similar language ("minimum effort" and "bare minimum") to describe expected student learning behaviour. Three of the four interviewed students are putting in significant amounts of work reviewing lectures, completing tutorials and solving additional exercise problems. This additional work does not in all cases result in good performance in the assessments, but it does point to a first possible disconnect between the way lecturers think about student learning and what is actually happening. A first tension in the teacher|learner pair.

There is a second disconnect (and resulting tension) that may exist. Although Students Alfa and Bravo were explicit in their move away from their high-school style learning to a new approach, that approach was never clearly articulated, and as a result it may have been abandoned in favour of their old habits. Even if some students do adopt deeper approaches to learning this is evidently not visible to the lecturers and so there is a second underlying tension in the teacher|learner pair arising from a misalignment in expectations about responsibility (i.e. in the system's division of labour).

These tensions should also be analysed in light of the student responses to the statement "I am responsible for how much I learn". All four students strongly agreed, but neither of the lecturers feel like students are prepared for this responsibility. It is not necessarily the case that students are shirking responsibility, but simply that the failing school system has not equipped them for the challenges of university.

> *"I think that there is a huge problem in high school."* – Lecturer Echo
>
> *"Inadequate, completely inadequate."* – Lecturer Foxtrot on high school

The lecturers do not regard high school as adequate preparation for university; not in terms of the mathematics they learn, or in terms of the approach to learning it has reproduced in them. Lecturer Foxtrot bemoans the emphasis on "rote learning" which was evident in Students' Alfa, Bravo and Delta's description of high school. Again, this should not be read as a reflection on the particular students that attend UCT, but rather on the system that produces them.

The students, bar Delta, all agree that their approach to learning mathematics at university has to change, but it is interesting to juxtapose this against the students own thoughts about the material covered at high school. All four agreed (Alfa and Beta) or strongly agreed (Charlie and Delta) with the statement "The mathematics I learnt at school was good preparation for university".

A third tension in the teacher|learner pair is evident; a disagreement about the existing knowledge (means) of the student. This goes to the heart of the problem since this is the most important part of the mediation process between the learners (subjects) and the intended learning outcomes of the course (the object).

A good teacher would try to address these tensions, and that is exactly what Lecturers Echo and Foxtrot do. They both make time in their class for discussion of metacognitive skills, time-management, context and so on. They also both say they are under significant time pressure and can't spend as much time as they would like discussing these sorts of issues.

> *"I would always emphasise to them please do examples, but [when] you do examples focus on these concepts rather than just [on] getting the method right"* – Lecturer Foxtrot

Here Lecturer Foxtrot provides guidance about how students should be learning; what students should be getting out of the time they spend solving problems. This instruction to students to reflect on their work encourages mediation. If a student uncritically solves problems they are exhibiting direct stimulus-response behaviour: see problem, solve problem. It's only when students think about how their action possibility space can be expanded that learning happens. It may be hard work to complete the hundred questions at the end of a chapter, but if a student struggles with the first twenty then gets the next twenty right, they are probably wasting their time on the last sixty. When students realise what they understand and what they don't, and when they work at the correct level, i.e. within the zone of proximal development, learning happens, and Lecturer Foxtrot is aware of this.

> *"What does it mean to learn? I think struggling is a big part of it. You need to know how to fail first... you need to try to be relatively sure of where you are going, how you are failing, and what your level of understanding is."* – Lecturer Foxtrot
>
> *"Reflect on the work, critically... then I would say you have learnt."* – Lecturer Foxtrot

This is a fairly sophisticated position and requires a lot from the students. A student can take responsibility for their own learning, spend additional time working through problems, and still fail (in Lecturer Foxtrot's view) to learn because they are misspending their time. Here, I think, lies the biggest tension within the teacher|learner pair. Even well-intentioned, hard-working students, who in their own minds are doing everything right, may in the opinion of their lecturers be doing everything wrong. This tension is, of course, aggravated by those students who are neither well-intentioned nor hard-working.

In this respect Lecturer Echo relayed an anecdote about a student who had come to him and said that he had studied really hard for the two days before the test. The following year he told his class about this interaction, intending it to be a cautionary tale about leaving things too late, but was horrified when most of the class nodded along as if this was a reasonable approach to learning mathematics. In this case it is less of a tension in the teacher|learner pair and more of a chasm.

Lecturer Foxtrot realises that he expects a lot of his students, but isn't able to resolve this contradiction. In Engeström's terminology [14] he is trapped in a dilemma caused by the time pressure of the course. The two incompatible courses of actions open to Lecturer Foxtrot are evident after the following question.

> *"They've made mistakes and you say that learning is about reflecting on the mistakes, so do you help them? Do you have time in class to go through the test with them? Or is that something that they do by themselves?"* – Interviewer
>
> *I would really, that is something that I would like to do. But because I have run a bit behind I won't be able to do that. I guess I could do it in my tutorial.* – Lecturer Foxtrot

Here we see both the dilemma and a possible resolution. This is an opportunity that could lead to changes in teaching practice; the problem could be resolved by using some time in the tutorial. There is however another hedge, "I guess", since Lecturer Foxtrot foresees other problems that could arise if he tried this.

From these interviews there are four evident points of tension in the teacher|learner pair, all interlinked. I cannot generalise to the entire class. This is a very small sample and my analysis is highly subjective, possibly even idiosyncratic. Nonetheless the following points may inform future attempts to align student and lecturer conceptions.

1. Students (learners) regard the mathematics they learnt in high school as good preparation for university. Lecturers (teachers) regard it as completely inadequate.

2. Students claim that they are responsible for their learning. Lecturers agree, in principle, but don't believe that high school has sufficiently prepared them for this responsibility.

3. Students do additional work for mathematics, even in the face of multiple courses making demands on their time. Lecturers perceive students as putting in minimal effort.

4. Students believe that the time they spend studying mathematics is effective. Lecturers believe that effective studying requires reflection, and it is difficult to do.

These tensions have an underlying cause – a failing school system. There is good reason that it's become *de rigeuer* to criticise South African schools; there is much to criticise. Having said that, I cannot hope to discuss either the causes or possible solution to these failings in this work. My ambit does not extend beyond first-year. I simply explain what I see at university.

However these tensions arise, they have consequences. Lecturers adopt a deficit model when thinking about their students. They perceive the majority of students as unmotivated, or lazy, although there may be significant work being done that is outside their reach and hence invisible to them. Their perception is justified by the poor performance of the class in the first test, which in turn reinforces their pre-existing notions of students as unprepared, ultimately reinforcing their view and lowering their expectations for the next year's class.

