Chapter 1. Introduction and rationale.

In the current climate of educational reform in South Africa, teachers and learners have had to adapt to changing practices of teaching, learning and assessment, practices reflecting outcomes-based principles. These principles are a radical shift from those by which most teachers of mathematics, including myself, were educated. The challenge is for educators and learners to grow into their new roles within this changing curriculum, to master those roles and subsequently be able to perform successfully with regard to teaching, learning and assessing mathematics processes.

I am a secondary school teacher, in my fifteenth year of teaching, and currently teaching at a single-sex private school in Johannesburg. This school currently writes examinations set by the Independent Examinations Board (IEB), an examining body not affiliated to the government in any way. Although independently set, these examinations are still based on the National Curriculum, as developed by the Department of Education (DOE) for South Africa.

During the many discussions that I have had with other Grade 9 and Grade 12 mathematics teachers in my school and other schools, concerns were often voiced regarding the pressures/stresses that teachers feel with respect to the development of assessment portfolios. The number of items that each learning area expects in fulfilment of the school-based assessment component of promotion requirements, the time taken to mark and remark such tasks, the time it takes the teachers to create/find appropriate tasks and the time it takes to develop appropriate rubrics or marking schemes, were often the dominant focus of discussion at school and cluster meetings. The IEB have assigned each school to a cluster group, a group of schools usually in close proximity to each other, where teachers from all the learning areas meet on a regular basis to discuss current issues and moderate portfolios whenever necessary. In the past, the curriculum was divided up into clearly defined subjects, for example History, Geography, Mathematics etc. With the move towards a more learner-centred approach, subjects with common strands of thought and skills have been integrated into eight Learning Areas, namely: Language, Literacy and Communication; Mathematical Literacy, Mathematics and Mathematical Sciences (MLMMS); Human and Social Sciences, Arts and Culture, Technology and Natural Sciences. This integration of learning into areas and not into subjects, "is aimed at promoting an understanding of linkages across different contexts, in order to make learning more relevant" to the learner (IEB Assessment Education and Training Course for Assessors, 2003: 43). There is a set of outcomes specific to each Learning Area, which identifies the skills and content required for deciding the competency of each learner. The focus on portfolios at these meetings, led me to consider it a starting point for my research.

At the beginning of 2003, all the high school staff at my school, were sent on an Assessor's Course focussing on outcomes-based education and assessment. Almost immediately, we were expected to make a paradigm shift towards the principles and approaches operating within an outcomes-based approach to teaching and to implement new teaching and assessment practices. The assumption was made that since all the mathematics teachers were highly qualified, experienced people, this shift towards Outcomes-Based Education (OBE) would be made easily and quickly. It was continually emphasised that outcomes-based education "places emphasis on what the learner [already] knows, understands and can do" (IEB Assessment Education and Training Department, 2003: 42), and that instead of focussing on memorisation of procedures and content, learning should take place in a contextualised environment, where the learners' skills, knowledge, attitudes and values are assessed. This meant the adoption of the following methods of teaching within all the learning areas:

- learner-centred approaches
- problem solving strategies
- co-operative learning approaches, and
- continuous assessment techniques (mostly formative assessment, not just summative assessment) (IEB Assessment Education and Training Department, 2003: 42).

The importance of portfolios that would form part of the school-based assessment mark for each learner was acknowledged. However, the selection of appropriate tasks reflective of all the Specific Outcomes (SOs)[1] for each Learning Area, was left for each teacher to work on.

During the year (i.e. 2003), I became increasingly aware of our lack of understanding as teachers of an outcomes-based approach to teaching mathematics. We were still operating as we had been for the last thirteen years of my teaching career, the only changes being the development of 'front covers' attached to each test, examination, project etc. and also the development of 'portfolios' for Grades 9 and 12. With regard to the Grade 9 term report, the SOs that had been assessed during that term, were reflected on the report. The whole process of designing from the Specific Objectives down to the content was not happening. Added to this, it was felt that the mathematics teachers involved in these two grades were experiencing much stress with regard to the development of an acceptable portfolio. There was obviously a problem with the development of this new form of assessment.

While the discussion above focuses on teachers' experiences, there were also ongoing confusions and discussions with regard to what this new form of assessment meant for the learners. How would the development of such a form of assessment affect learner workload, interactions between peers and teacher with regard to peer, self- and teacher assessment, group work demands, overall results and of course competency in performing well in these new forms of assessment. With both the concerns of teachers and learners in mind, I thus decided to set up a case study of mathematics portfolio assessment in my own school.

With portfolio assessment as the broad problem area, there are a vast number of issues that could have been researched, such as teachers' beliefs of what good teaching practice is, what tasks they should select in order to adhere to outcomes-based principles, how they and their learners interpret and cope with their new roles within this new approach, to name but a few. I have, however, chosen to focus on task selection, with the emphasis being on the competencies covered by those tasks and the competencies actually demonstrated by the learners involved in this study. I have also focussed on how different ability groups of learners fared across different types of tasks. The mathematical competencies assessed, would be revealed through an analysis of the initial tasks that were selected for the portfolios. The mathematical competencies that the learners displayed, would be interpreted through an analysis of each learner's portfolio.[2]

With regard to the two teachers involved in teaching the Grade 9 learners during 2003, both were well qualified and experienced. They were also very helpful, supportive and caring teachers who were always available to their learners, providing any help whenever necessary. The learners involved in this study, come from middle to upper class families. These learners are very privileged with regard to the facilities they have available and the support structures that are in place.

This study is centred within the context of a private, well resourced single-sex school, one where the principles of OBE are being encouraged and where an ethos of learning and respect for the teacher are the order of the day. Each class size is kept to a minimum (± 23 in the lower grades and less where possible in the senior classes). But how have the principles of OBE and the development of portfolios in the Grade 9 year come to fruition in the classroom? What are the problems and tensions that have developed from the development of these portfolios and what suggestions are there for its improvement?

This research report focuses on how new forms of assessment have taken shape in practice, with a particular focus on learner competency as revealed in portfolio assessment. More specifically, it focuses on the way in which tasks selected for the Grade 9 portfolio reflect a predetermined list of mathematical competencies and if the Grade 9 learners themselves can demonstrate those competencies when exposed to the tasks.

The promotion marks obtained by each learner in Grade 9 in 2003, were analysed in order for me to divide the learners involved in this study into ability groups. The tasks were studied from the point of view of being ‘open-ended’ (i.e. promoting further investigation of concepts involved in the tasks and encouraging learners to ask more questions about the work involved in the task, where solutions and final productions of each learners cannot be anticipated completely be the teacher), versus the more ‘closed’ types of tasks (such as revision exercises and tasks with a set number of solutions, that can be anticipated by the teacher). They were also studied from the point of view of providing little challenge to the learners, where recall of concepts and procedures would provide correct solutions and where no understanding of previously learned concepts was required (i.e. tasks that can be seen as ‘low cognitive demand tasks’) versus tasks that are really challenging to the learners, placing them in uncomfortable situations, where previously learned work needs to be applied in unconventional or non-algorithmic ways in order to solve the task (i.e. referred to as ‘high cognitive demand types of tasks’)[3]. These issues led me to form the following questions for this research report:

Research questions:

1. What mathematical competencies were assessed by the tasks used in this research project?

2. How do mathematics portfolios affect the learners' academic results? In particular:

    a) Do the results of different ability groups of learners reflect differing apparent benefits?

    (b) How do each of the different ability groups of learners fare with regard to:

        i) the more 'open-ended' types of tasks compared to the more 'closed' types, and

        ii) tasks that are considered to be of 'high cognitive demand' versus those that are classified as being of 'low cognitive demand'?

    (c) Do the different ability groups of learners fare differently within each group of mathematical competency assessed in this portfolio? If so, how? That is, which groups are proficient (or not) in the different mathematical competencies assessed in these portfolios?

The implications of this research project are firstly to provide teachers of mathematics with a list of mathematical competencies that our learners need to be engaging with during our lessons, secondly to provide some exemplars that serve to illustrate these mathematical competencies and lastly to highlight any apparent differences in the competency of different ability learners. This should improve the quality of our assessment practices, making teachers more aware of the importance of task selection when developing mathematical portfolios.

The structure of this research report:

In the following chapter, Chapter 2, I discuss the South African education system as it has changed from being performance-based to competency-based, with the focus being on the assessment practices that occur within the two approaches to education.

Chapter 3 provides a theoretical framework based in Bernstein's theory of curriculum and pedagogy, integrated with additional concepts such as the ZPD and scaffolding, all of which together provide a framework or gaze onto assessment practices.

Chapter 4 discusses the forms and functions of portfolio assessment, the cognitive demand involved in tasks and current factors affecting task selection.

In Chapter 5, I present a composite set of mathematical competencies, drawing on relevant research literature in the field.

Chapter 6 discusses the approach used for this research report, plus the open-endedness of the tasks selected for this study.

Chapter 7 then follows with the results from the analysis of the mathematical competencies assessed in the tasks used and those competencies demonstrated (or not) by the learners.

Chapter 8 concludes the discussion, making suggestions for further study.

My aim for this research is to highlight the demands of choosing appropriate tasks for mathematics portfolios very carefully, how task selection affects all learners in our classes and also how this relates to an analysis of the mathematical competencies to be assessed. An additional aim is that as mathematics teachers, we become more conscious of the mathematical competencies to which we are exposing our learners. The coverage of mathematical competencies within our portfolios needs to be addressed, if we are expected to produce successful mathematicians who will be able to apply their mathematical knowledge in a critical, self-monitoring, independent-thinking manner to real life issues of the future, to the benefit of society. This research should thus provide one small case study of how teachers enact their assessment practices within the confines of an outcomes-based approach to education, with implications for how this might be improved.

Notes:

1. At the time this research report was initiated, Mathematics in Grade 9 was assessed according to ten Specific Outcomes. Since 2004 however, this number has been reduced to five Learning Outcomes. This discussion of Specific Outcomes versus Learning Outcomes is discussed at the end of Chapter 4 (See the Notes at the end Chapter 4, p 47).

2. I also collected data through the medium of questionnaires and selected interviews, where we discussed each learner's experiences while they were working through these tasks. In terms of the scope of this report however, I focus only on the mathematical competencies and not on the learners' experiences. The interview and questionnaire data can be used for further study but will not be used for this research report.

3. 'Open-ended' versus 'closed' types of tasks and 'high' versus 'low' cognitive demand within a task, will be discussed in Chapter 4.

Chapter 2. Education in South Africa: Changing models of assessment.

Education in South Africa has gone through radical change in the past fifteen years, a function of the political shift away from apartheid, towards a society based on democracy, where the legacies of apartheid education had to be eradicated. Basil Bernstein (1996) and others who draw on his sociology of pedagogy and curriculum change (e.g. Taylor and Vinjevold, 1999), describe this shift in education as from a 'performance' to a 'competence' model.

2.1 From a 'performance' to a 'competence' outcomes-based model of pedagogy

In a performance model, the assumption is that 'understanding' is synonymous with 'performance', performance being indicated by the achievement and demonstration of correct answers (Goldin, 1992). The predominance of standardised tests and its associated mastery of procedures, was characteristic of the educative system of the mid 1970s.This emphasis on high stakes examinations and tests, and the strong control over content and 'subject differentiation', was carried through to the 1980s. This performance-based model of education allowed little or no control by learners over selection of content, sequencing of content, pace of learning and social base (Graven, 2002: 31). It was characterised by more overt control by teachers, was interventionist by nature and where assessment was based on determining what the learners did not already possess (Taylor and Vinjevold, 1999). Most of the teachers of today, are a product of this education model, which highlights one of the major obstacles to the current innovations within education in South Africa.

In contrast to this 'performance model' of a curriculum, Bernstein also identifies a 'competence model'. He describes the discourse of such models as taking the form of projects, themes etc., where the learners have a great deal of control over the selection of content, sequence and pace (Bernstein, 1996), since

> the weak and implicit sequencing of different activities (no apparent progression) combines with weak pacing to emphasise the present tense (p 59),

and

> [t]he absence of explicit structures and classifications[1] makes both the possibility and use of positional control a low priority strategy (p 60).

Thus he describes this model as learner-centred, where learners are expected to be active, creative and self-regulatory in the learning process (Bernstein, 1996, also cited in Taylor and Vinjevold, 1999). Within this model, teachers' roles are more covert, seen more as a guide and facilitator, mediator, creator-of-opportunity and co-developer of concepts (Taylor and Vinjevold, 1999; Windschitl, 1999) and not merely as a transmitter of knowledge. Assessment in this model is based on the assumption that learners will demonstrate their competence in different ways and that all learners are capable of achieving the outcomes (Taylor and Vinjevold, 1999), given enough time and the appropriate learning environment. This philosophy of teaching and learning should empower the learners with the knowledge that they themselves can construct knowledge, create their own understandings and then apply this knowledge to the solving of any problems that they may encounter (Windschitl, 1999).

With the election of the African National Congress in 1994, a major change had to occur in the education system. What has transpired was a shift towards that of a ‘competency model’, where teachers and learners would have more control over the selection, sequencing, pace and practices, with less emphasis on time driven tests and examinations and pre-selected content and an integrated approach to learning (Graven, 2002). It is this greater control over content and more emphasis on the use of a variety of assessment forms, that encouraged the introduction of the portfolio into most (if not all) learning areas.

2.2 Outcomes-based principles in our educational system

Added to this shift from performance to competence, the principles of Outcomes-Based Education (OBE) were factored into the South African educational system. This is not a direct import of one of the outcomes-based models of another country, but one that has had a number of influences from different areas and is thus unique to our country.

Although constructivist in intent, an outcomes-based assessment approach could be characterised essentially as behavioural. This is since it measures clearly observable outcomes according to given assessment criteria. These outcomes have to be demonstrated and then measured according to pre-determined unit standards set out by the Department of Education (DOE), in order to determine the competence[2] or not, of those being assessed. All that the assessor needs is a list of the actual outcomes (i.e. performances) that the learner needs to demonstrate, and to tick them off as they are each demonstrated (Harley and Parker, 1999). This contradiction in terms leads to tensions between the provision of time for learners to construct their knowledge, versus the measurement of clearly defined curriculum outcomes. Thus in an outcomes-based model, learners have to be given credit for what they can do.

Another characteristic of OBE, is its criterion-referenced nature of assessment (Pahad, 1999), which serves to measure each learner against pre-determined standards and does not result in a comparison between learners (as is characteristic of a norm-referenced system).

OBE also emphasises a ‘learner-centred’ approach, where learners are not just expected to assimilate information as provided by the teacher, but where critical negotiation and discussion are encouraged in order to come to a negotiated meaning of what is being taught and learnt. This constructivist approach implies less emphasis on time frames and the time it takes for the learner to demonstrate that competency/outcome and more use on the past experiences of each individual learner, building on what they already know. Continuous assessments involving projects, assignments, investigations and group work exercises, are expected. These theme based projects are a characteristic of the competence model (Bernstein, 1996) as discussed in 2.1 above.

Outcomes-based education, with its emphasis on the demonstration of a competency/outcome, often results in less coverage of traditional content. This could result in students who excelled in the traditional content-specific curriculum, no longer being the top of the class in this more broadly based outcomes-based curriculum (Malcolm, 1999:78).

The concept of mastery learning, established by Bloom, has also had an influence on outcomes-based principles, where the assumption is made that all learners can master a concept, given enough time and the correct methods of instruction (Baxen and Soudien, 1999). As mentioned above, all these factors have resulted in a new interpretation of ‘outcomes-based education’ unique to South Africa, a system of education that is a radical move from the content-driven curriculum of the 1980’s.

2.3 Outcomes-based education: A success or failure?

One of the criticisms of OBET (outcomes-based education and training), competency-based models and their associated behaviouristic nature of the assessment process, is the issue of expecting people in similar circumstances, to behave in the same way. This variation in display of the competencies, means that there is a problem with the mastery and accurate measurement of them (Kraak, 1999). Learners may demonstrate some skill or competency to varying degrees of success and this variation can be interpreted to differing degrees by different assessors. Thus issues of reliability may arise.

Jansen, in his article "Why outcomes-based education will fail: An elaboration" (1999), mentions a number of other criticisms of an outcomes-based education, such as:

- Its language being too complex.
- Its assumption that teachers in all South African classrooms understand the proponents of an outcomes-based education and have the knowledge and ability to apply these principles to develop appropriate tasks and materials and to assess their learners using outcomes-based principles.
- As mentioned above, issues of reliability must be considered, since outcomes can be interpreted in many different ways, depending on the circumstances and past experiences of those involved at that time and the specific context they find themselves in.
- The integrated nature of the curriculum, across learning areas, demands being competent in a number of cross-curricular and interdisciplinary competencies.
- OBE demands the full co-operation of all stakeholders, i.e. policy makers, principles, teachers, learners, parents and community stakeholders, which necessitates a complete mind-shift from the test-driven, exam-orientated approach of the 1980's, towards a

closer relationship between purely academic studies and the inclusion of vocational training within courses. And

- With regard to assessment, teachers will possibly attempt to use old methods of assessment for new purposes, since as Marzano (1994: 6) (cited in Jansen, 1999: 153) stated, "given their complexity, outcome-based performance tasks probably cannot be used very frequently by classroom teachers; thus, they will probably not totally replace more traditional assessments…"

Nevertheless, the National Qualifications Framework (i.e. the NQF) was set up to bridge the gap between the academic studies and vocational training, to ensure the abolishment of all apartheid education and to embrace the outcomes based principles mentioned earlier. According to Harley and Parker (1999), there seems to be a move toward a combination of a competency-based and an outcomes-based model, where competencies are to be assessed through a comprehensive list of outcomes.

Teachers' interpretations of the principles of OBE and how it fits into their everyday lessons, added to their beliefs of best teaching practice, influence their choice of teaching strategy, classroom organisation and task. Teachers who are the product of a behaviouristic, examination- and test-dominated, content-driven (i.e. performance-based) system, may offer resistance (both intentional and unintentional), to those advocating a constructivist, learner-centred approach. Even on the surface, teachers could just be providing lip service to the principles of OBE, yet still be functioning as in the past. As Fullan (1983, cited in Handal and Herrington, 2003: 62), stated, teachers could be using new resources or changing teaching practices, without "accepting internally the beliefs and principles underlying the reform". This change in teacher belief and hence practice, demands a process of unlearning and learning (terms used by Mousley, 1990, cited in Handal and Herrington, 2003). In an article written by Handal and Herrington (2003: 65 - 66), they concluded that:

> The current trends in mathematics education towards constructivist learning environments and assessment of learning based on demonstrable outcomes will only succeed if teacher' beliefs about these reforms are considered and confronted. Otherwise, teachers will maintain their hidden agendas in the privacy of their classrooms and the implementation process will result in a self-deceiving public exercise of educational reform and a waste of energy and resources.

2.4 Conclusion

This research report should give one such case of the way in which teachers in a private school have incorporated the principles of a competency and outcomes-based model of teaching and learning into their assessment practices. As was mentioned earlier, the teachers involved in this research, were themselves the product of a performance based model and who are now expected to assimilate pedagogic principles that are in total contrast to that which is most familiar to them. The ability to choose appropriate tasks for the grade 9 portfolio, ones that reflect mathematical competencies in an acceptable ratio of occurrence, takes practice and demands a conscious analysis of the tasks with respect to the competencies actually being assessed

There is often a difference between the curriculum that is intended by the innovators and prescribed by policy makers, the implemented curriculum (i.e. the one actually taught by the teachers) and the attained curriculum (i.e. the one learnt by the learners) (Handal and Herrington, 2003). We need to realise that teachers and learners need time to assimilate these new principles and practices into their teaching and learning and that this assimilation will not occur overnight. It may take a number of years before this shift can claim to be producing citizens that have the characteristics called for in the Critical and Specific Outcomes[3] of the model.

Thus, at a conceptual level, there are contradictory tensions that are likely to play out empirically in the classroom. Constructivist teaching methods assessed according to outcomes, will certainly influence the tasks that teachers select as part of their portfolios. Certain concepts from Basil Bernstein's sociology of pedagogy and curriculum change plus other theoretical resources with which to analyse this change in classroom practice, will be discussed in the following chapter.

Notes:

1. The concept of classification will be discussed in Chapter 3, see page 17 for a definition though.

2. Note that the word 'competence' is not the exact meaning in Bernstein's terminology.

3. See the note at the end of Chapter 4 (p 47) for a discussion of these outcomes.

Chapter 3. Towards a theoretical framework for interrogating the problem.

In order to investigate the learners' competencies in the Grade 9 portfolios, I draw from a number of theoretical resources. In order to explore the changes in pedagogy, Basil Bernstein's theory of curriculum and pedagogy is used. In particular, his concepts of 'classification', 'framing' and the 'recognition' and 'realisation' rules, provide useful tools to discuss these changes. I have also drawn from the work by Cooper and Dunne (2000), who showed that students from a working-class background, did not have the realisation rules necessary to perform successfully in the new forms of assessment that were to be used in Britain. In order to focus on the changes taking place in assessment, in terms of the analysis of the tasks chosen by the teachers for the portfolios, the competencies covered within these tasks and the competencies demonstrated by the learners involved in my research project, I referred to the work written by Saxe, Gearhart, Franke and Howard (1999), who discussed the use of old forms of assessment for new purposes. While the above theorists' concepts provide useful conceptual tools with which to do my analysis, I also draw from others' work, i.e. Vygotsky's 'zone of proximal development' (Vygotsky, 1979) and 'scaffolding' (Jaworski, 1990 and 1994), in order to explore elements of learners' responses to the assessment tasks.

3.1 Bernstein's concepts

3.1.1 Classification

According to Bernstein (1996: 20), this concept refers to

> a defining attribute not of a category but of the relations *between* categories,… …. [i]f these discourses are differently specialized, then they must have a space in which to develop their unique identity, an identity with its own internal rules and special voice....Thus, the principle of the relations between categories, discourses – that is, the principles of their social division of labour – is a function of the degree of insulation between the categories of the set we are considering.

Bernstein distinguishes between <u>strong and weak classification</u>:

- Strong classification implies 'strong insulation between the categories', where 'each category has its unique voice, its own specialized rules of internal relations', and
- Weak classification implies 'less specialized discourses, less specialised identities, less specialized voices' (Bernstein, 1996: 21)

In order words 'classification' refers to the nature of differentiation between contents. Where classification is strong, contents are well insulated from each other by strong boundaries. Where classification is weak, there is reduced insulation between contents, for the boundaries between contents are weak or blurred (Bernstein, 1982: 159, cited in Graven, 2002: 28).

In a <u>strongly classified system</u>, the teachers and learners are easily able to recognise the "speciality of the context that they are in" (Bernstein, 1996: 31, cited in Harley and Parker, 1999: 192), i.e. what is expected and appropriate in different situations and contexts. Content within a 'subject' is clearly specified and has little or no overlap with other subjects. However, as the 'classification' within the curriculum (the boundary between different fields/regions/areas of learning) gets <u>weaker</u>, learners and teachers have to learn new rules. Learners should now not only be taught as one ability group continually and be taught 'subjects' with clearly defined boundaries that do not overlap, but be taught in an environment where the differences between the learners are encouraged and developed as well. As subjects are combined into different ‘learning areas’, shifting classification from being stronger to weaker, teachers will be expected to work together with other teachers and learners, to promote team work, co-operative learning and project-based work that span all the necessary ‘subjects’. Teachers then also have to become accountable to the other stakeholders in this process with regard to the progress of each learner, the assessment levels assigned each learner and that which the learner is engaging in in the classroom.

Within a weaker classification system, such as is apparent within an Outcomes-Based Educational system (OBE), the changing roles that teachers have to become proficient in are, amongst others, those of mediator and facilitator, designer of curriculum materials, administrator and manager plus competent assessor (as listed in Graven (2002), taken from the Norms and Standards for Education contained in the February 2000 Government Gazette of the National Department of Education (2000)). Learners also have a role shift, from being submissive, unquestioning and non-critical, to questioning, critical and becoming more actively involved in the learning process. They have to learn to function appropriately within this new framework of assessment, with its new expectations of developing portfolios, working successfully in groups, doing self- and peer-assessments etc. and its integrated approach to learning content.

The question then begs to be asked: Whether the parties involved have the ability to recognise these changes and to perform proficiently within each new role. Specifically, with regard to the introduction of continuous assessment involving the use of alternate forms of assessment such as the use of journals, correction items, projects, investigations, debates on mathematical topics, designing one’s own test etc., teachers are expected to ‘design down’, i.e. start with the outcomes they want to assess and then to set tasks that cover those specific outcomes. As is probably still the case in the majority of schools, teachers are choosing tasks and setting tests and then only ascertaining which outcomes they have covered. This may result in an unbalanced coverage of the outcomes, with some Learning Outcomes not even being touched on during the year.

3.1.2 Framing

Bernstein's concept of '<u>framing</u>' refers to *who* controls *what* (Bernstein, 1996: 27), that is to the "nature of control over:

- the selection of the communication;
- its sequencing (what comes first, what comes second);
- its pacing (the rate of expected acquisition);
- the criteria; and
- the control over the social base which makes this transmission possible" (Bernstein, 1996: 27).

When framing is <u>strong</u>, the teacher (i.e. the 'transmitter' in Bernstein's (1996) terminology) has complete control over the selection, pacing, sequencing, criteria and social base, yet when framing is <u>weaker</u>, the learner (referred to by Bernstein (1996) as the 'acquirer'), has more *apparent* (emphasis Bernstein, 1996: 27) control over these factors. Within an OBE type of curriculum, where the criteria are clearly specified, not by the teacher, but by the Department of Education, the teacher has control over the other factors mentioned above but not over the criteria. This results in an environment where framing is strong with respect to criteria but weak with respect to selection, sequencing, pace and social base. This tension between strong and weak framing, places the teacher in a difficult position, where he/she is expected to be creative in the design and implementation of the curriculum, but still cover all the necessary outcomes. Similarly this tension exists for the learners, who are then expected to take more responsibility for their own learning in terms of pace and selection of content and to have a say in the assessment process in terms of when and how it will take place, but be operating in an environment where questioning and critical thought from the learners may still be seen as unacceptable behaviour.

Thus ‘classification’ establishes who is allowed to speak and ‘framing’ establishes what is acceptable to say.

3.1.3 Recognition and realisation rules

Bernstein’s concepts of recognition and realisation rules apply to the learner (i.e. the ‘acquirer’ (Bernstein, 1996)). He states that as the classification strength changes from strong to weaker, there are changes in the “recognition rules by means of which individuals are able to recognise the speciality of the context that they are in” (Bernstein, 1996: 31). For instance, learners need to be able to recognise when and when not to use contextual information/past experiences while completing some task. Then, although a learner may possess the recognition rules in operation at that time, he/she may or may not be able to produce the legitimate text required for that activity. Thus some learners may be able to recognise the specific context that they are in, but nevertheless not be able to produce legitimate text appropriate to that context (Cooper and Dunne, 2000). This point about being able to produce legitimate text is what Bernstein refers to as the ‘realisation rules’. When questions are structured to have only one correct answer/solution, the possession of these recognition and realisation rules is easier to identify since the solution is either right or wrong, compared to when questions have various acceptable solutions and approaches. Since the mathematical competencies assessed for this research project, will be deduced from the manner in which the learners have interpreted and answered the questions, one needs to be extremely careful when making conclusions about the possession or not of these rules.

Thus, the move from clearly defined ‘subjects’ towards ‘learning areas’, indicates a weakening of the classification within the curriculum; and the introduction of portfolios into Mathematics, indicates a weakening of ‘framing’ with respect to selection, sequencing, pace and social base, but not with regard to the criteria demanded for the development of these portfolios.

Although Bernstein’s terms are very useful for the interpretation and analysis of the tasks from the point of view of the curriculum being taught and learnt, there are no tools to discuss how this process of teaching and learning actually takes place, i.e. the mediation that occurs between teacher and learner and between learners themselves in order to develop these recognition rules. For this reason, I turn to Vygotsky’s ‘zone of proximal development’ and the concept of ‘scaffolding’.

3.2.1 Vygotsky’s ‘zone of proximal development’

While the learners are working with each task (and depending on the nature of each task), there should be some discussion occurring between teacher and learner in order to allow each learner to function productively in his/her own zone of proximal development (ZPD). This Vygotskian notion is defined as follows:

> It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (Vygotsky, 1979: 86).

This notion of operating within the ZPD, is explained by Moodie (1999: 11) as

> [T]hat domain in which learning could happen through problems and tasks which are designed to unfold the child's almost-but-not-yet-functioning abilities.

Moodie thus explains that one should differentiate between the actual levels of performance of one's learners and each individual's 'potential performance' on a task, the latter being the upper limit of the ZPD. In order for each learner to learn from a task, he/she needs to be pushed beyond the current levels of competence and ability, to achieve improved competence. Learners operating within this zone of proximal development, need to possess the recognition and realisation rules in order to operate successfully in this zone. Moodie's mention of tasks that are designed to reveal a learner's abilities, emphasise the importance of task selection and also the circumstances under which each task is carried out.