On the other hand, students that perform badly in the first test despite their additional work (which is certainly visible to them!) may be upset by what they regard as the unreasonably

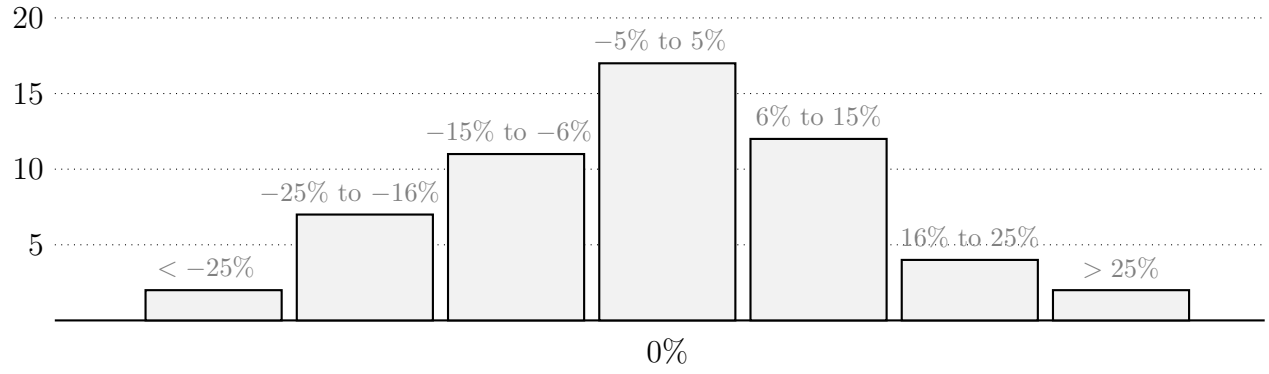

Figure 3.1: A histogram of the difference between the score a student predicted they would score and the score they actually attained. Positive values correspond to underprediction (students performed better than they predicted) and negative scores to overprediction (students performed worse than predicted). The mean predicted difference was −0.3%, with a standard deviation of 14.6%, a maximum difference of 33% and a minimum difference of -27%.

high expectations of their lecturers. This is a demotivating experience. Although some students can adapt, others fail, alienated from what appears to be an irrational system. In extreme cases it may trigger what Bateson [6] called Learning III: "a person or a group begins to radically question the sense and meaning of the context and to construct a wider alternative context"[12, p.138]. It is precisely this process of radical questioning that is evident in the ongoing protest action across South African campuses.

This is and will be a difficult issue to address, but it is also an important issue. The gap needs to be closed. Students at UCT are drawn from the very top of the South African school system. Our lecturers should be celebrating the opportunity to work with them, rather than bemoaning the deficiencies they perceive in them. Of course, not all of their complaints are unfounded. Most South Africans schools are bad; the system is "grossly inefficient, severely underperforming and egregiously unfair" [51, p. 3]. One can hardly expect university lecturers to be pleased with this state of affairs. The tensions between students and lecturers are not the fault of either party, and neither has the power to address the root causes of the issue. My current work can not solve the root causes either, but I hope that I will at least be able to change the way students and lecturers think about each other and the academy.

I turn my attention now to the data collected from the online questionnaires and my analysis thereof.

3.2 Questionnaires

In addition to the face-to-face interviews additional data was collected from 55 other students through an online questionnaire. The questions were the same questions that students Alfa, Bravo, Charlie and Delta answered before their interviews.

I am interested in different student and lecturer conceptions of learning. Although they are highly imperfect, universities use assessment scores as a proxy for learning. The last question on the questionnaire asked students to predict their performance in the first assessment, i.e. to make a judgement about their learning. The lecturers also made a judgement about those students' learning when they marked the first test. By comparing the predicted and actual marks of the students I identify those students where there is a mismatch. In figure 3.1 I have plotted a histogram illustrating this data. The first observation is that the mean predicted difference was only −0.3%. The students, in aggregate, did only very slightly worse in the test

than they predicted they would. There was, however, enormous variation in the predictions of any particular student. The most pessimistic student, the largest underpredictor, scored 33% higher than they predicted. The most optimistic student, the largest overpredictor, scored 27% less than they predicted. The standard deviation of the predictions was 14.5%. Since I am interested in different conceptions of learning my next step was to look more closely at the outliers, those students whose predictions were more than one standard deviation from the mean. Note that under this classification Students Alfa and Bravo would be overpredictors and Student Charlie would be an underpredictor. Student Delta scored close to what they predicted.

I want to know if there is some difference evident in these over- and underpredictors' response to the questions. Of the thirteen questions, there were significant differences in the distribution of under- and overpredictors responses in three of the Likert-style questions. Those questions were to indicate level of agreement (strongly disagree, disagree, agree, strongly agree) to the following statements.

1. My lecturer is responsible for how much I learn.

4. My time spent learning mathematics is effective.

8. I understand why the material we are learning is important.

The responses to question 1 are illustrated in Figure 3.2. An equal number of overpredictors agreed and disagreed with the statement that "My lecturer is responsible for how much I learn" but the majority (75%) of underpredictors disagreed with it. There was little difference in the responses to the related question 2 "I am responsible for how much I learn" since almost all (54 of the 55) students agreed or strongly agreed with the statement. Despite this overwhelming endorsement of personal responsibility, it may be that students who also believe the lecturer is responsible did not take their obligations as seriously as they claimed. This interpretation should be considered in light of the over- and underpredictors' responses to questions 4 and 8.

The responses to question 4 are illustrated in Figure 3.3. The vast majority (91%) of overpredictors agreed with the statement that "My time spent learning mathematics is effective" with the remaining overpredictors strongly agreeing. Conversely, the underpredictors were less certain about how effectively they were spending their time. There was an even split between agree and disagree. This result is not unexpected. The overpredictors overpredicted precisely because they were feeling confident in the time they had spent learning mathematics. What is surprising is that some of the underpredictors agreed that they had been spending their time effectively – if this was the case why were they so pessimistic about their prospects? Student Charlie is an underpredictor who thought they had been spending their time effectively, but was still nervous about the new environment and worried that they hadn't been able to spend as much time as they usually would given the workload for all their other courses.

Finally, I illustrate in Figure 3.4 the responses to question 8 which had the question statement "I understand why the material we are learning is important". The difference here is less dramatic than for the previous two questions I've discussed but it is still clear that a majority of overpredictors either agreed or strongly agreed with it, while a majority of underpredictors either disagreed or strongly disagreed with it. The responses from students Alfa, Bravo and Charlie were all consistent with this behaviour: the overpredictors Alfa and Bravo (strongly) agreed and underpredicting Charlie disagreed. I think these results can be interpreted the same way I interpreted the results to Question 4. The overpredictors were confident that they understood what and why they needed to learn, but had misjudged their ability.