3.2.2 Assessment and the ZPD:

When assessment is used for educative purposes i.e. when formative assessment is used to provide a learning environment for the learners to improve and learn from their mistakes, successful operation on the part of both teacher and learners within this zone of proximal development, is essential to aid in the learning process. In order to assess reliably, teachers must be aware of the upper limits of each learner's zone of proximal development. Providing too much help to a high mathematical achiever, may be detrimental to his/her work and may reduce the thought processes that he/she may have progressed through. Similarly, providing too little help to a weaker mathematical learner, may result in this learner not even beginning to engage with the task at hand. Finding the appropriate level of help needed by each individual in the class, although the answer, may not be practical in terms of number of learners in each class and hence dividing learners into groups may enable better interaction between teacher and learners and between the learners themselves.

Although operation within this zone of proximal development is most often analysed from classroom observations and from interviews, aspects of it can be deduced from the way in which tasks are initially presented to the learners as well. Where hints or suggestions of approach are provided on the initial question paper, some movement into this 'zone' is enabled, however one must be careful not to reduce the thought processes expected from the learners because of the hints/help provided, but to increase the level of thinking taking place. This thus introduces the concept of 'scaffolding' that would occur while operating within this zone of proximal development.

3.3 Scaffolding

While the teacher and learner are operating within this zone of proximal development, it is expected that the teacher provides some sort of 'scaffolding' to the learner, i.e. providing useful hints/advice on how to proceed. Jaworski (1994:31) explains it in terms of "a teacher's offering strategies for thinking and learning". This scaffolding is not without its cautions, since it could result in the learner becoming dependent on this scaffolding provided by teacher and other learners or (2) it could destroy any initiative that the learner would have shown if allowed to progress totally on his/her own (Jaworski, 1990). As mentioned in the previous paragraph, scaffolding (intentionally or unintentionally), could also reduce the cognitive demand (Stein et al, 2000) expected from a task. A teacher that is more comfortable with more routine type tasks, may feel compelled to provide more direct help to the students, defeating the whole exercise of using non-routine type problems (Goldin, 1992). However, as Klenowski (2003) states, the information gained from these interactions between teacher and learner while operating within this ZPD, could aid the assessment and subsequent teaching process, by helping each learner identify their own strengths and weaknesses in their learning. Also, by providing appropriate scaffolding strategies, learners who then successfully solve the problems, may develop a sense of confidence in their own ability to handle problems (Jaworski, 1994). This metacognitive development is extremely useful to the development of the portfolio process, since these formative and developmental forms of assessment help with future learning and not just with what is being completed at that time (Klenowski, 2003). Students learn to self assess their work, judging whether their work is of an acceptable standard to warrant being presented as one of the portfolio pieces. They also learn to judge when certain sections of work require more attention. However, it then also demands competency by the teacher, to be able to allow each learner to operate within this ZPD efficiently, but not provide too much scaffolding as to result in a state of dependency between self and learner. The understanding of what is acceptable behaviour in the classroom and what can be expected from the teacher and also the learners in terms of guidance and help, work ethic and presentation of tasks, thus demands acceptance of these implicit rules between all the parties concerned.

3.4 'Performance' versus' 'competency-based' models in relation to the theoretical framework developed above

As was mentioned in the previous chapter, South Africa is currently adopting a 'competency based' model for education, where learner-centredness is encouraged and where the roles for the teacher are that of facilitator and mediator. The differences/similarities between the 'performance-based' model and 'competency-based' model, have been analysed using Bernstein's terms of 'classification' and 'framing' in Table 3.1 (p 26) below. Using these concepts, we can see that the 'performance' model is strongly classified and has strong framing, whereas the

Table 3.1 Table comparing performance models to competency models (Bernstein, 1996)

CATEGORIES OF COMPARISON:	PERFORMANCE MODELS	COMPETENCE MODELS
1. Pedagogic discourse	Clear differentiation between subjects; recognition and realisation rules are explicit in texts; learners have little control over selection, sequencing and pace.	Takes the form of themes and projects; wide range of experiences; recognition and realisation rules are implicit in texts; all learners are assumed to possess the competencies, they just have to be revealed; learners have relatively more control over selection, sequencing and pace.
2. Space for learning	Space is clearly demarcated and controlled; clear regulatory boundaries limiting access and movements of learners.	No clearly defined spaces; absence of regulatory boundaries limiting access and movements of learners.
3. Time	Clearly defined time limits for activities.	Emphasis on the present tense, weak pacing of activities.
4. Evaluation	Emphasis on what is absent in the learner's work; criteria of evaluation are explicit; the learner is aware of the criteria for the production of legitimate text.	Emphasis on what is present in the learner's work; criteria of evaluation are implicit, although criteria for regulative discourse (i.e. for conduct and manner in the classroom) are explicit.
5. Control	Teacher as transmitter, where learners are in a disciplining environment where deviation from the norm (i.e. deviant behaviour) is quickly noticed; strong positional control.	Teacher as facilitator and learner as self-regulatory, weak positional control.
6. Pedagogic text	Only that which the learner produces, is assumed to be the pedagogic text, i.e. performance is indicated clearly by the text; this performance is assigned a grade, on the basis of explicit grading procedures.	Product implicitly reveals the acquirer's competence development as well as the product itself, this competence is evident to the teacher from the work produced.
7. Autonomy	All pedagogic practice needs to abide by the external curriculum regulation for the selection, sequencing, pace and criteria of transmission.	Although high autonomy is implied, those in the same practice need to produce a similar environment to create similar learning conditions for all the learners; context and practice is dependent on each individual acquirer's context; resources are not often provided as textbooks or pre-packaged teaching routines, since each individual teacher should be constructing his/her own resources.
8. Economy	Transmission costs are lower than that needed for competency models as teacher training requires less sophisticated theoretical bases, where entire packages and algorithms may be provided; less dependent on the personal characteristics of the teacher; more susceptible to external controls; no hidden costs w.r.t. planning and monitoring.	Transmission costs are higher than that for performance models as interaction time with learners is higher, development of resources takes time, assessments for each learner take time and extensive interaction between teachers for planning and monitoring takes time.

‘competence’ model has weak classification, weak framing with regard to selection and sequencing of content, pace of work and social base, but strong framing with regard to criteria needed to achieve certain qualifications. The ‘competence’ model lends itself more to the use of portfolios, since it allows for more autonomy with regard to task selection and content of tasks, added to the fact that it can then take into account each learner’s prior knowledge. Its more learner-centred approach also encourages each learner to become involved in each portfolio task, challenging him/her to produce high quality work and not just to seek correct answers in as little time as possible. This real engagement with portfolio tasks cannot become a reality if teachers and learners are more concerned about time and number of tasks that need to be completed, instead of providing ample opportunities for active engagement with complex mathematical concepts and thought processes.

3.5 Conclusion.

As the curriculum changes from being strongly classified in a performance model, to one where classification is weaker (as in our current outcomes-based, competence model), assessment practices change too. These changes may be explicitly stated or indirectly implied in the tasks used for the assessment. Either way, both the teachers and the learners need to be aware of what responses are considered to be acceptable and appropriate in this new model of teaching and learning. As the tasks become more investigative and discovery based, the assistance expected from the teachers has to be reduced and the amount of assistance/interaction between peers is increased. So too, the mediation and amount of scaffolding expected from the teacher have to change, in line with the expectations from these alternate types of tasks.

This chapter has discussed a number of concepts that can be used to analyse and discuss the competencies assessed by a mathematics portfolio. The use of such a new form of assessment reflects the weaker framing in operation, i.e. allowing more autonomy over selection of tasks, the pace at which these tasks and other classroom activities are covered, the order of the work covered and a change in the interactions that occur between the teacher and learners and between the learners themselves. In order to challenge the learners to produce work of a continually high standard and to solve problems that are cognitively challenging to them, the teacher and the learners need to be able to operate successfully in each learner's zone of proximal development. What is considered appropriate questions, being able to make use of both everyday- and school-based knowledge at the appropriate times, being able to produce text that is considered both legitimate and suitable to that specific context and ultimately to produce work that is of a high standard, implies the possession of both the correct realisation and the recognition rules in operation at that time. Some mathematical competencies are explicit in their demand, such as being able to successfully manipulate symbolic equations, whereas others such as being able to predict and generalise depend more on understandings of what is considered to be an appropriate extension of one's previous work, thus more implicit in nature. The successful demonstration of mathematical competencies thus also depends on the possession of the recognition and realisation rules for that specific context. What it means to posses some mathematical competency, the derivation of a list of mathematical competencies that will be used to analyse the tasks used for this research report and the criticisms and concerns regarding the use of a competency-based tasks analysis framework will be discussed in the following chapter.

Although found at the end of Chapter 5, Figure 5.2 (p 72) shows diagrammatically the relationships between the theoretical concepts discussed in this chapter and the mathematical competencies developed for the analysis of the tasks used for this research project.

Chapter 4. Assessment and portfolios: A new form and function?

In order to operate within an outcomes-based curriculum, a complete shift in the approach to teaching and learning and in the assessment is needed. This shift will take time, since all stake holders need to understand and support these new principles. It is often assumed that mathematics teachers, who are highly qualified and experienced, will easily make this shift, yet what are the realities, especially in the private schools in this country? The Department of Education has tried to provide mathematics teachers with appropriate guidelines for outcomes-based teaching, yet there is still a wide interpretation of what is expected.

The importance of task selection is entrenched in the following statement by Clark (1996: 349):

> Our conclusions as to the student's achievement of any learning outcome will only be as sound as the range of tasks that we employ to model the outcome (Clark, 1996: 349).

The purposes, forms and functions of assessment, using a portfolio as a new form of assessment in mathematics and how task selection and cognitive demand impact on the development of portfolios in the Grade 9 year, will be discussed in this chapter.

4.1. Assessment: Its purpose, forms and functions

Assessment, that process which was and is still viewed as a separate part of the educative process, one that opens and closes many doors for our learners, one that many see as an interruption in the daily activities of schooling and one which causes much stress and anxiety for our learners, should not take this form within a learner-centred approach. Current assessment in South Africa should be modelled on sound outcomes-based educative practises; it should monitor valued performances, by providing enough opportunities for all our learners to demonstrate their capabilities in forms that can be documented for future reference; and it should inform the actions of all interested stakeholders (Clark, 1996). It should thus be part of the teaching and learning process, not seen to be a separate part of the activities. Teachers should be reflecting on what was learnt from the assessments in order to improve their teaching practises and learners should have the opportunity to learn from their mistakes and improve their competence in all that they do. But is this the reality within mathematics classrooms of today? According to Wiggins (1998), it is possible for our learners to improve, but he states that this will not occur in a norm-referenced, once-off testing system. Real progress is only possible in a system that makes feedback and opportunities for improvement central to the whole assessment process. As in the past, Mathematics assessment has served as a gate keeper for many careers. Selection into many courses has demanded good grades in mathematics and created much competition between learners to gain places in such courses. Assessment should thus motivate and encourage learners (Wiggins, 1998) to produce work of a high standard on an ongoing basis.

4.1.1 So what are the purposes of assessment?

Clark (1996: 363) makes the following important point regarding assessment becoming integrated into the teaching and learning process:

> As assessment is increasingly integrated into instruction, as an inevitable consequence of the demands of outcomes-based performance assessment, both teachers and students will find themselves confronted with assessment information that makes action imperative. It is at this point that assessment will become appropriately located within the curriculum and the relationship between learning, teaching and assessment will become one of symbiosis.

According to the Department of Education (1998, cited in Chamberlain, 1999), the purposes of assessment are diagnosis, evaluation, guidance, grading, selection, prediction and control. The formative purposes are that of diagnosis and guidance, while evaluation, grading, selection, prediction and control are generally considered to be summative. It is the means by which schools and government are held accountable to the community for producing learners with specific competencies required by society. Teachers are held accountable for effective teaching practises and learners are held accountable to produce acceptable standards of work. However, the overall purpose of assessment must be to improve the learning that is taking place, becoming more educative, i.e. instructive, to students, teachers and other stakeholders (Wiggins, 1998). Comparisons between learners should become less important and should be replaced by comparisons of previous assessments on an individual basis (Stenmark, 1989). Thus it should inform future teaching and learning, resulting in good teaching practises, according to the principles expected of the educative system of that time.

It is important to keep in mind that assessment reveals that which society values most, i.e. "what is assessed determines what is taught" (Clark, 1996: 329). Just as teachers teach to the test, so too do assessments reveal to learners what is important. If task selection is still dominated by lower-order skills, with few higher order skills being examined, then that is what learners will aim at. However, if society expects certain mathematical competencies to be mastered at school level, then the assessments used, need to provide enough opportunity for the learners to demonstrate these adequately. The predominance of the importance of systemic (i.e. national) assessments, with its use of written, time restricted examinations in the past, has resulted in a somewhat restricted range of competencies being assessed. By continually using only one such form of assessment, may have served to disadvantage some learners in the following ways:

- a learner may have understood the content/task, but may have required more time than what was allowed, to complete it;
- a learner may have been able to complete the task, but whose demonstration was not adequate due to stress factors;
- second language speakers were and are affected by tasks that require much reading;
- if the context of the task was unfamiliar to the learner;
- if the mode of assessment being used, was a source of cultural conflict for a learner;
- if a learner was expected to respond in writing for example, but who was more capable of demonstrating competency in some other manner; and
- if a learner misunderstood the expectations of the assessment, by perhaps responding simply to an open-ended investigation, when an extended answer was required (Clark, 1996).

These disadvantages become minimised, if teachers are forced to make use of a number a different assessment forms and if ample opportunity is provided for each learner to demonstrate competency. Although generally drawing on their own beliefs and knowledge about school mathematics, assessment principles and strategies and upon their own beliefs about what mathematics is (i.e. whatever paradigm they are operating in, whether ‘absolutism’, ‘fallibilism’, ‘constructivism’ etc.), within their practice, teachers will increasingly become pressured by different stakeholders to use different forms of assessment in their evaluative process.

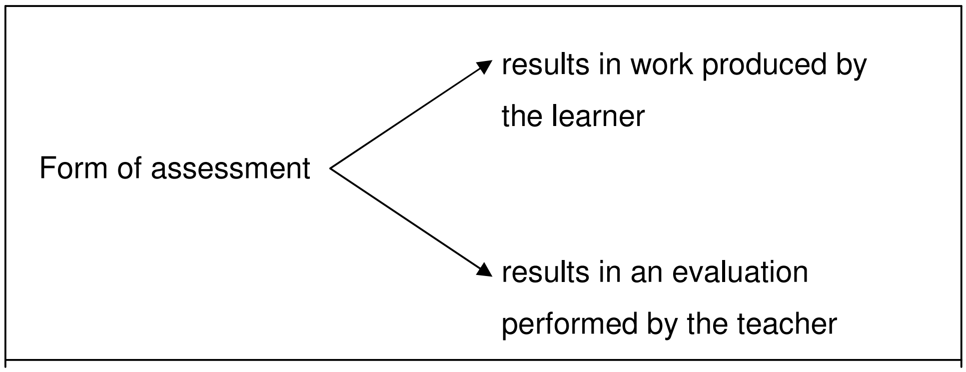
4.1.2. Assessment forms and functions

With regard to assessment practices, Saxe et al. (1999) differentiated between two types of technologies:

- those assessment forms that were used for producing some *performance* from the learners (e.g. exercises, more open-ended problems, investigations), and

- those assessment forms used to *evaluate* learner performance (e.g. percentages, numerical tallies of totally correct answers and rubrics)

Figure 4.1 Assessment forms summary



Assessment for Saxe et al. (1999) is thus a combination of these two forms, one necessary to produce some result by the learners and one used to evaluate the learner's performance. See Table 4.1 (p 34) for a list of different assessment forms and then the functions to which they can be put. However, as Pahad (1999: 251) stated:

> [I]t is not the *form* of the assessment which determines whether or not it is formative or summative (or both), but the *use* to which it is put, that becomes the dominating factor.