At this point it is worth remarking on the actual performances of the under- and overpredictors. The entire population averaged 63% for the first test with a standard deviation of 11.9%. The overpredictors averaged 51% while the underpredictors averaged 76%. It's not

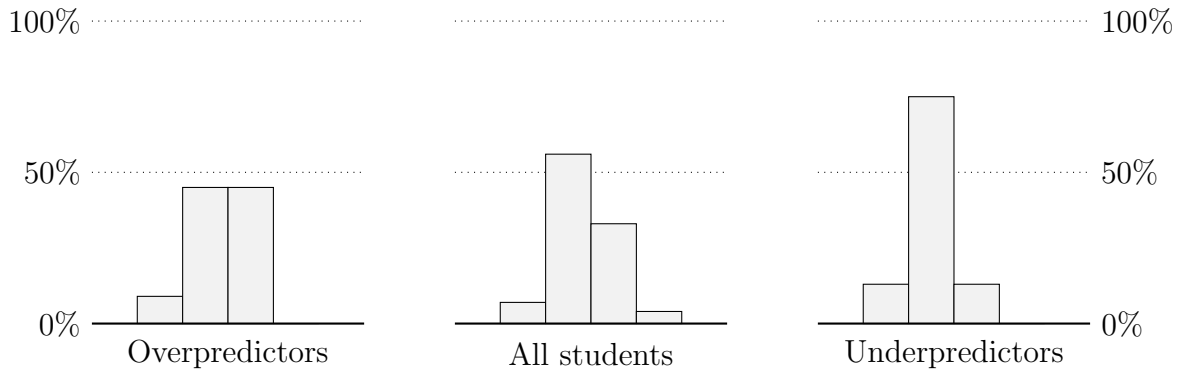

Figure 3.2: Different responses to Question 1 (My lecturer is responsible for how much I learn.) from the overpredicting students, the entire population, and the underpredicting students. The four columns in each subfigure correspond to the percentage of the group that answered strongly disagree (on the left), disagree, agree, strongly agree (on the right).

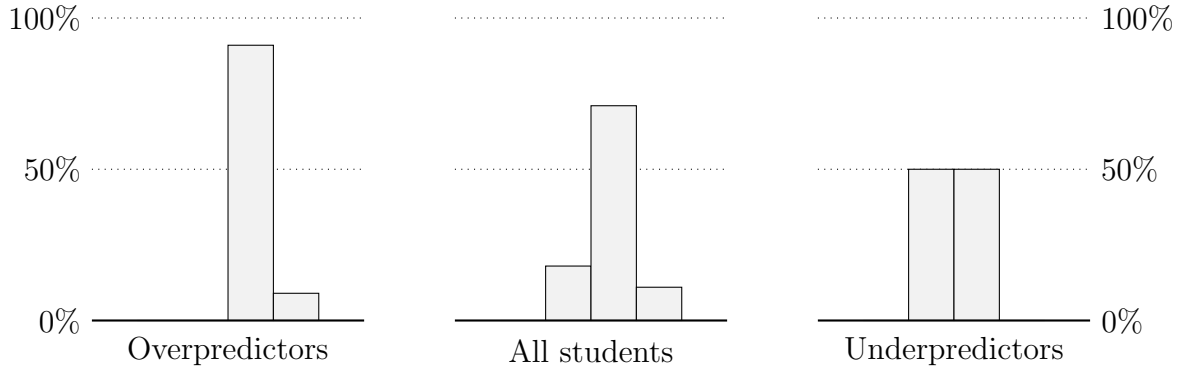

Figure 3.3: Different responses to Question 4 (My time spent learning mathematics is effective.) from the overpredicting students, the entire population, and the underpredicting students.

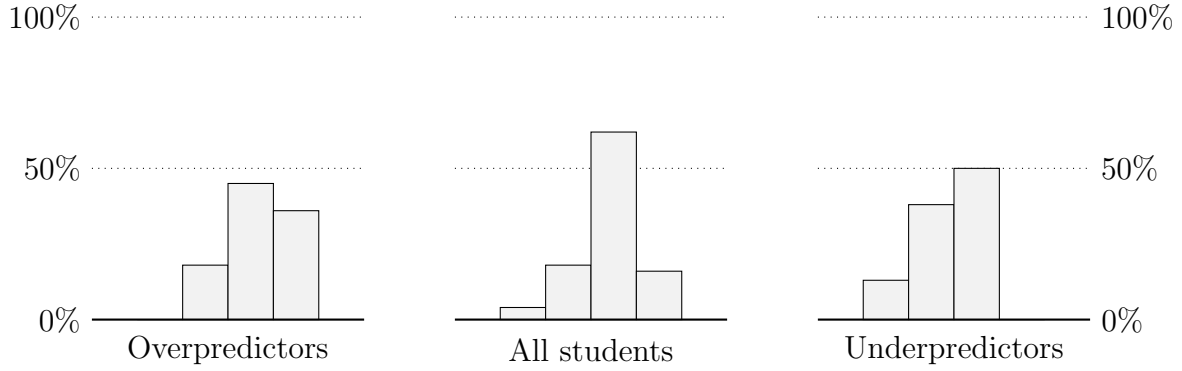

Figure 3.4: Different responses to Question 8 (I understand why the material we are learning is important.) from the overpredicting students, the entire population, and the underpredicting students.

the case that these two groups performed similarly but had different predictions – their actual performance was significantly different. The results described above are therefore consistent with the Dunning-Kruger effect where "participants scoring in the bottom quartile on tests of humor, grammar, and logic grossly overestimated their test performance and ability" [22]. Astute readers might point out that I have come at this backwards by starting with predictions and moving to performance. The results are the same in the other direction. The bottom performers (ten students who scored below a standard deviation from the mean) overpredicted their marks by an average of 14%, and none of them performed better than they had expected. Conversely the top performers (fifteen students who scored above a standard deviation from the mean) underpredicted their marks by 13.2% and all but one performed better than they had expected.

The responses of the top and bottom performers are included in the next set of Figures 3.5 to 3.7. Their similarity to the responses of the over- and underpredictors is not surprising given the large overlap between the groups. There are 11 overpredictors, 10 bottom performers, and 5 students are common to both groups. There are 8 underpredictors, 15 top performers, and 7 common to both groups. Many of the students belonging to one group but not the other were close to the cutoff for the corresponding group.