With regard to the use of <u>exercises</u>, Saxe et al. (1999), found that teachers could be using these 'old' forms of assessment to serve 'new' functions. They concluded from their two case studies, which revealed that the two teachers involved in their study, were attempting to <u>analyse</u> the students' responses to the exercises and not just to mark them right or wrong. Hence the use of exercises is not all bad.

Differentiation of exam and test type questions in terms of their cognitive demand, such as: questions involving repetition of definitions and theory

Table 4.1 Table demonstrating assessment forms and possible functions

Assessment forms:	Assessment functions	
	More traditional functions	Reformist functions
Exercises	To rank learners (i.e. norm-referencing), focussing on skills and correct answers.	To study learner's misconceptions, methods and thinking processes and to aid in future planning.
Journal writing		To reflect on teaching practices; to reveal learner interests, concerns and misconceptions.
Open-ended tasks	To determine the number of correct answers.	To study learners' insights into methods of problem solving and levels of understanding of certain mathematical concepts; reveal misconceptions; encouraging discovery.
Rubrics and investigations	To use the levels given for each category, as a mark, determining the number of "correct answers", linking grades with percentages.	To study learners' insights into methods of problem solving; their understanding of certain mathematical concepts; ability to generalise; ability to communicate, provide opportunity for self-assessment; encouraging discovery. To reveal to learners their levels of understanding of concepts involved.
Projects and assignments	To rank learners, by assigning percentages.	To offer learners practical experience in applying some mathematical concepts in real world contexts.

only, questions involving the repetition of routine algorithms, those involving the application of previously learned algorithms to unseen situations, and non-routine investigative type questions, will increase the cognitive demand of examinations and tests, but may then make parts of the question paper inaccessible to the weaker learners. Also the time needed to answer such non-routine type questions will have to be factored into the total time allowed for the examination/test. Nevertheless, ‘old’ forms of assessment do still have their place in the classroom and cannot just be abolished for the sake of reform. These more traditional forms of assessment may serve a function as a type of task in the portfolio, but the extent to which they should be used could possibly be limited, compared to the use of more open-ended and investigative type tasks.

With regard to the use of open-ended tasks, Saxe et al. (1999) concluded that after a group of teachers went through some type of reform training, they were more likely to use this form of assessment, yet were less likely to evaluate them by means of rubrics. They concluded then that in contrast to the teachers mentioned earlier who used an ‘old’ form of assessment for a ‘new function’, it could still happen that teachers use a new form of assessment to serve an ‘old function’. Here an open-ended task was evaluated using responses of correct vs. incorrect, an ‘old’ method of scoring learners’ work (Saxe, et al., 1999). Thus old forms of assessment can with a little rethinking, be used for new functions, but the danger remains that teachers may still use new forms of assessment for old functions.

4.2. Portfolios as a collection of different forms of assessment

4.2.1 Towards a definition

Portfolios come in many shapes and sizes; they can be used for a number of purposes and can reflect a number of different perspectives. However, in mathematics teaching and in the General Education and Training Certificate requirements (i.e. the GETC, referring to the certificate issued after satisfying all conditions for promotion at the end of Grade 9), the portfolio has a definite function: to provide evidence of each learner’s work over a period of time. As is stated in the Curriculum 2005

Assessment Guidelines (p 29):

> This evidence of assessment is collected into a **portfolio** that gives a full picture of the learner's performance covering SKVA (skills, knowledge, attitudes and values). To be most effective CASS should employ a variety of forms of assessment.

[CASS refers to the Continuous Assessment component of the year mark for Grade 9, gathered together as the portfolio of work.] The portfolio should reflect a number of different assessment strategies and a number of different tasks spanning exercises, projects, assignments, open-ended tasks and investigations.

Arter and Spandel (1992: 36, cited in Klenowski, 2003: 3) provide a definition of what a portfolio could be:

> [A] purposeful collection of student work that tells the story of the student's efforts, progress, or achievement in [a] given area[s]. This collection must include student participation in selection of portfolio content; the guidelines for selection; the criteria for judging merit; and evidence of student self-reflection.

This definition implies a developmental nature of portfolios, reflecting learner's works over some time, active learner involvement and teacher accountability. Learners can become involved in their assessment, by perhaps including learner-constructed test items in the portfolio, having some input into selection of pieces of work for their portfolios, including a mathematics journal as part of the portfolio, plus using a number of learner self-assessments in the portfolio (Clark, 1996). Its development requires important cognitive and metacognitive skills such as monitoring, planning, reflecting and self-evaluation, although the overall purpose influences the extent of reflection and self-evaluation that will occur (Klenowski, 2003). For this research project, portfolios are thus a collection of tasks reflecting different forms of assessment, it is not a form of assessment on its own. The functions of assessment to which each task is put, is individual to each task, the function of the portfolio is to reflect the mathematical competency of each learner within each task.

4.2.2 Portfolios in MLMMS

Within the Mathematical Literacy, Mathematics and Mathematical Sciences (MLMMS) Learning Area, teachers were expected to teach towards the Critical Outcomes[1] and Specific Outcomes[2] set out by the DOE, assessing the learners using a wide variety of forms (Curriculum 2005 Assessment Guidelines). For both the GETC and the Further Education and Training Certificate (i.e. the FETC, issued at the end of Grade 12), the use of new forms of assessment are expected. As is stated in the FETC Policy document (2005: 1):

> Integrated assessment needs to be incorporated appropriately to ensure that the purpose of the qualification is achieved, and such assessment shall use a range of formative and summative assessment such as portfolios, simulations, workplace assessments and also written and oral examinations.

Hence the use of portfolios in both Grades 9 and 12.

Specific criteria for the appropriate development of these portfolios have been provided; criteria mathematics teachers have to abide by. Within the Independent Education Board (IEB), moderation of these portfolios is carried out by other mathematics teachers and an independent examiner to ensure reliability of results. The power of assessing by means of a portfolio though, is the freedom it allows these teachers and learners with regard to the tasks used and content studied.

As mentioned above, within the MLMMS Learning Area, the portfolio is referred to as the continuous assessment component (CASS) of the GETC. It is expected to cover a range of types of assessments, such as teacher assessment, self assessment, peer assessment and group assessments. In order to satisfy the requirements for the GETC in South Africa in 2003, it had to cover a range of items, the minimum number stipulated by the Independent Examinations Board (IEB) being 19 items. These 19 items included six tests/examinations, eight homework exercises, two individual assignments, one project and two investigations (Curriculum 2005 Assessment Guidelines: 30). There thus existed a tension between doing enough practise on content spanning the more traditional topics and optional sections of work so that the learners would perform well in the Continuous Task of Assessment (CTA) (which was set eternally and which accounted for 25% of the GETC final promotion mark), versus spending enough time exposing learners to portfolio items that span different assessment forms sufficiently.

The intention of the mathematics portfolio was and is to provide quality information about each particular learner's performance (Klenowski, 2003), plus provide evidence that the teachers are using a range of assessment forms, exposing their learners to investigations and projects and not just tests and examinations. So how do teachers go about this, and how do learners respond? This research project will hopefully reveal some other concerns too that need to be kept in mind, in order to improve our teaching practice and be more informed about tasks that we select for our portfolios.

4.3.1 Task selection and cognitive demand: Their impact on the development of mathematics portfolios

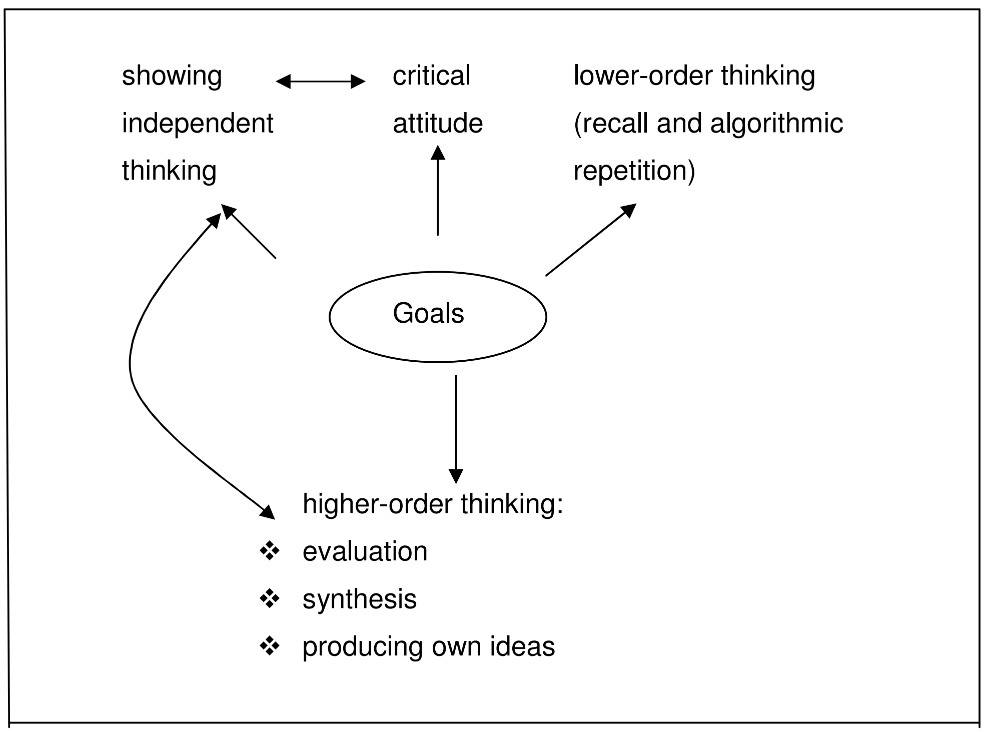
According to Taylor and Vinjevold (1999, 109 - 110), one of the goals[3] of teaching and learning is to

> equip learners to exhibit independence and initiative in directing their own learning….to ask questions, evaluate evidence, defend arguments, and apply their knowledge to new situations. …aquir[ing] higher order thinking skills that

go beyond recall, recognition and reproduction of information, to the evaluation, analysis, synthesis, production and application of ideas.

These goals (see Figure 4.2, below) can be clearly tackled by the use of a portfolio with appropriate tasks being selected, since tests and examinations often do not incorporate many questions requiring higher-order thinking skills and critical, applied thought. As the tasks used in the portfolio form the basis of the learners' opportunities to engage in and learn mathematics, it is important to be clear about these goals for student learning (Stein, Smith, Henningsen and Silver, 2000).

Figure 4.2 Goals of teaching and learning



In order to achieve the above mentioned learning goals, these tasks need to be cognitively challenging and have the potential to involve the learners in complex thinking (Stein et al., 2000). They also need to take into account the age, grade, prior knowledge and individualised experiences of the target group of learners. This is in order to be realistic about the level of challenge provided by each task (Stein et al., 2000).

Complex, high level tasks also need to be done on a regular basis as classroom activities in order to give the learners opportunities to practice that which will be expected of them during the assessment process and not just to satisfy portfolio requirements. However, as Stein, Grover and Henningsen (1996) (cited in Stein et al., 2000:14) caution:

> Although starting with such a task does not guarantee student engagement at a high level, it appears to be a necessary condition since low-level tasks virtually never result in high-level engagement.

Stein et al. (2000: 11) explain the concept of ‘<u>cognitive demand</u>’ as “the kind and level of thinking required of students in order to successfully engage with and solve the task”. Different tasks require different levels of thinking by the learners, as some tasks require only memorisation of concepts or procedures, compared to other tasks that expect the learners to make connections between concepts. For example, as Stein et al. (2000) discuss, most students can do the symbolic manipulation to obtain the correct solution to the product of a binomial multiplied by another binomial (such as $(2x - 1)(x + 3)$), yet may not link this multiplication to finding areas of rectangles with those specific dimensions. The use of manipulatives (such as algebra tiles) may then help the learners to make links between different mathematical concepts.

Stein et al. (2000) also mentioned that although a teacher may begin a lesson using a task of high cognitive demand, there may be a number of factors that could result in it being reduced. These factors could be any of the following:

- an over emphasis on time allowed to solve the task;
- too much emphasis on obtaining the correct answer or using the ‘correct’ procedure;

- ❖ students not being held accountable for using high level processes or producing high level products of work;
- ❖ the task not building on the learners' prior knowledge;
- ❖ challenges within the task not being tackled appropriately, if the learners do not make some necessary conceptual links;
- ❖ students pressurising the teacher to simplify the task;
- ❖ inappropriate scaffolding;
- ❖ task expectations not being made clear enough to the learners (Stein et al., 2000).

Teachers thus need to be clear about the learning goals that they have selected, the level of cognitive demand (Stein et al., 2000) necessary to solve each task and the mathematical competencies that each task demands. In Vygotsky's (1979) terminology, teachers need to be very clear about these goals, in order to facilitate successful operation in the ZPD. The appropriate amount of scaffolding necessary for each learner needs to be determined prior to task introduction. In order to prevent the level of cognitive demand for these tasks decreasing, the learners should also be clear about the expectations for each task and the criteria to be used to assess each one.

The two main findings of the research conducted by Stein et al. (2000: 4) were that:

> mathematical tasks with high-level cognitive demands were the most difficult to implement well, frequently being transformed into less demanding tasks during instruction, and [that] student learning gains were greatest in classrooms in which instructional tasks consistently encouraged high-level student thinking and reasoning and least in classrooms in which instructional tasks were consistently procedural in nature.

Thus the important point is to use high cognitive demand tasks as often as possible, in order to produce good problem solvers. Portfolios lend themselves to the use of such tasks; provided the tasks used are of an appropriate cognitive demand and that the factors mentioned (in the previous paragraph) are reduced to a minimum.