In addition to the Likert-type questions, the students also asked to indicate how much time they spent each week on various activities: attending lectures, working on the tutorial, completing additional exercises and so on. The mean response was 15 hours a week on mathematics, but this was highly variable. Some students only attended the lectures and tutorial, roughly 6 hours of work each week, while others did (or claimed to do) significantly more; in some cases upwards of 30 hours a week. Some of the higher reported figures are difficult to believe, or are clearly not representative of the workload across all courses. If a student is working for 30 hours a week on each of their four subjects that accounts for 120 of the 168 hours of the week. This leaves almost no time for eating, sleeping and other basic needs. The mean response of 15 hours extrapolated over four subjects means that students would have to work roughly 60 hours a week during term. A heavy workload, but believable.

Putting aside the trustworthiness of the data set for the moment, there are a number of interesting conclusions that can be drawn. Firstly, there was no correlation between the time spent working on mathematics and either the students' actual scores, or their predicted scores[3]. The process of learning is highly idiosyncratic and nonlinear. Doubling the amount of time spent working on mathematics does not double the amount of mathematics learnt. What is important in this process is likely the sort of critical reflection that Lecturer Foxtrot described in their interview.

The second interesting observation is how the mean amount of time students spend studying relates to a second set of numbers. Lecturers Echo and Foxtrot were asked how much time an ideal student should spend working on mathematics each week, and also how much they thought their actual students worked each week. I summarise the results in the table below.

	Ideal Student	Actual Student
Echo	16 hours	$8\frac{1}{2}$ hours
Foxtrot	26 hours	15 hours

In this table two different ways in which lecturers' expectations of students are not being met are evident. Lecturer Echo appreciates that mathematics is not their students' only subject and has a fairly realistic expectation of the amount of work a student can do. Their estimate of 16 hours is reasonably close to the mean amount of work students claim to do, but they simply

[3]The correlation coefficients are $R = 0.04$ (actual scores) and $R = 0.003$ (predicted scores).

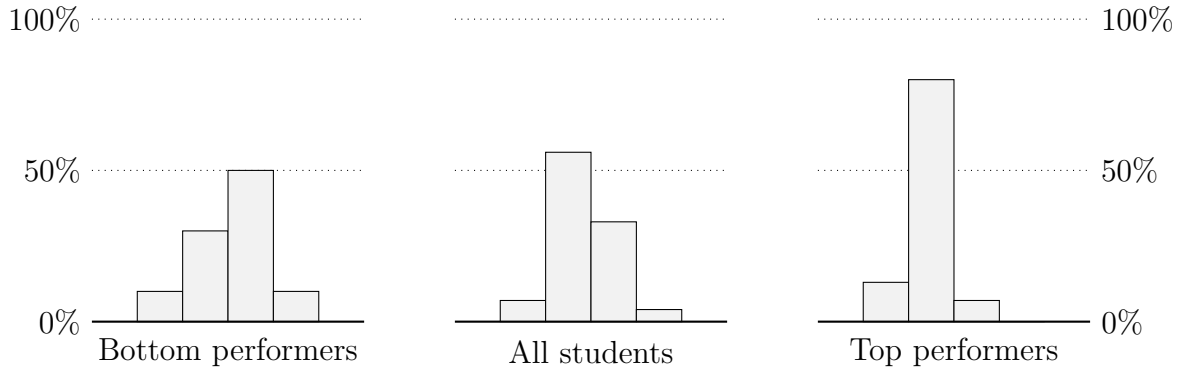

Figure 3.5: Different responses to Question 1 (My lecturer is responsible for how much I learn.) from the bottom performing students, the entire population, and the top performing students.

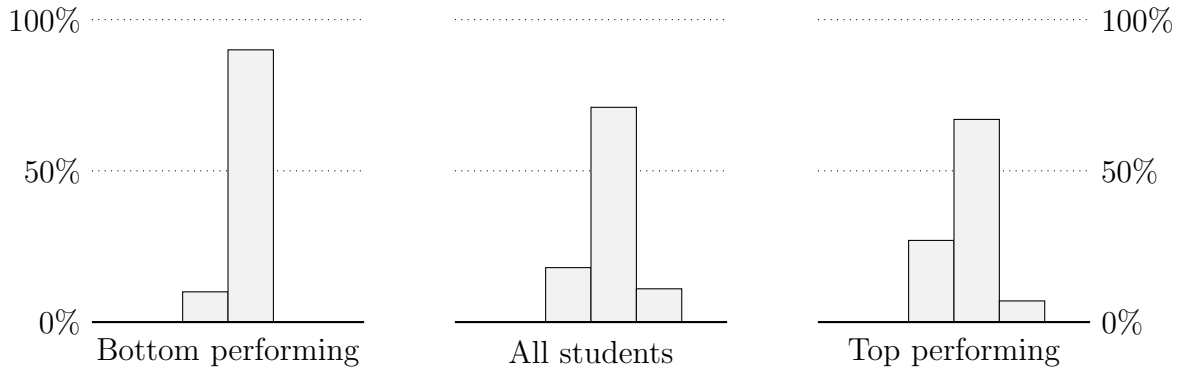

Figure 3.6: Different responses to Question 4 (My time spent learning mathematics is effective.) from the bottom performing students, the entire population, and the top performing students.

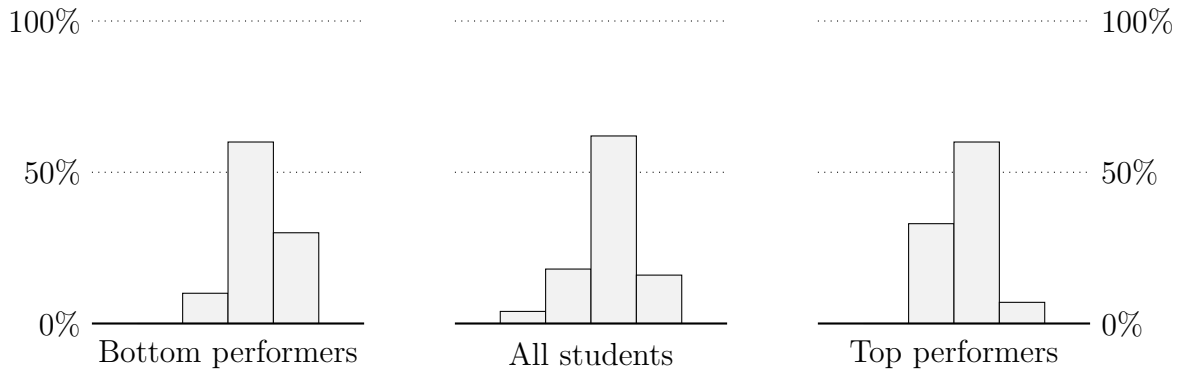

Figure 3.7: Different responses to Question 8 (I understand why the material we are learning is important.) from the bottom performing students, the entire population, and the to performing students.

don't think their students are doing that work. On the other hand, Lecturer Foxtrot thinks their students are doing about as much work as they actually are, but their expectations are simply not realistic. This is additional evidence for one of the four points of tension identified in the preceding section.