4.3.2. What are the current factors affecting task selection?

i) Firstly, there were certain minimum requirements that needed to be satisfied for the grade nine portfolio in 2003, these being six tests/examinations, eight homework exercises, two individual assignments, one project and two investigations (Curriculum 2005 Assessment Guidelines:30). Teachers involved in this grade, felt pressurised with regard to the number of items that had to be included in the portfolio.

ii) When selecting tasks, the amount of time needed to complete and to mark them was considered.

iii) Teachers had to consider the types of assessment that they had to cover for the portfolio, which had to include peer assessment, self assessment, group assessment and teacher assessment. All forms of assessment had to be covered and thus tasks were often selected on the basis of which type of assessment was needed.

These aforementioned considerations do not emphasise the in-depth analysis of the tasks used with regard to their specific competencies demanded by each task, but more the quantity and spread of assessment methods used. This, I feel is a downfall of the present system and one that needs to be addressed if we wish our learners to benefit from doing portfolio work. Since 2003 however, the number of items to be included in the portfolio has been reduced. Nevertheless, this reduction in number should have allowed teachers to make better choices of tasks. But on what basis should this choice be made?

4.3.3 Improving task selection

i) Mediation in the ZPD

In order to link past learning with the present, tasks should build on and make use of prior knowledge that the learners may have. This prior knowledge may take the form of everyday knowledge (that knowledge the learners bring to the classroom, knowledge imbedded in their personal experiences), or be formal school-based knowledge, that which has been learnt in the classroom (Taylor and Vinjevold, 1999). Tasks selected for a portfolio, should reflect the importance of valuing both types of knowledge, imperative in a learner-based model of teaching and learning, although we do need to exercise caution against placing all (or too much) emphasis on real world examples and also the use of inappropriate everyday situations, as learners may then conclude that all school learning can then be derived from and be applied to the real world (Taylor and Vinjevold, 1999). Competence models as discussed earlier, value the use of both everyday knowledge and school knowledge (Taylor and Vinjevold, 1999) and since we are operating within an outcomes-based model that assesses competencies (i.e. outcomes), both of these knowledge bases need to be built on in the initial stages of working on tasks.

The importance of selecting tasks that build on the learners' prior knowledge, is also mentioned by Clark (1996: 361 - 362) who lists a number of characteristics that a 'rich' assessment task should satisfy, in order to reveal each learner's true competency level. These are:

- The task should connect naturally with what has just been taught.
- It should assess a range of outcomes.
- It should allow all students to become involved in the activity.
- It should allow a range of methods/approaches to solve it.

- It should encourage each learner to reveal his/her level of understanding of what they have learned.
- The task should encourage the learners to show any connections between what they have learned.
- The task should itself be a worthwhile task.
- It should draw the attention of teachers to important aspects of mathematical activity. And
- It should aid teachers in making informed decisions regarding moving on to new concepts or consolidating the present work.

Tasks should not be done just for the sake of providing a certain number of tasks within the portfolio, but should be seen as worthwhile by both the learners and the teachers concerned and where high academic standards of work are subsequently produced in return.

ii) <u>Abstract versus real-life tasks</u>

Some tasks should not involve real-life applications, but should be of a purely abstract mathematical nature, so that the learners view both the workings of pure mathematics versus that mathematics applied to real-life situations.

iii) <u>Enabling informed assessments</u>

Clark (1996: 361 - 362) also mentions the importance of using tasks to make informed assessments about the competency of the learners. Teachers should be able to design and adopt assessment instruments that would enable them to make valid and reliable judgements about what the learners actually know and are capable of doing, exposing their knowledge, insights and skills about mathematics and not only trying to identify what they do not know (Niss, 2002; Harley and Parker, 1999). That is, the tasks thus selected should not result in misleading/unsubstantiated judgements being made about student competency, but be adequate and varied enough to make informed judgements about each learner's competency within each specific outcome. That is, reliability and validity should be maintained.

iv) Enough time and opportunity

Since learners are expected to learn at different rates, teachers should strive to provide enough opportunities for each learner to learn and demonstrate that which is required. There is thus a two-fold expectation of teachers, one to provide the correct learning environment and one to provide enough opportunities to make valid and informed deductions about each learner's competency/demonstration of an outcome.

Portfolio tasks should thus be varied and of adequate number, involve real-life and purely abstract issues, validity and reliability should be ensured for task selection (Niss, 2002), enough time should be provided for the completion of tasks, competencies involved in the tasks need to be identified before they are given to the learners and the final portfolio should reflect all learning outcomes in some appropriate ratio.

4.4 Conclusion

Since the production of a portfolio is a compulsory prerequisite for receiving a GETC and since it dominates much of the teachers' and learners' time during the grade 9 year, we need to devise methods of working efficiently and economically to produce a portfolio of work reflecting all the necessary criteria, yet still involve tasks that are worthwhile for our learners. This highlights the tension caused from operating within a system allowing weaker framing with regard to the selection of communication, the sequencing and pace of work and the control over the social base in operation between the teacher and learners (Bernstein, 1996) versus the strong framing with regard to the criteria stipulated for these portfolios. These tasks should have an initial high cognitive demand (Stein et al., 2000), so that the learners are challenged from the outset to think, investigate, question, hypothesise, predict, critique and explain in order to produce work of a high standard, work that will be worthwhile for them to learn. Tasks used for a portfolio should also build on the learners' everyday knowledge and school-based knowledge, using prior knowledge to initiate their work.

The work produced by the learners can be increased, if the teacher and learners are operating successfully in the ZPD. Appropriate amounts of scaffolding can extend the level of academic success for individual learner, thus maintaining the cognitive demand initially assumed in these tasks.

The purpose of producing an educative portfolio (Wiggins, 1998) (i.e. one that is useful to the learners and to inform teaching practice), should be made clear to all the stakeholders, so that appropriate tasks are selected and also to promote both the use of formative as well as summative assessments. The reality of the current system however, is an emphasis on a summative, certification process, where little (or no) consideration of the actual mathematical competencies being assessed are taken into account. By making more informed choices with regard to task selection, we as mathematics teachers may in the long run produce better mathematics learners, people whose mathematical competencies have been developed adequately through ample exposures to these competencies.

Portfolios do have the potential to produce learners who are willing to accept a challenge, yet it is dependent on the initial tasks that the learners are exposed to. From my own observations at cluster meetings and with discussions with other mathematics teachers, there is a wide range of tasks used in the Grade 9 portfolios across the schools. This is not a problem if everyone has covered some basic minimum expectations, but is this truly the case? What would the result be if one had to analyse the range of mathematical competencies covered by all these portfolios? The development of a composite list of mathematical competencies is presented in the next chapter, which will then in the following chapter be used to analyse the tasks included for the portfolio developed by the 2003 Grade 9 learners at my school.

Notes:

1. The Critical Outcomes that were adopted by SAQA (Taylor and Vinjevold, 1999) as at 2003 and still used in the Revised National Curriculum Statement (Grades R to 9), are as follows:
    1. Identify and solve problems in which responses display that responsible decisions using critical and creative thinking have been made.
    2. Work effectively with others as a member of a team, group, organisation or community.
    3. Organise and manage oneself and one's activities responsibly and effectively.
    4. Collect, analyse, organise and critically evaluate information.
    5. Communicate effectively using visual, mathematical and/or language skills in the modes of oral and/or written presentation.
    6. Use science and technology effectively and critically, showing responsibility towards the environment and health of others.
    7. Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

2. The Specific Outcomes (used in 2003) were that each learner of mathematics, mathematical sciences and mathematical literacy (i.e. MLMMS) needed to be exposed to and be aware of, were as follows:
    1. Demonstrate understanding about ways of working with numbers.
    2. Manipulate number patterns in different ways.
    3. Demonstrate understanding of the historical development of mathematics in various social and cultural contexts.
    4. Critically analyse how mathematical relationships are used in social, political and economic relations.
    5. Measure with competence and confidence in a variety of contexts.
    6. Use data from various contexts to make informed judgements.
    7. Describe and represent experiences with shape, space, time and motion, using all available senses.
    8. Analyse natural forms, cultural products and processes as representations of shape, space and time.
    9. Use mathematical language to communicate mathematical ideas, concepts, generalisations and thought processes.
    10. Use various logical processes to formulate, test and justify conjectures.

SOs 1, 2, 5, 6 and 7 were considered to be the core Specific Outcomes since they were considered to address the main concepts in the MLMMS learning area (Curriculum 2005 Assessment Guidelines: 28). Each SO was assigned a certain number of credits (5, 4, 1, 3, 5, 5, 5, 2, 3 and 3 respectively), 16 in total. Although all the SOs were important, the elective SOs had a lower weighting, since they were closely linked to the five core SOs). Over and above the importance of emphasising the importance of the above SOs, MLMMS also included the study of statistics, financial mathematics, numeracy and spacial literacy, the inclusion of critical analysis, historical development of mathematics and its use in different cultures, plus an emphasis on problem solving and investigative work. These SOs should have guided the development of portfolios and selection of tasks, yet in many cases, teachers were selecting tasks first and then considering which SO's had been assessed.

Since 2005 however, the Revised National Curriculum Statement has changed from the Specific Objectives to Learning Outcomes (LOs), of which there are only five, as follows:

1. Number, operations and relationships:
   When solving problems, the learner is able to recognise, describe and represent numbers and their relationships, and to count, estimate, calculate and check with competence and confidence in solving problems.
2. Patterns, Functions and Algebra:
   The learner is able to recognise, describe and represent patterns and relationships, as well as to solve problems using algebraic language and skills.
3. Space and Shape (Geometry):
   The learner is able to describe and represent characteristics and relationships between two-dimensional and three-dimensional objects in a variety of orientations and positions.
4. Measurement:
   The learner will be able to use appropriate measuring units, instruments and formulae in a variety of contexts.
5. Data Handling:
   The learner is able to collect, summarise, display and critically analyse data in order to draw conclusions and make predictions, and to interpret chance variation.

3. In South Africa, the learning goals were referred to as the Specific Outcomes (SOs) (in 2003) but in 2004, were changed to Learning Outcomes (LOs).

Chapter 5. Mathematical competencies in portfolio assessment.

For the successful implementation of outcomes-based education to occur, assessment practices that reflect the principles of this approach are required. Teachers need to be clear about 'why' they are assessing the learners at that time, 'what' they are assessing and 'how' they are to assess that which is to be assessed (Pahad, 1999). It is the 'what' that I am interested with, since many teachers are just managing to satisfy the numerical requirements necessary for the GETC certificate, but are not totally clear as to what they are assessing in each task. The discussion on competencies will be framed around two foci: one being the use of competencies within the changing assessment practices in South Africa and the other the actual analysis of the competencies in the tasks used in the portfolio assessment.

5.1. Why the use of 'mathematical competencies'?

Niss (2002: 12) states that competencies can be used for two different purposes: (1) for normative purposes, e.g. expressing desired outcomes within the specification of a curriculum, and (2) for descriptive purposes, i.e. to describe and characterise teaching practice, what happens in the mathematics classroom, what is being achieved in tests and examinations and also the actual outcomes of student learning occurring. He also states that a list of competencies can be used for metacognitive purposes, i.e. to inform teaching and learning by "assisting them to clarify, monitor and control their teaching and learning" (Niss, 2002: 12). From a Mathematics teacher's perspective, the descriptive and metacognitive purposes of competencies are to me extremely important in the selection and development of mathematical portfolios and needs to be brought to more teachers' attention.

Added to the purposes of competencies mentioned in the previous paragraph, according to Kraak (1999), there seems to be a return to the use of the word ‘competency’ as is used in the Green Paper on *A Skills Development Strategy* (Department of Labour, 1997) (cited in Kraak, 1999:52), which defines three kinds of competencies:

- “Practical competence: Our demonstrated ability to perform a set of tasks;
- Foundational competence: Our demonstrated understanding of what we or others are doing and why; and
- Reflexive competence: Our demonstrated ability to integrate or connect our performances with our understanding of those performances so that we learn from our actions and are able to adapt to changes and unforeseen circumstances.”

Thus, practical competence would be demonstrated in an authentic context, where certain decisions are made by the learner and the actual task is performed. Foundational competence (i.e. disciplinary thinking) is the ability of the learner to demonstrate an understanding of the knowledge and thinking which that task demanded. And reflexive competence is the ability of the learner to adapt to change, by integrating performances and decisions in unforeseen circumstances (Harley and Parker, 1999). Thus both from a political and practical point of view, by considering the importance of metacognition, plus the descriptive purposes mentioned by Niss above, encouraged me to consider moving away from the analysis of the tasks in the portfolio from the perspective of the Specific Outcomes currently used in South Africa, towards a competence based examination of the portfolio tasks used.

The portfolio items in this research project could have been examined from a number of perspectives, such as listing the different ways in which each task could be solved, their requirements for student communication (while on task), or even the number and kinds of representations used by the students to mention but a few. At present however, I feel that the importance of task analysis in terms of cognitive demand (Stein et al.,

2000) and mathematical competencies involved (Niss, 2002), and in terms of reflecting the goals of teaching and learning, are not being emphasised enough.

With regard to the development of portfolios in Mathematics in South Africa, our teachers need to be provided with some sort of framework that is simple enough to use for the analysis of tasks, but will result in a portfolio develops learners who are critical, independent, adaptable, self-monitoring thinkers. A framework attempting to focus on too many perspectives may result in becoming cumbersome for teachers and thus not practical either. Since many teachers are still operating within a more traditional paradigm and have not changed their teaching practice to the extent required when operating within an outcomes-based system, an analysis from the perspective of mathematical competencies, could provide a new perspective for selecting tasks. This framework could also improve the quality of mathematics taught, develop better portfolios, enable teachers to become more self-reflective and critical of their own teaching methods and philosophies, improve overall teaching practice and provide a new framework for those attempting to develop appropriate tasks/modules themselves.

5.2. Influences on the development of the composite list of competencies used for this analysis

5.2.1 What it means to demonstrate or posses some mathematical competence

The following is an explanation provided by the KOM Project (Niss, 2002: 6 - 7) regarding competence and mathematical competence:

> To posses a competence (to be competent) in some domain of personal, professional or social life is to master (to a fair degree, modulo the conditions and circumstances) essential aspects of life in that domain. *Mathematical competence* then means the ability to

> understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role. Necessary, but certainly not sufficient, prerequisites for mathematical competence are lots of factual knowledge and technical skills, in the same way as vocabulary, orthography, and grammar are necessary but not sufficient prerequisites for literacy.

Thus, to be competent, a demand mastering essential aspects of the field within which one is working is expected; similar to an apprenticeship in other fields of study. Mathematical competence demands the ability to extract the underlying mathematics from a problem (i.e. understanding the problem), being able to make informed decisions (i.e. judging), being able to perform mathematical operations (i.e. doing), and being able to use mathematics in a variety of different domains, i.e. being able to apply one's past experiences and knowledge in order to solve mathematical problems efficiently and sensibly. It also however still depends on possessing the initial mathematical concepts and building blocks that can be applied to these mathematical problems.