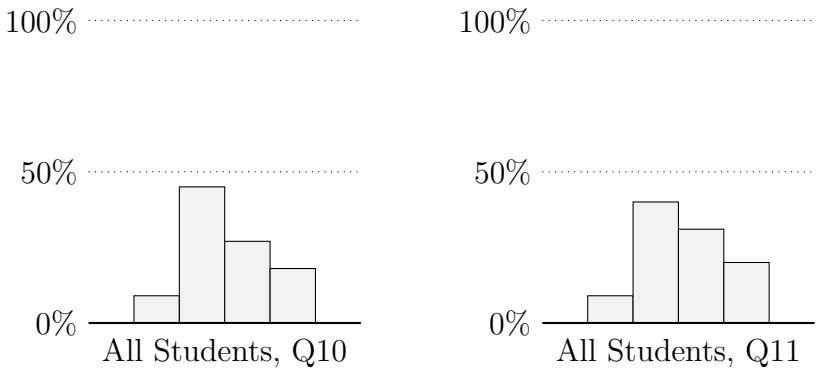

Figure 3.8: Different responses to Question 10 (I study at university the same way I studied at school.) and Question 11 (The mathematics I learnt at school was good preparation for university.) from the entire population.

The other three points of tension were on the adequacy of high school as preparation for university, the effectiveness of students' time spent studying, and the degree of responsibility students have for their learning. The relevant quantitative data for two of these points have already been introduced in Figures 3.2 and 3.3. I present two final sets of relevant data in Figure 3.8, the responses to the statements "I study at university the same way I studied at school" and "The mathematics I learnt at school was good preparation for university". In Chapter 4 below I elaborate on what can be learnt by reconciling the quantitative data with the issues raised in the qualitative part of the study.

Chapter 4

Conclusions

In this chapter I will do two things. First, I am going to reconcile the qualitative and quantitative data that I have collected. In Chapter 3 I started with a preliminary analysis of the data, but that analysis was mostly siloed – the qualitative and quantitative data did not speak to each other. Now I will highlight some of the links between them, and by using these links make clear what is important, and what conclusions we can draw that have multiple supporting types of evidence. Once I've done this I proceed to a discussion of some interesting questions that have been left unanswered, or raised, by the present work.

The research question that underpins this work is the following: how does the learning context of first-year mathematics at the University of Cape Town (UCT) shape conceptions of teaching and learning among lecturers and students? More specifically, I suspected at the start of this project that there might be different conceptions of teaching and learning among the faculty and student body. Indeed, when I analysed the interviews with the lecturers and students I identified four key points of tension: efficacy (whether or not students are learning effectively), responsibility (whether or not students are taking responsibility for their learning), preparation (whether or not school adequately prepared students for university) and effort (whether students were putting in an appropriate amount of work).

When I proceeded to the quantitative analysis I did not start by looking for the data that would be directly relevant to addressing the points of tension I'd identified in the interviews. Instead I allowed the same research question to guide my analysis, and that question made the quantitative data regarding efficacy, responsibility and direction salient. By direction I mean whether or not students understand what they are supposed to be doing in a given lecture or tutorial – in the language of CHAT, whether or not they understand their relation as subjects of the activity system to the object of the system. Note that some of the same issues that were raised as points of tensions in the interviews recurred in the salient quantitative data. Only after that was done did I present the quantitative data that are relevant to the other points of tension unearthed by the qualitative analysis.

These five issues can be broadly grouped into two major themes: what students do (responsibility, direction) and how they do it (efficacy, preparation, effort).

4.1 What students do

Within the teacher|learner pair at UCT we have students, who in an ideal world are learning, and their lecturers, who are teaching[1]. The responsibility for student learning lies nearly exclusively with the student. The lecturer has some obligation to make an appropriate selection of material, to present it in a coherent manner, provide opportunities for the students to ask

[1]The lecturers may themselves be learning, but what they are learning is how to teach. This is part of a meta-activity system that lies on top of the one I am investigating, in which the object is first-year calculus.

questions, and to clarify any misunderstandings, but learning happens by doing, and it is the students that need to do.

On the issue of responsibility, which is fundamentally about the division of labour within the activity system, both lecturers and students are near unanimous that students are responsible for their learning. This was evident not only in the interviews, but also in the quantitative data. Possible problems around the issue of responsibility seem to manifest in three related ways.

1. Students may espouse personal responsibility without embodying and enacting it.

2. Lecturers believe that school has not adequately prepared students for the responsibilities of university.

3. Some students (particularly bottom performers and overpredictors) believe that it is also their lecturers that are responsible for their learning.

Points 1 and 2 above taken together suggest that students may be willing but unable to take responsibility for their own learning, and critically, are not aware of their inability. The high school activity system and the university activity system are simply so different (in terms of the division of labour and rules of the system) that they are incapable of doing the work that Lecturer Foxtrot described. Deliberate, self-driven reflection on one's mistakes is difficult and public school students like Alfa and Bravo have simply never been given the opportunity to practise.

Points 2 and 3 above explain why some lecturers regard students as unmotivated. Lecturers believe students are inadequately prepared to learn on their own, and the worst performing students believe that the lecturers are jointly responsible for whether or not they learn. These students will make bigger demands on their lecturer's time than students who believe they are solely responsible. The majority of lecturer interactions are therefore going to be with poorly performing students which reinforces their belief that students are underprepared and hence incapable.

Points 3 and 1 are also related. If a student believes that their lecturer is responsible for their learning, it is easier for them to avoid responsibility for their own learning. They may not develop the skills required by university when they first arrive because they trust that their lecturers will ensure they succeed, in the same way that their teachers at high school ensured they succeeded.