As mentioned earlier, any mathematical task demands the use of one or a number of mathematical competencies at a time and thus to inform our teaching practices, it should become standard practice to analyse the tasks before they are given to the learners. To assess each learner's actual mathematical competence, we need to be aware of the following three dimensions:

(1) The degree of coverage: The extent to which each learner satisfies the descriptions of the competence as listed in its explanation provided.

(2) The radius of action: The range of contexts and situations that the learner can apply this competence to.

(3) The technical level: How conceptually and technically advanced the tools are that the learner can apply within this competence. (Niss, 2002:10)

To prevent making misleading judgements regarding the competency or not of each learner, teachers need to be very clear about the characteristics of each competency, provide enough opportunity for the learners to demonstrate each competency and be aware of the range of tools and other instruments that could be used to demonstrate each one.

5.2.2. Derivation of the composite list of mathematical competencies used for this research project

According to Niss (2002: 9), the list of competencies used for analysis, should have a 'dual nature', one of being analytical (focussing on 'understanding, interpreting, examining, and assessing mathematical phenomena and processes) and secondly a productive aspect (that of actually carrying out some mathematical process). Thus, to begin with I decided to use the Danish KOM Project's pre-existing list of mathematical competencies (Niss, 2002: 7 - 9) as a starting point, since this dual nature within each competency is very clear in the list below:

i) **The Danish KOM Project's list of mathematical competencies:**

[Note that competencies (or certain aspects of competencies) listed in this list of mathematical competencies, marked with *, have, in my list of mathematical competencies, not been included. This may be due to the fact that they are not at all assessed in the portfolios used for this research and will then not reveal anything else other than their non-representation; or for reasons explained in the discussion below.]

1. **Thinking mathematically** (mastering mathematical modes of thought) such as
   - ** posing questions* that are characteristic of mathematics, and k*nowing the kinds* of answers (not necessarily the answers themselves or how to obtain them) that mathematics may offer;
   - understanding and handling the scope and *limitations* of a given *concept*;

- extending the scope of a *concept by abstracting* some of its properties; *generalising results* to larger classes of objects;
- *distinguishing* between different *kinds of mathematical statements* (including conditioned assertions ('if-then'), quantifier laden statements, assumptions, definitions, theorems, conjectures, cases).

2. **Posing and solving mathematical problems** such as

- *identifying, posing*, and *specifying* different kinds of mathematical *problems* - pure or applied, open-ended or closed;
- *solving* different kinds of mathematics problems (pure or applied, open-ended or closed), whether posed by others or by oneself, and, is appropriate, in different ways.

3.* **Modelling mathematically** (i.e. analysing and building models) such as

- *analysing* foundations and properties of *existing models*, including assessing their range and validity;
- *decoding* existing models, i.e. translating and interpreting model elements in terms of the 'reality' modelled;
- *performing active modelling* in a given context:
  - structuring the field
  - mathematising
  - working with(in) the model, including solving the problems it gives rise to
  - validating the model, internally and externally
  - analysing and criticising the model, in itself and vis-à-vis possible alternatives
  - communicating and controlling the entire modelling process.

4. **Reasoning mathematically** such as

- *following* and *assessing chains of arguments*, put forward by others;

- *knowing* what a mathematical *proof* is (not), and how it differs from other kinds of mathematical reasoning, e.g. heuristics;
- *uncovering* the *basic ideas* in a given line of argument (especially a proof), including distinguishing main lines from details, ideas from technicalities;
- *devising* formal and informal mathematical *arguments*, and *transforming* heuristic arguments to valid proofs, i.e. *proving statements*.

5. **Representing mathematical entities** (objects and situations) such as
   - *understanding* and *utilising* (decoding, interpreting, distinguishing between) different sorts of representations of mathematical objects, phenomena and situations);
   - understanding and utilising the *relations between different representations* of the same entity, including knowing about relative strengths and limitations;*
   - *choosing* and *switching* between representations.

6. **Handling mathematical symbols and formalisms** such as
   - *decoding* and *interpreting symbolic and formal* mathematical *language*, and understanding *its relations to natural language*;
   - * understanding the *nature* and *rules* of *formal mathematical systems* (both syntax and semantics);
   - *translating* from *natural language* to *formal/symbolic language*;
   - *handling* and manipulating statements and *expressions* containing *symbols* and *formulae*.

7. **Communicating in, with, and about mathematics** such as
   - *understanding others'* written, visual or oral 'texts', in a variety of linguistic registers, about matters having a mathematical content;

- *expressing oneself*, at different levels of theoretical and technical precision, in oral, visual or written form, about such matters.

8.* **Making use of aids and tools** (IT included) such as

- *knowing* the *existence* and *properties* of various tools and aids for mathematical activity, and their range and limitations;
- being able to *reflectively use* such aids and tools.

(Niss, 2002: 7 - 9).

ii) Derivation of my list of mathematical competencies

I found however, that the tasks in my portfolios did not span this entire list of competencies. I thus decided to use most of the listed competencies, but with the following changes:

Firstly, I combined 'thinking' (competency 1) and 'reasoning' (competency 4) into one competency. This was to encompass both the ability to think mathematically and to reason logically, in one gaze. Also, trying to identify these categories separately in the portfolios, without having access to the learners' thoughts at that time, would be no easy task. Within this competency, I then added in the ability to self-monitor one's own work and the ability to use generalisations to predict other cases. These are also aspects of thinking and reasoning mathematically and needed to be included if we are expected to include self-assessment as part of our portfolio development. The ability to generalise and to seek patterns, was listed in the SOs of 2003; reflecting frequently asked questions within tasks chosen for portfolios in the Grade 9 level.

Secondly, I added to the competency involving 'representing mathematical entities' (competency 5), that of 'explaining' them too. The ability to explain the mathematics used and the solutions obtained, is a mathematical competency that needs to be developed in the learners of today. This ability to communicate one's knowledge to others, in an understandable manner, is included in the COs of all the learning areas and thus highlights the importance of this competency.

Thirdly, I also added in ‘memorization’ as a competency on its own. [This addition was due to a consideration of Stein et al.’s Task Analysis Guide (Stein et al., 2000: 16), where low level cognitive demands included ‘memorisation tasks’ which included the reproduction of “facts, rules, formulae, or definitions” and “procedures without connections tasks” that were algorithmic in nature. This addition was made since some problems that the learners were given, could be solved simply by applying previously learnt procedures without having to demonstrate a clear understanding of the procedure itself.]

[The competencies I did not use for my analysis were those of ‘making use of aids and tools’ (competency 8) and ‘modelling mathematically’ (competency 3) (i.e. being able to analyse and build models). Although these competencies are important, they were not examined at all in any of the tasks used and thus would not have revealed anything of importance in my results other than to note their absence.]

With regard to ‘communicating in, with, and about mathematics’, I replaced the word ‘understanding’ in the first line with ‘interpreting’ others’ written, visual or oral texts.

In order to triangulate the derivation of such a list of mathematical competencies, I referred to other theorists who had also mentioned lists of mathematical skills/competencies.

1. Chazan and Yeruchalmy (1992: 91), stated that in order for our learners to become competent at solving open-ended tasks, the following skills should be developed:
   learning to work in groups, knowing how to break down a large ask into smaller bits, using technology, being able to formalise their hypotheses, being able to generalise their hypotheses, being able

to change and extend a problem and argue convincingly about their solutions.

Other skills listed by them were:
communicating, conjecturing, general problem-solving, attitudes about oneself, proving, thoughts about mathematics, generalising, beliefs about inquiry.
[Other than group work, each of these skills can be seen in the pre-existing Danish KOM Project list.]

2. Wiggins (1998: 200), listed the following as mathematical competencies forming part of a performance-based assessment:

- Communication
- Team work
- Problem solving
- Information processing
- Use of numbers and data
- Use of technology.

[Other than group/team work, each of these skills can again be seen in the pre-existing Danish KOM Project list.]

3. Stenmark (1989: 75) listed the following competencies that one should strive towards assessing:

- The ability of the students to use mathematical processes to solve complex problems.
- The ability of the students to formulate a hypothesis, collect and organise the necessary data, explain the concepts orally or in writing.
- Establishing the extent of each student's understanding and any misconceptions about the concepts being used.
- Students should be able to demonstrate their thinking by means of pictures, diagrams, written word or numerical problems, using appropriate tools, e.g. calculators, computers, models etc.

- They should be able to work in groups if needed. And
- Establishing how each student's work changes over time.

[Other than studying misconceptions revealed, group work and looking for some evidence of the developmental nature of the portfolio, each of these competencies can be seen in the pre-existing Danish KOM Project list.]

4. Kilpatrick, Swafford and Findell (2001: 5) discussed what they referred to as "mathematical proficiency" to mean what it means for someone to learn mathematics successfully. Their concept consisted of five strands:

- *conceptual understanding* – implying the comprehension of mathematical concepts, operations and relations;
- *procedural fluency* – referring to the skill in carrying out procedures flexibly, accurately, efficiently, and appropriately;
- *strategic competence* – referring to the ability to formulate, represent, and solve mathematical problems;
- *adaptive reasoning* – the capacity for logical thought, reflection, explanation, and justification; and
- *productive disposition* – the ability to view mathematics as 'sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy'.

It is possible to find a match for each of these five strands with the competencies used for this research. As these researchers mention, there is an "interwoven" (Kilpatrick et al., 2001: 5) nature to these strands and hence to the competencies listed in Table 5.1 (p 61) below. This interwoven nature of competency became evident when looking for evidence from each portfolio for the competence (or not) of each learner. Some statements/tables/diagrams were used to indicate two or more competencies simultaneously.

The importance of metacognition was also emphasised by some theorists. Davidson et al. (1994, cited in Klenowski, 2003: 34), list the following four metacognitive processes that aid in the development of problem-solving skills in an integrated learning area:

1. identifying and defining the problem;
2. mentally representing the problem;
3. planning how to proceed; and
4. evaluating what you know about your performance.

Although processes 2 and 3 are not represented in my list of competencies (as they would have been difficult to assess, given that I was using the end results of the learners' work), those of 'identifying and defining the problem' and 'evaluating' (referred to in my list of competencies as self-monitoring) were included in the final list. This emphasises the importance of the metacognitive process that should be occurring during teaching and learning and during the development of a portfolio. However, further research is needed to expose the full extent of these processes actually being developed during portfolio work.

The category '<u>self-monitoring'</u> that I added into the mathematical competency of 'thinking and reasoning mathematically' has also been mentioned by a number of writers, but under a number of synonyms, such as 'self-management and self-appraisal' (skills explained by Klenowski (2003) as the learner's thoughts about his/her own abilities and the ability to think in action, in order to organise problem-solving experiences). Another synonym for self-monitoring is 'self-regulation', explained by Glaser (1990, cited in Klenowski, 2003: 44) as encompassing the following skills:

- monitoring one's performance;
- checking the appropriateness of strategies;
- judging the difficulty of tasks;
- apportioning time;
- asking questions about the task;
- assessing the relevance of knowledge; and
- predicting the outcomes of performances.

Although 'prediction' was added into the 'thinking and reasoning' competency as a separate category, the rest of Glaser's skills imply the

Table 5.1 Composite list of mathematical competencies

MATHEMATICAL COMPETENCIES	
1. Memorization	a) Memorisation of definitions, concepts and proofs without expectation of any application, interpretation, analysis or synthesis. b) Recall of algorithmic procedures without any expectation of application, interpretation, analysis or synthesis (e.g. solving simple equations, factorising, products of binomials).
2. Thinking and reasoning mathematically	a) Understanding the scope and limitations of a given concept. b) Extending the scope of a concept by abstracting some of its properties, generalising to larger classes of objects. c) Being able to distinguish between different kinds of mathematical statements (such as definitions, assumptions, quantifiers, theorems, cases, conjectures). d) Following and assessing chains of thought by others. e) Knowing how a mathematical proof differs from other kinds of mathematical reasoning. f) Being able to identify the main lines in an argument. g) Proving statements. h) Self-monitoring. i) Using one's generalisations to predict other cases.
3. Posing and solving mathematical problems	a) Identifying different kinds of mathematical problems. b) Solving different kinds of mathematical problems.
4. Representing and explaining mathematical entities	a) Being able to explain procedures of approach used. b) Being able to use different forms of representation of mathematical objects, phenomena and situations. c) Being able to switch between different forms of representation.
5. Communicating mathematically and interpreting mathematical statements	a) Interpreting/decoding others' written, visual or oral texts about issues of a mathematical nature (including open-ended tasks). b) Expressing oneself in oral, visual or written form, using natural language.
6. Handling mathematical symbols and formalisms	a) Translating from formal/symbolic language to natural language (and visa -versa). b) Handling and manipulating statements and expressions containing symbols and formulae. c) Decoding and interpreting statements in the form of symbolic or formal mathematical language.

ability to monitor the process, plan appropriately and reassess the end product before handing it in to the teacher. [See Chapter 6 for actual examples of this concept.]

Table 5.1 (p 61) above, outlines the final list of mathematical competencies used for this research. It is based heavily on the competencies used by Niss (2002) in the KOM Project, but with the aforementioned changes. The dual nature (Niss, 2002) (see p 53 above), of each competency is evident in the table, where the analytical and productive aspect of each competency is still evident.

5.3 Current dilemmas in the development of portfolios for assessment in Mathematics in South Africa

5.3.1 Threats to validity

The issue of validity of these portfolios, i.e. whether the portfolio is actually assessing what it was intended to assess, is perhaps being neglected for a number of reasons.

i) Although each task should involve a number of outcomes they cannot all be covered in one task and if, at the end of the development of the portfolio, all the learning outcomes have not been covered, misleading judgements could be made. “Construct under-representation” (Messick, 1995, cited in Klenowski, 2003: 69) could occur, since the final assessment of the portfolio is not based on all the characteristic dimensions of what the portfolio should represent. Heller (1998: 11, cited in Klenowski, 2003: 69) provided an example of this threat to validity, i.e. when “some aspects of performance do not receive sufficient evaluative attention”. Any conclusions teachers make regarding the proficiency of their learners needs to be based on tasks that have offered their learners ample opportunity for development of the specific outcomes (i.e. the competencies).

ii) In order to gain insights into ‘students thoughts, understandings and explanations’ (Klenowski, 2003: 31), more time is required for assessments than is needed if one is only relying on tests and examinations. However the pressure that the teachers are under to complete all the tasks required for the portfolio in Grade 9, added to the content that also still needs to be taught, reduces the amount of time that can be spent on identifying learners’ misconceptions and probing deeper into their thoughts and explanations.

iii) Also, little consideration is being given to the weightings of the Specific Outcomes within the portfolio.