These issues point to problems in the activity system in the way that the subjects (students) interact with the division of labour (expectations and responsibilities), the rules (especially academic discourse) and the means (their experience at high school). These *misinteractions* within the activity system can be explained by the cultural-historical backgrounds of the students. They simply haven't been exposed to the appropriate sets of academic behaviours, or had the opportunity to internalise the tacit rules for behaviour. I want to draw attention to the similarity here between the current problems and Bourdieu's notions of cultural capital [8] and habitus [21]. The theoretical backgrounds and terminology differs, but the same problems are evident.

The previous discussion was about what students do in a general sense, the types of behaviour that they should ideally exhibit and the behaviour they actually do exhibit. The quantitative data also suggests that the specifics of what they do is important. Here the salient data were the responses to the statement "I don't understand what I need to learn in each lecture and tutorial" (Question 7) and to "I understand why the material we are learning is important" (Question 8, results displayed previously in Figures 3.4 and 3.7. These two statements probe the relationship between the subject and object of the activity system, between the students and the mathematics that they are supposed to be learning.

The responses to these statements can be summarised thus. Sixty percent (60%) of bottom performers agreed or strongly agreed with the statement of Question 7 and 90% agreed or strongly agreed with the statement of Question 8. By comparison less than half (47%) of the top performers agreed or strongly agreed with the statement of Question 7 and only two-thirds (67%) agreed or strongly agreed with the statement of Question 8. It seems as though the bottom performers weren't sure what they were supposed to be doing, but definitely thought it was important. The top performers had a better idea of what was going on, but weren't sure that it mattered.

This is not a good situation. Ideally the courses that students take at university should be both internally coherent, and presented as part of a larger coherent degree. The internal structure and logic of a course is unfortunately not always obvious to students. Sometimes it is only in the assessments that the intended learning outcomes are visible. Although a lecturer may have a good idea of what they hope to achieve in a course, it is not always possible to make that tacit knowledge explicit [1]. Nonetheless the students in our study may have benefited from greater motivation at the start of the course for why particular material is important, and greater clarity of what needs to be achieved in each lecture, or week of lectures, or over the semester. The motivation for teaching something may become retrospectively obvious when a student in second-year draws on what they have previously learnt, but that doesn't help them while they are learning it.

4.2 How they do it

In the section above I looked at what students should do first in a general sense (take responsibility for their learning), and then in a more specific sense (whether or not they know what to do in a given lecture or tutorial). I keep narrowing my focus and discuss in this section the detail of how students work. I am interested in how much time they spend working on mathematics, whether the time they spend is effective, and whether their schooling has prepared them for the work that they need to do at university.

At the root of these issues are the individual students' histories, specifically their educational history. The mathematics they learn at high school is their primary means of mediation with the mathematics that they have to learn at university. Students who didn't learn mathematics at high school will simply not cope at university, which is why a certain level of performance in high school mathematics is a prerequisite for admission to an engineering or science degree at UCT.

The lecturer's feelings about high schools were very clear in their interviews. They regard high school education as "completely inadequate" (Foxtrot) and "a huge problem" (Echo). This opinion covers many aspects of that education. They think the actual material covered is insufficient, that it encourages a shallow approach to learning, and that students at high school can pass with only a small amount of work. To some extent, the students that I interviewed agreed. Alfa and Bravo, the two students who went to public schools in South Africa both said that they had changed the way they worked, and how much they work, since they arrived at university.

In contrast, Charlie and Delta, who went to private schools outside of the country, had not changed how they worked. It's difficult to draw any conclusions here, since the lecturers were talking about South African schools, and I am not sure to what degree, if any, the experiences at those schools are similar to the experiences of Charlie and Delta.

The quantitative data shows a similar ambivalence among the entire population to their schooling. The relevant results were plotted in the previous chapter in Figure 3.8. Nearly half (45%) of students agreed or strongly agreed that "I study at university the same way I studied at school", and very few (9%) strongly disagreed. In comparison the lecturers' opinion

of high schools was "*completely* inadequate" or a "*huge* problem" (emphasis added). Their use of language here shows the intensity with which they hold the opinion. High school is not just inadequate, it's completely inadequate. There isn't a problem with our schools, there is a huge problem. This is a serious divergence from the students' ambivalence, and we see it again in the responses to Question 11.

All four of the interviewees agreed or strongly agreed that "The mathematics I learnt at school was good preparation for university" as did more than half (51%) of all the students who completed the questionnaire. This is certainly not what the lecturers believe. Many first-year students arrive at university thinking that they have been well-prepared for university by school. They would have finished with an A (or equivalent) for mathematics and are confident in their abilities. They will nonetheless fail the first class test, probably while predicting a pass. However, these failures are, from the lecturers' point of view, completely normal and expected. It's natural to them that some of their students fail, they are underprepared and don't know how to work effectively, or how much to work.

The students interviewed, particularly Alfa and Bravo, gave a good account of how they had changed the way they studied, and all four of the students believed that they were effective at studying mathematics. The students who answered the questionnaire believed the same. A large majority (82%) agreed or strongly agreed that "My time spent learning mathematics is effective". (As we discussed above, this agreement was stronger among the overpredictors and bottom performers, a Dunning-Kruger-type effect). Both lecturers expected that the average student would disagree with that statement. I think that the explanation is simply that the lecturers are effective learners of mathematics, and they know that it is a difficult thing to do. Both lecturers expressed the desire for more time to talk about metacognitive learning strategies, and to provide more guidance to their students about how to learn, but by their own account only spend "something like twenty minutes" (Echo) or "five or ten minutes" (Foxtrot) each week actually doing this. I make this observation not as a criticism of the lecturers, but of a system which has prioritised easily described and measurable subject material. At UCT, and perhaps at other universities too, it is easy to justify a syllabus with entries like "The Definition of a Derivative (1 Lecture)". It is unfortunately much harder to justify "Thinking Like a Mathematician (as long as it takes)".

The gap between students' and lecturers' opinions is not just about how well students are prepared, or how effectively they work, but also about how much they work. I discussed this in some detail in Section 3.2, so I will simply summarise the results here. On average, students claim to work on mathematics for 13 hours each week during term. Lecturer Echo thinks his students are only working for 8 hours each week, and would be happy if they were doing 13 hours. Lecturer Foxtrot thinks his students are working as much as they are, but thinks they should be doing much more. There are two different ways in which lecturer expectations might fail to be met, and they are both evident here.

4.3 Reflections on validity, the CHAT framework, and power

My hope in running this project was that I could produce what is in Lincoln's terms [27] a "sufficiently authentic" representation of the way first-year students and their lecturer think about teaching and learning in MAM. That term, sufficiently authentic, presupposes sufficiency for a particular purpose, and my purpose is ultimately to improve the way I teach, in that hope that better teaching leads to better learning which leads, eventually, to better student outcomes – however that may be measured.

In that respect I think I have succeeded in producing a piece of valid research. I may not

be able to make broad claims about teaching and learning across all of the first-year courses, but I think that the qualitative and quantitative data are enough to draw useful conclusions in some cases, specifically in the case of overpredicting (or underperforming) students. That I cannot generalise beyond this group does not worry me, since that is the group I am most interested in helping.

It is in this group where I have the richest data. By good fortune two of the four students who volunteered for interviews, Alfa and Bravo, fell into this group. Their independent qualitative descriptions of their learning experiences exhibited a number of similarities, and that is as much as anyone could hope for at the outset of this type of project. Their descriptions were augmented by the quantitative data drawn from a broader pool of respondents which naturally surfaced a number of interesting factors to consider when teaching these groups. Among this data was some that supported the previously observed Dunning-Kruger effect. That I found such evidence without explicitly having set out to look for it further strengthens my confidence in the data I collected.

Finally, I don't expect that any researcher who tries to replicate this work will produce the same data. That is clearly impossible. I do however feel that the CHAT framework I used provides a fairly clear set of guidelines for replicating the research procedure, and I hope that my interpretations of the data I collected have been presented in such a way as to make my interpretations both reasonable, and transparent in their logic.

I think that the CHAT framework, and activity theory more generally, lends itself to educational research of the type I've conducted for a number of reasons. My project is fundamentally about identifying problems that might arise when or if students and lecturers think differently about what learning mathematics is. This is exactly the type of contradiction that is at the heart of dialectical thought, and forms (part of) the foundations of CHAT. Other dialectic principles, like aggregating quantitative change to explain high-order phenomena, one also well-suited to tackle problems of learning, an inherently complicated, subjective, neurological process that seems to arise from a series of individually mundane actions like reading through a paragraph of text, or listening to someone speak for half an hour.

The CHAT framework I adopted could easily be extended in a number of ways which might be appropriate. Firstly, I have not spent much time on what Engeström calls "expansive learning". The student protests of the last few years certainly fit his description and CHAT is certainly capable of accommodating those protests for analysis. The second thing that could be done is to move from analysing just a single activity system as I've done here, to a number of interlocking or overlapping or connected systems. A brief sketch of some possibilities. The object of the MAM1021F system is first-year calculus, which becomes one of the means of later systems that students participate in. Students (and lecturers) participate in many activity systems concurrently; they are not only studying mathematics. A single student may be the subject of many academic activity systems, and many more non-academic, including, at the least, their home life. Third, there are meta-activity systems overlaid on the others. As lecturers teach their students they also learn to teach, and this can be understood as the object of a concurrent but analytically distinct system. Finally, one might simply choose to focus on different parts of the activity system. I was interested in the different conceptions of learning that students and lecturers hold; this was an investigation of how the subjects of the activity system relate to the idealised object.

The CHAT framework could be used as a springboard to investigate some of the other aspects of the activity system, for example the rules of and division of labour within the system. In our study, one issue which was raised during the interviews with the lecturers was their feeling that students can't learn because they don't know how to learn. Their position is easy to understand. Although they probably haven't conducted an empirical study of first-year students' learning habits, their anecdotal experience as lecturers, coupled with the generally

bleak coverage of South African education in mainstream media (for example [56]) makes this sort of deficit model easy to adopt. The students, conversely, will have been told that they are the very cream of the South African education system, and that they are either fortunate to have had such a good education, or that they are exceptional for having succeeded in spite of the system that is so heavily stacked against them. The resulting mismatch in expectations seems like it would produce problems, and, in my experience, it does.

Similarly one could focus on the different communities within the activity system. Inside MAM1021F a single student might be part of a number of overlapping or interlinked communities. They sit in a lecture venue of one hundred or more students with a single lecturer and in a tutorial with thirty students to a tutor (who may also be their lecturer). They might belong to a study group of their peers, or be part of a small group led by a second-year engineering student acting as a mentor. In the tests and exams they are simultaneously part of the biggest and smallest possible communities. All the students write their exams together, and they all write them alone. Each of these different communities has their own set of rules that govern the acceptable behaviour, and within each community there is a different division of labour. The student who confidently leads a study group might talk deferentially to their tutor and sit entirely quietly in a lecture.

The means of the activity system is another node that interests many researchers. As discussed much earlier in section 1.2 many South African CHAT practitioners are interested in educational technology. They are looking at whether or not particular interventions might be effective means for mediation between the subjects, the teacher|learner pair, and the object, the intended objective of their education.

Underlying all of these possible different focuses one might take when investigating education in South Africa, whether at universities or at school, is the discomforting notion of power. South African society is incredibly unequal, not only in terms of economic capital (it has one of the highest Gini coefficients in the world [5]), but also in terms of social and cultural capital. The policy of apartheid systematically denied the majority of the population any access to higher education or professional employment, while simultaneously denying them the basic dignities of free movement and property rights. Until 1994 the Republic of South Africa may have been, nominally, a single country, but it has never been a single society. The great disappointment is that over the past 24 years there has been little progress in that direction.

South African society is incredibly unequal, and education in South African has to deal with additional problems. Education has historically been a site of political resistance since the Bantu Education Act of 1953. In 1974 The Afrikaans Medium Decree forced the language of the oppressor onto the oppressed, which ultimately culminated in the 1976 Soweto Uprisings. In the early 1990s South African Democratic Teachers' Union (SADTU) successfully campaigned for the removal of school inspectors and the new ANC government in 1994 had to introduce a number of reforms to distance themselves from the policies of the apartheid regime. A large number of experienced teachers were retrenched, and many of the teacher training colleges were closed. Although the colleges were eventually reopened, there was a generation of teachers forced out, and another generation of prospective teachers lost. The reintroduction of school inspectors, and greater accountability for the quality of education has never been a politically tenable prospect. The ruling ANC is strongly allied with the Congress of South African Trade Unions (COSATU) of which SADTU is a member.

A critical analysis of the problems in South African education, at any level, must take this particularly toxic history into account. The power structures within the academy can not overwrite the far deeper societal dynamics. Although lecturers ostensibly hold power over their students it is not always so clear. Last year UCT's student newspaper ran a series of stories about the teaching on the law campus. The second-year law class had complained to the Dean about two of their lecturers. It appears that these lecturers, both young and black, had, at some

stage during the semester, lost the respect of the class and the normally collegial relationship between lecturers and their students had broken down.