5.3.2 Reliability

Another concern when using portfolios for summative purposes, is whether the results are reliable or not. ‘Reliability’ refers to ‘the accuracy with which an assessment measures the skill or attainment it is designed to measure’ (Gipps, 1994: vii, cited in Klenowski, 2003: 65). As Klenowski (2003: 65) explains: ‘would the assessment of a portfolio of work result in the same or similar assessment on two occasions if assessed by two (different) assessors?’ Tasks need to be assessed consistently; hence tremendous care needs to be taken especially when criteria can be interpreted in different ways. Moderation on a regular basis is thus extremely important to establish reliability of portfolio assessment. Within the IEB, to ensure equity, fairness and comparability, the portfolios need to be (and are) moderated by a cluster of teachers and a selection from each school is sent to the IEB for external moderation

5.4 Relating the list of mathematical competencies to changing assessment practices in South Africa

The use of a portfolio in the Mathematics Learning Area in South Africa is an excellent form of educational reform, since it has made teachers aware of the benefits of using other forms of assessment and not just time-related tests and examinations. What is possibly not being emphasised during task selection, are the cognitive processes that should occur and what skills and competencies are needed to complete each task. Good teaching practice is being sacrificed in place of stringent course requirements and perhaps it is time that we as mathematics teachers step back and attempt to readdress the actual purpose of introducing the portfolio into the GETC.

In order to ensure curricular appropriateness of my list of mathematical competencies, I needed to cross-check this list with the Critical Outcomes and Specific Outcomes[1] as stated in the National Curriculum Statement for MLMMS (See Table 5.2, p 65, for a comparison of these three aspects). The list of Mathematics Competencies (Table 5.1, p 61) used, may serve to compliment the essence of the current competency-based model of education, with its learner-centred approach to teaching and learning, providing another focus for analysing the tasks selected for the portfolios. As will be noticed from my derived list of mathematics competencies (Table 5.1 and Table 5.2), these mathematical competencies are more general than the Specific Outcomes. The latter are more content-specific as opposed to the mathematical competencies being more generally applicable to any section of work. The mathematical competencies are more directly comparable to the Critical Outcomes but are generally more maths-specific.

There is no match for the mathematical competency involving memorisation, however I feel that this is a competency that needs to be mastered in order to be able to apply the definitions, concepts, proofs and algorithms learnt to other mathematical problems. As mentioned previously in the initial derivation of my list of competencies, the competency involving the use of technology effectively and also now teamwork/group work (i.e. Critical Outcomes 2 and 6), have no matches in my list, although one could find a comparable competency for the former in the list derived by Niss (2002). As mentioned in 5.2.2 above, the

Table 5.2 Relationship between the mathematical competencies, the Critical Outcomes and the Specific Outcomes as used in 2003.

Mathematical Competencies	Critical Outcomes	Specific Outcomes as at 2003
1. Memorisation of definitions, concepts, proofs and procedures.	No match found.	No match found.
2. Thinking and reasoning mathematically.	7. Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation. 3. Organise and manage oneself and one's activities responsibly and effectively.	2. Manipulate number patterns in different ways. 6. Use data from various contexts to make informed judgements. 10. Use various logical processes to formulate, test and justify conjectures.
3. Posing and solving mathematical problems.	1. Identify and solve problems in which responses display that responsible decisions using critical and creative thinking have been made.	4. Critically analyse how mathematical relationships are used in social, political and economic relations.
4. Representing and explaining mathematical entities.	3. Organise and manage oneself and one's activities responsibly and effectively. 4. Collect, analyse, organise and critically evaluate information.	7. Describe and represent experiences with shape, space, time and motion, using all available senses. 8. Analyse natural forms, cultural products and processes as representations of shape, space and time.
5. Communicating mathematically and interpreting mathematical statements.	5. Communicate effectively using visual, mathematical and/or language skills in the modes of oral and/or written presentation.	9. Use mathematical language to communicate mathematical ideas, concepts, generalisations and thought processes.
6. Handling mathematical symbols and formalisms.	4. Collect, analyse, organise and critically evaluate information.	1. Demonstrate understanding about ways of working with numbers. 2. Manipulate number patterns in different ways. 5. Measure with competence and confidence in a variety of contexts.
No matches found.	2. Work effectively with others as a member of a team, group, organisation or community. 6. Use science and technology effectively and critically, showing responsibility towards the environment and health of others.	3. Demonstrate understanding of the historical development of mathematics in various social and cultural contexts.

use of aids and tools was not emphasised in the portfolios used for this research and hence not included in my composite list of mathematical competencies. Further research using other portfolios may require the addition of this mathematical competency. Working in groups/teams could not be studied using these completed portfolios and so is not reflected in my list of competencies either.

5.5 Criticisms and concerns with regard to the use of a competency-based task analysis framework

One concern with regard to the assessment of competencies is that a competency demonstrated in one community of practice cannot always be assumed to be transferable to another community of practice. Thus for example, one could possibly assume that the competency of ‘posing and solving problems’ is generalisable over the whole learning experience. However it may be possible that a learner displays this competency better in the mathematical sciences than in the human sciences for example. As is discussed and cited in Kraak (1999: 51), Wolf (1998) argues that “skill competencies are highly contextualised” and thus a broader set of competencies is needed. This issue of transferability across learning areas is one that needs to be addressed, demanding more discussion between teachers of the different learning areas. Also, making the list of competencies too broad, then subjects the list to the criticism that they are open to different interpretations. Teachers need specific guidelines when using some new approach to task selection. Each competency needs to be clear and unambiguously stated.

Another criticism aimed at the attempt to break up each competency into small bite sized components, is mentioned by Resnick and Resnick (cited in Klenowski, 2003), who argue that one cannot list all the components when assessing complex competencies. This is a valid criticism, and one which I needed to keep firmly in mind when discussing the final results.

This list of competencies and categories should by no means be seen as a complete list of mathematical competencies, but one that revealed some inadequacies in the portfolios that I was using as my data. By using some other list, I would expect that other issues would also be revealed, important issues that those in political positions and teachers of mathematics need to be made more aware of. This research is one case of portfolio development and obviously cannot be generalised to the whole mathematical community.

With regard to the analysis of a competency, teachers should be aware of the distinction between being able to demonstrate some competency, versus being able to explain why the procedure takes the form it does, i.e. demonstrating ‘how’ versus knowing ‘why’ (Clark, 1996). Different degrees of demonstration may result in different inferences being made regarding the competency of some learner. According to Clark (1996: 348), errors of inference can occur in two different ways:

- Firstly, a successful demonstration of a competency, may lead one to assume a level of understanding that is actually not present; and
- Secondly, if some competency is unsuccessfully demonstrated, then one may make the assumption that there is a lack of understanding, when it may actually be there.

These errors of inference are also mentioned by Cooper and Dunne (2000: 112), who discuss the issue of ‘false positives’ and ‘false negatives’ in their results. The former occurred when the learner obtained full marks for a problem yet may have used their own everyday knowledge and not the given data to solve it and the latter is when a learner’s “*performance* has not [truly] reflected their *mathematical competence*” (Cooper and Dunne, 2000: 112). Also, considering the degree of difficulty of tasks, invalid inferences could occur when a learner, assigned a specific grade in an easier task, is compared to another more capable learner who is assigned a similar grade in another more difficult task (Koretz, 1998, cited in Klenowski, 2003: 89). The difficulty of each task thus also needs to be taken into account.

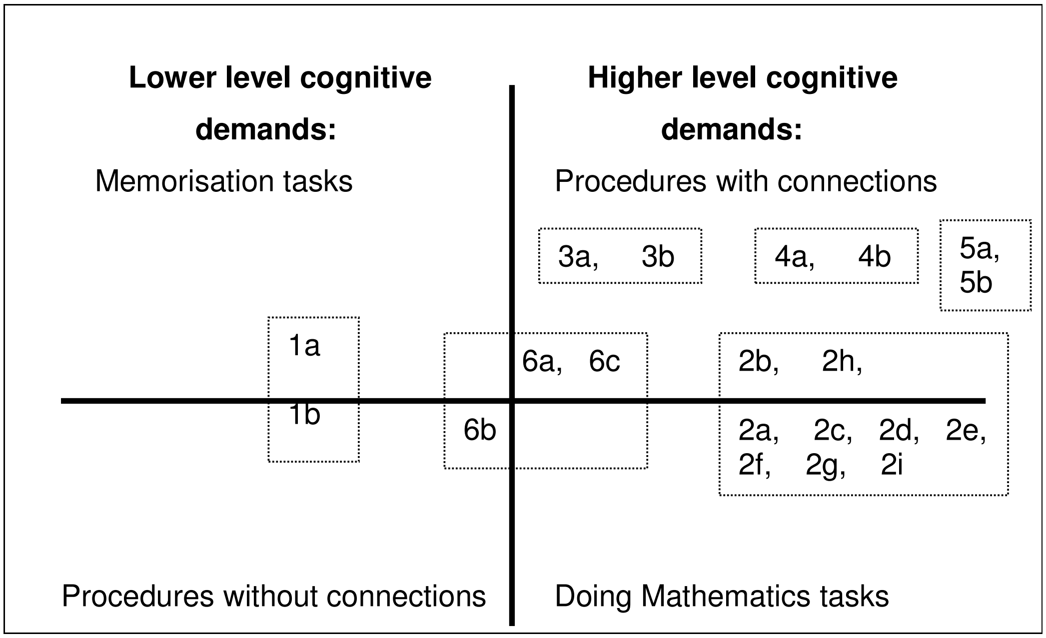
Since errors of inference are an issue within any assessment process, Clark (1996) suggests including tasks that are spread over a variety of contexts, i.e. a physical activity demonstrating the competency/concept; a real world application and a task imbedded in abstract mathematics. The importance of selecting tasks that demand the use of everyday- and school knowledge (Taylor and Vinjevold, 1999) was mentioned earlier (see 4.3.3). Clark states that one can then safely and 'confidently infer satisfactory achievement of the learning outcome' (Clark, 1996: 349). Since outcomes-based education is based on the successful *performance* of some outcome, this need for inference is reduced, however it does require careful consideration of how the learning outcome is stated and 'successful performance' needs to be clearly defined.

We should also ask the question: Does the portfolio reflect a developmental process of learning and improved competency? This developmental process should inform future teaching, as isolated/irrelevant tasks may not encourage further discussion and learning.

In attempting to analyse the cognitive level of competencies, I referred to the Task Analysis Guide provided by Stein et al. (2000: 16). One can categorise each competency according to cognitive demand (see Figure 5.1 below, p 69).

It must be kept in mind however that just as the cognitive demand varies throughout a task from question to question, so too there may be some overlap in cognitive demand depending on the task analysed and the category one is considering within each competency (hence the overlaps shown in each box). This categorisation thus remains dependent on the

Figure 5.1 Cognitive levels of competencies



[Note that the numbers in this figure refer to the competencies 1 – 6, discussed in Table 5.1, p 61 above.]

task analysed and the amount of scaffolding that may take place during the exercise, as stated by Niss (2002: 10) this would depend on the radius of action and the technical level of that competency. Also, the dual nature of the competency affects this categorisation of the cognitive level of the competencies, since analysing and interpreting a problem may be considered of higher cognitive demand than that of performing a mathematical procedure/process.

5.6 Conclusion

Providing mathematics teachers with a framework for the analysis of assessment tasks may be an important step in improving the types of tasks that teachers are currently including in their Grade 9 portfolios. However, this framework needs to be simple and user-friendly, in order to encourage teachers to use it on an ongoing basis. As is implied in the use of a portfolio in Mathematics, its power lies in the wide variety of tasks that can be used, its ability to be applicable to different learners in various circumstances and economic situations and also the improvement it has had in the ways in which we as Mathematics teachers assess our learners. However we must not get too complacent in our work, since there is still much to improve on. In 2003 not much emphasis was placed on the importance of assessing (and the learners 'achieving') the core specific outcomes in the portfolio according to the specified weightings (Curriculum 2005 Assessment Guidelines, p29). Teachers had thus not taken this into account when selecting tasks for these portfolios. Other factors such as the time it took to mark a task, the type of assessment it involved and the time it took to complete the task were possibly considered more than satisfying some expected ratio of assessment of outcomes. It thus meant that they had as yet not fully assimilated the specific outcomes into their teaching practices.

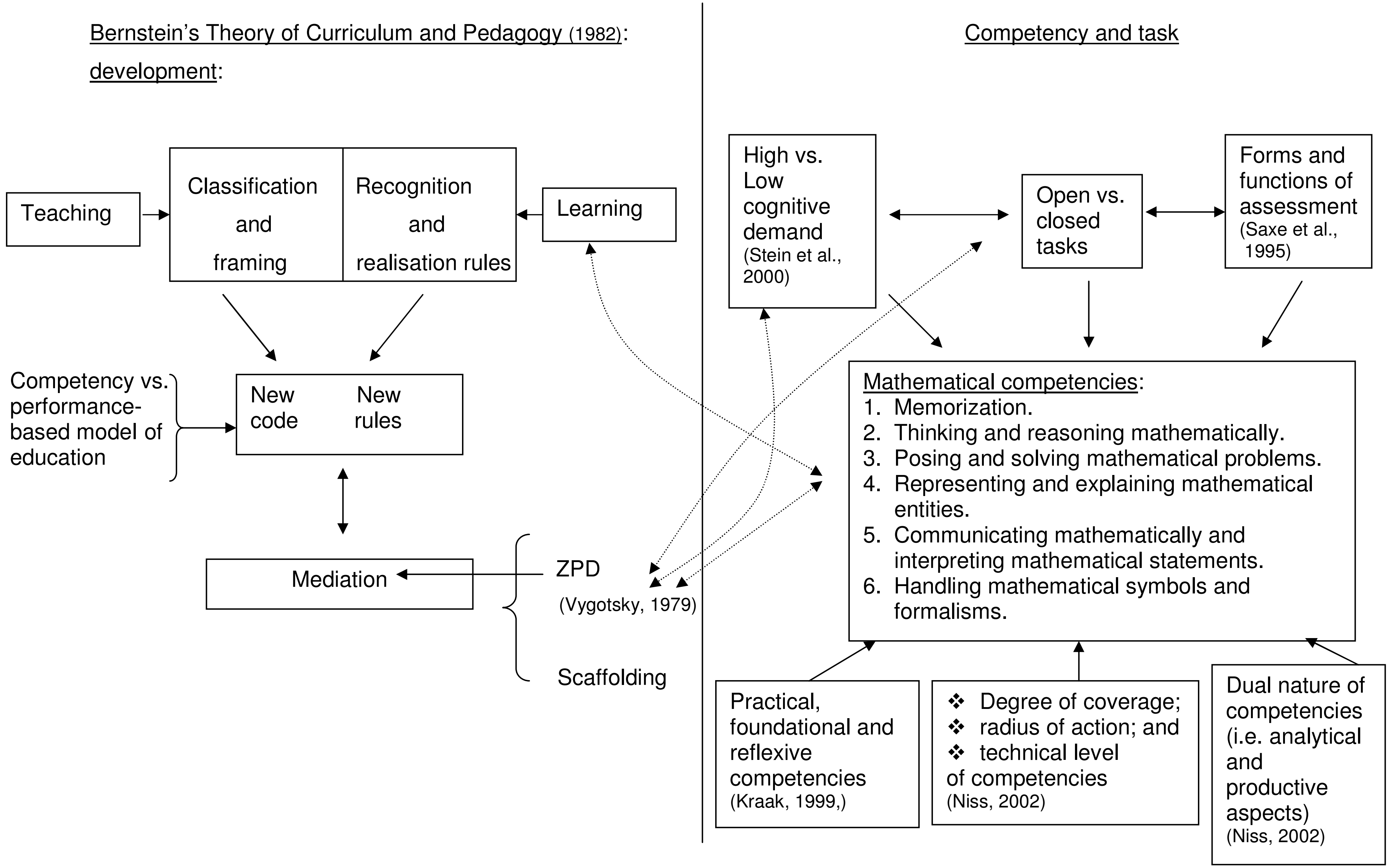
The reflexive competence mentioned by Kraak (1999) regarding the ability to adapt to change is an important aspect of teaching/learning in South Africa in the context of technological improvements and internet availability. Our learners need to be able to adapt to the circumstances that they may find themselves in, apply their knowledge and solve problems, using different sources of information and technology available to them. The weaker classification (Bernstein, 1996) of the current educational system that is in use in South Africa, allows the learners to master this competency across all learning areas, integrating content and skills across 'learning areas'.