A discussion of power dynamics at universities should also make a distinction between collectively and individually exercised power. The university is a large organisation, and even the vice-chancellor serves at the pleasure of the university council. No single individual can dictate policy, although they may be able to steer the broad direction. Collectives, either of students, or workers, or academics that can engage in (or simply threaten) mass action have leverage that affords them much greater power and concomitant action than any of them acting individually could produce. This analysis is again complicated by the centralisation of much of the power in higher education with the Minister of Higher Education. Collective action cannot be effectively directed at the Minister, so some protests on campuses in South Africa can be understood as proxy protests. There is no way for management at the affected universities to meet the protesters demands, but these protests are made anyway with the intention of forcing the minister to act.

A critical approach that adopts power as one of the central pillars of its analysis would not be inappropriate, especially given the current situation at South African universities. It is, however, an enormous undertaking, that would best be conceived as a joint venture incorporating all affected parties into the project. Having a single observer, or an external observer, drive a project of this size would centre one particular viewpoint and undermines the project as a piece of critical work before it starts.

4.4 What next?

Having completed this project, there are a number of things that I would do differently if I were to run it again. Nonetheless, the data collection and analysis I have done suggests two different types of response to this project, an academic and a pragmatic response. The academic response would be to identify some of the more interesting issues that have been raised, to develop a new set of research questions, and to plan a project that may answer them. The pragmatic response is to reflect on what I have already learnt from this project, to think carefully about how I could change my own teaching practice (or the practice of others in the department) to better help my students learn, and to implement those changes the next time I teach a first-year course.

Academically, there are a number of issues that I think are interesting and merit further discussion.

1. This project was a snapshot of students conceptions of learning at a particular time, just as they have arrived at university in the weeks before the first class test. I'd like to know if and how their conceptions of learning change, whether and how these changes are related to their environment at UCT, if different conceptions of learning lead to different outcomes, be it in terms of grade point average, or time to completion, or sense of belonging at UCT, or even beyond UCT and into the workplace.

2. In the interview with Student Delta it became clear that they thought about learning mathematics completely differently from learning their other subjects. Is this a rare view, or is it shared by other students?

3. The questionnaire that students completed did not collect possibly sensitive demographic data like first-in-family status [9, 54], type of school attended [52, 60] and other relevant factors in how they may think about learning. Without this information it's difficult to bring the full analytic lens of CHAT to bear since we are missing the subjects cultural-historical backgrounds.

4. Not all of the areas probed by the questionnaire overlapped with the areas of interest surfaced in the interviews. It would be useful to extend the parts of the questionnaire that deal with issues of responsibility, effective study, and the possible gap between high school and university.

Answering these questions would not be easy. The first point, for example, would require a longitudinal study that tracks a cohort of students over a number of years. Regarding the third point, some students might find questions about their backgrounds to be intrusive, and in some cases it might contribute to a sense of alienation by reinforcing an idea that they are different and do not belong.

The second response is a pragmatic one. It has become clear to me, both through this project and also in conversations with my colleagues, that everyone wants to spend more time in class discussing strategies for learning, for effective time management, for dealing with setbacks, but doesn't because they feel like they simply won't have enough time to get through all their material. When the class is under a little pressure it is these "extras" that are the first to go, despite the importance of this material.

The mathematics lecturers at UCT know mathematics, they understand mathematics and can explain mathematics. But most mathematics lecturers, most lecturers in any subject, have never had any formal training in education. They were appointed on the strength of their research. I've had the good fortune of doing a Masters degree in education while I've been teaching, and I've learnt a little about effective pedagogy. I now believe that the informal and often unscheduled conversations I have with my classes about learning are important enough to warrant the same degree of care and planning that the rest of the course does. When I teach MAM1004F again next year I will make a point of preparing a coherent set of auxiliary lectures on learning that I can present to my class throughout the semester. I intend to encourage the rest of my department to do the same.

I think that this sort of meta-cognitive teaching is becoming increasingly important as the student body at UCT diversifies. I started teaching because I believed that I could make a positive impact on the world, or if that's too ambitious, at least to the lives of the students that I teach. The protests on campus are complicated and resist distillation to a singular explanation but I believe that they are in part due to the difficulty many students have upon arriving at university; the sense of alienation they feel at an institution that may strike them as culturally and academically unfamiliar. As teachers we are asking the same types of questions we always have: "What is my role as a teacher?", "How should I teach?", "What can I do to help my students learn?" but our answers have to account for the problems our students face and must help to solve them. If there is work that can be done to demystify the academy, and to smooth the transition from high school, then I want to do it.

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Appendix A

Research Instruments

A.1 Questionnaire

Please indicate whether you strongly disagree, disagree, agree or strongly agree with the following statements.

1. My lecturer is responsible for how much I learn.
2. I am responsible for how much I learn.
3. There is no difference between studying mathematics and learning mathematics.
4. My time spent studying mathematics is effective.
5. I learn better when I work on my own.
6. I enjoy studying new mathematics.
7. I don't understand what I need to learn in each lecture and tutorial.
8. I understand why the material we are learning is important.
9. I know what my lecturer expects of me.
10. I study at university the way I studied at school.
11. The mathematics I learnt at school was good preparation for university.
12. There is no point in studying material that is not going to be assessed.
13. *Assessments (tests, exams, labs etc.) may serve a number of different purposes. They may be diagnostic: the assessment is done to aid decisions about future teaching. They may be formative: the assessment itself is part of the learning process. They may be summative: the assessment is done to measure student learning against a set of norms or criteria and assign them a mark.*

    The first class test in MAM1020F is summative.

Please indicate how much time you spend each week on the following activities.

1. Attending lectures or watching lecture recordings.
2. Working on the weekly tutorial outside of your scheduled tutorial timeslot. (If non-zero: How much of that time is spent working alone?)

3. Reviewing material covered in class that you didn't understand.
4. Preparing for upcoming lectures.
5. Solving problems from the exercise sheets.
6. Engaging with other resources. for example watching Khan Academy videos or reading Paul's Online Math Notes. Please specify for each resource.

Finally, please predict what mark you will score for the first class test (as a percent).

A.2 Open-ended questions

If the participant agreed or strongly agreed that there is a difference between studying and learning mathematics – what is the difference between studying mathematics and learning mathematics?

If the participant agreed or strongly agreed that they know what there lecturer expects of them – what does your lecturer expect of you?

If the participant disagreed or strongly disagreed that they study at university the way they studied at school – how have you changed your studying from school to university? Why did you make this change?

If the participant spent any time engaging with other resources – how did you find [these other resources]? Do you think [these other resources] are more useful than the ones provided by your lecturer? Why?

What is learning?

How do you learn?