Not only will the learners then benefit from such a framework of competency analysis for task selection where the tasks will have a better 'balance' of competencies being assessed, but teachers could also develop their own competency in developing mathematical portfolios. We as teachers should be analysing more carefully the mathematics that we are exposing our learners to when developing such portfolios. Added to which we should be using our analysis of the tasks used from previous years in order to inform our own teaching practices for each subsequent year. The weaker framing with regard to the selection of the communication and control over the social base, allows for the use of alternate forms of analysis wherever deemed necessary.

Also, not only is the consideration of the mathematical competencies being assessed in the tasks used, important, but also the cognitive demand expected by each task. In order to enable high level cognitive thoughts to take place within our learners, we need to begin with high level cognitive tasks. It is important also for teachers to be aware of how the different ability groups of learners fare in respect of these mathematical competencies. This research is aimed at reflecting one case of such an analysis with respect to the cognitive demand expected by the tasks and also the competencies assessed by them.

There are a number of lists of competencies that one could use for such an analysis; however I have attempted to develop one more reflective of the South African context. It is by no means a complete list of competencies, since as was discussed, the competencies involving the use of aids and tools and the making of models, was not at all assessed in this portfolio and was thus excluded in my list of competencies completely. The tasks analysed in my research, will be analysed from the perspective of the competencies that each task demanded as they appeared before the learners were introduced to them (i.e. as they initially appeared) and then what competencies the learners could actually demonstrate in order to successfully complete each task. The question of who benefits from which tasks and who performs better at which competencies, will also be addressed in the chapters to follow. In summary, the following schematic diagram (Figure 5.2, p 72) links the theoretical and practical influences and relationships between the concepts used for this research.

Figure 5.2 Relationships between theory, competencies and task development



<u>Notes:</u>

1. See footnote 1 (p 47) at the end of Chapter 4, for a list of the Critical and Specific Outcomes as stated in the National Curriculum Statement.

Chapter 6. Methodology.

6.1 Initial aspects of the research process

6.1.1 Description of initial thoughts, environment of research and research approach

This research was initiated from a discussion with my supervisor regarding the concerns that many Grade 9 and Grade 12 teachers (at the cluster group meetings and conferences that I attended) voiced with regard to pressures felt whilst developing the required portfolios for each grade. These teachers were concerned about the vast differentiation noticed at the moderation and cluster meetings regarding tasks chosen and assessment strategies used for the assessments across the various schools. The levels of cognitive demand varied widely from task to task and from school to school, and thus some standardisation seemed necessary.

This research takes place in a single-sex private school. It involves an analysis of the Mathematics Grade 9 portfolios developed during the year 2003, focusing specifically on the competencies assessed by a selection of the tasks included in this portfolio (i.e. the initial tasks as presented to the learners prior to any discussion in class) and the competencies actually demonstrated by the 29 of the 54 Grade 9 learners of that year who had agreed to be involved in my study.

It is based on an interpretive case study approach, a small-scale project, with some subjectivity involved (when I had to decide the competence (or not) of the learners). It is an attempt at understanding the actions/interpretations of current assessment changes in South African school, in terms of the way in which a new form of assessment is introduced and incorporated into the current Grade 9 year. This project investigates the taken-for-granted idea that teachers who are well-qualified in Mathematics and have many years of experience in teaching the subject, will automatically internalise and begin practising the expectations of the new curriculum as intended by the curriculum designers, in terms of the use of alternate forms of assessment to develop a portfolio reflective of each learner's ability at that time. However, some calculations involving the mean of a group include a quantitative aspect to the project. These calculations are subjected to interpretation rather than being used to state significance. Thus a pragmatic approach has been used.

The sample used is a convenience sample (McMillan and Schumacher, 1993), since it took place at the school at which I am presently teaching. As mentioned above, of the 54 Grade 9 learners in 2003, 29 agreed to take part in my research. I was initially disappointed with this number, but realised that that is what happens in realistic research. It was however a relief to see that I did have a selection of learners that could be grouped according to ability (see below for an explanation of how the different ability groups were obtained).

Informed consent was achieved by providing each of the Grade 9 learners with a letter explaining the purpose of my research, guaranteeing total anonymity with regard to the use of their portfolios in my study, stating that their participation would be totally voluntary and requesting parental permission for their participation [See appendix A, 159, for this letter of consent]. This letter of consent also requested their participation in terms of answering a questionnaire and possibly being selected to take part in an informal group interview. However, I believe that those portfolios that I was allowed to use, did provide enough of a spread to provide insight into the problems of introducing a new form of assessment into schools with similar characteristics as the school at which this research was done, although this small sample does not allow me to make any generalisations to the wider community of learners and also schools.

6.1.2 Tasks: Open-ended or not

Since the decision to use the Grade 9 portfolios for my research was only made near the end of 2003 when their portfolios were completed and since I had not been involved in the teaching of the Grade 9's during that year, any effect that I may have had as researcher on the performances of the learners was reduced. The only influence that I had on these portfolios was providing one task, that of the Hide the Spies Investigation to the teachers.

Once the portfolios and all necessary work for the school were completed, I was then allowed to begin my work on the portfolios. After analysing all 19 tasks used to make up the portfolio for 2003, I decided to use only seven of these, since the rest were the more traditional test and examination oriented types of tasks that we were used to using up till that time anyway. These seven were the most open-ended tasks or tasks that involved everyday contexts of study familiar to the learners. They were the only tasks used that year that could be regarded as alternate forms of assessment. [See Appendix B, p 162 – 184, for the seven tasks used for this research.]

The open-endedness of tasks encompasses the idea that there is not just one solution to the problem, obtained in only one way, but a number of possible solutions. An open-ended task would usually consist of a number of aspects/problems that need to be considered to solve the task. As the learners solve each aspect of the task, each of these may lead them to move in various directions. Hence the uniqueness of the final work produced by each learner or group of learners. The extent of such tasks are limited only by the initiative shown by students or the time available to them. Appropriate scaffolding may help each learner to reach heights and solve aspects of the task that he/she would not have been able to solve without the intervention of teachers/peers. Investigations usually allow for extensions of the task, although the ability to extend such tasks in appropriate directions needs to be practised, since some learners may extend tasks in a manner that is not related in any way to the initial task or will not lead to new information.

As was mentioned earlier, the tasks making up the whole portfolio, were not all 'open-ended' or investigative in nature. Since this research project was to study the use of open-ended tasks in new forms of assessment, not all the tasks were used. The tasks that were classified as most open-ended, were as follows:

Task 1:	Towers of Hanoi
Task 2:	Thomas Saint's Test and Memo
Task 3:	Hide the Spies
Task 4:	Cartesian Plane Exercise
Task 5:	Homework Exercise on Interpreting Graphs
Task 6:	Going Shopping
Task 7:	Homework Exercise on Statistics

[See Appendix B for the tasks used.]

The one purely investigative task was Hide the Spies. This task is clearly a higher order task in terms of cognitive demand. There is no set procedure to solve this task and no scaffolding is provided for the extension part of this task. The Towers of Hanoi is less open-ended in nature compared to the Hide the Spies task, although it can still be classified as 'open-ended'. The cognitive demand for Thomas Saint's test and memo differ for different questions asked within the test. There are 5 questions that demand only one step and 3 that demand two or more steps in order to be solved. These are procedural in nature when asked in the test, yet when following Thomas's methods in the solutions provided, it demands other competencies, i.e. that of following and assessing chains of thought by others and communicating mathematically (i.e. Competency 2 (e) and Competency 5). The cognitive demand for these three tasks were high. However, the rest of the tasks tended not to be open-ended at all, since only one correct answer was expected for all the questions asked in the graphs, shopping and statistics tasks. Also, some of these more 'closed' tasks were reduced in cognitive demand, due to some provision of formulae by the teacher (see the exercises on graphs and the shopping exercises).

Some tasks are initially open-ended, but may be reduced or have the potential to be reducible due to actions verbal or written, by the teacher or peers. By providing hints or suggestions, or attempting to work in the zone of proximal development (but providing too much help), tasks may be reduced in cognitive demand. Thus my expectation of using only open-ended tasks was not totally accomplished. Overall however, the tasks chosen for this research were the more varied in exposure with regard to the mathematical contexts, compared to the usual tests and examinations.

The choice of tasks used for this portfolio indicates the problem of expecting the teachers to produce a new form of assessment, within the confines of strong framing with respect to criteria and weak framing with respect to selection of content, sequencing, pace and social base. By specifying what has to make up the portfolio and by noticing that there is still a dominance in the use of exercises (an old form of assessment), there is still a problem with the development of the portfolio as a new form of assessment. Old forms of assessment (i.e. the exercises) are beginning to be used for new purposes (as items included in the portfolio), yet what then is the overall purpose of the portfolio? Are these exercises informing future teaching and learning that occurs with these learners, or are they simply being used as summative evaluations of each learner's capabilities at that time? What are we achieving by including such items in the portfolio? Is it still dominated by traditional forms of assessment, or are we moving towards a portfolio that indicates mathematical progress/development over time?

6.1.3 Grading of tasks

With regard to the grading of these tasks, they were all graded using percentages. Even the one purely investigative type task, i.e. Hide the Spies, although assessed using a rubric, these levels were eventually converted to marks and finally a total was found. Perhaps instead of levels, one should alter the rubric to one which used words of "attained', "partially attained' and 'not yet attained'. New forms of assessment were used for old purposes, to provide a percentage that could be used to compare learners and did not provide opportunity for improvement of work, since this once-off mark was never changed. One should also remember that assessment is not synonymous with 'grading', since grading is only one simplistic form of coding some assessment data (Clark, 1996). Assessment conclusions should not be communicated via only one means of coding such as grading, especially not open-ended tasks and investigations, since grading tends to condense and categorise learners' work (Clark, 1996), sacrificing a whole lot of detail that may be of importance when deducing the competency of some learning outcome.

From the above, one notes that the marks obtained and any conclusions made about each learner, are still based on each form of assessment being used for more traditional functions and not to analyse misconceptions, reflect on teaching practices, study learners' insights into problem-solving strategies. A study of the recognition and realisation rules

(Bernstein, 1996) in operation in each task, have been overlooked. The ability to produce legitimate text, i.e. possessing the 'realisation rules' to answer the different tasks, have not been analysed within the assessment criteria, hence not leading to an appropriate interaction on the part of the teacher to provide further opportunity to attain these 'realisation rules'. Each task is summative in its own right and hence does not provide for improvements in competency.

6.1.4 Initial steps towards the analysis

[Note that this initial discussion refers to tables that will only be found in the following chapter, i.e. Chapter 7. Although referring forward, these tables are part of the analysis and are hence included in that chapter and not this one. Page references have however been provided for easy reference.]

The initial part of this research involved the derivation of the list of mathematical competencies that would be used as the instrument of analysis (see Table 5.1, p 61, for this list of competencies). As was discussed in Chapter 5, this list was based on the mathematical competencies listed by Niss (2002) and used in the Danish KOM Project, with some minor changes. It was compared to other theorists in order to establish validity and reliability of the instrument. What followed then was an analysis of the tasks and each learner's work according to this composite list of mathematical competencies

The seven tasks used for this research, were analysed according to the list of mathematical competencies in order to answer the first of my research questions, i.e. which competencies were actually assessed by the tasks in this portfolio and the number of times they were assessed across the seven tasks. Identifying characteristics of the different competencies had to be derived from each task, in order to begin the analysis. Table 7.1 (p 97 - 98) provides an explanation of what I considered to be indicative of the competencies incorporated in these tasks, i.e. indicating how each competency was identified in each task.

From this table, I could calculate which competencies were assessed most frequently and which were not assessed at all. Table 7.2 (p 99) summarises the number of occurrences in the original tasks.

In order to answer my second research question, I listed all the learners and their percentages obtained for their final promotion mark at the end of Grade 9, the percentage obtained from the portfolio (referred to as their CASS mark) and the percentages obtained for each of the seven tasks used for this research. These percentages did not clearly show any relationships or points of interest and thus I decided to divide the learners into ability groups in order to see if there were any patterns to be noticed with this division (see Tables 7.3 and 7.4 (p 107 - 108) for these percentages). The learners were grouped according to levels of ability deduced from percentages obtained from their final promotion mark for Grade 9. I divided them into 4 levels:

Level 1 = 0 – 39 %
Level 2 = 40 - 59 %
Level 3 = 60 - 79 %
Level 4 = 80 - 100 %

This division indicated that I had one level 1 learner, five level 2 learners, eighteen level 3 learners and five level 4 learners. Due to having only one level 1 ability group learner, I decided to exclude this learner's results from all of the discussions presented here. Making any conclusions about level 1 learners, would be very misleading since the sample was so small. Although Levels 2 and 4 were also small samples, I had no option but to use these samples as is. These divisions helped me answer sub-question 2(a) regarding any apparent benefits that the different ability groups had from the inclusion of the portfolio in their promotion marks.

The seven tasks were then divided into two groups, those that were more open-ended (i.e. the Towers of Hanoi task, the Hide the Spies Investigation and Thomas Saint's Test and Memo) and those that were the more closed types of tasks (i.e. the Going Shopping, Cartesian Plane Exercise, Interpreting Graphs and Statistics tasks). By using the percentages obtained for each of these seven tasks by each of the 29 learners, two comparative means were obtained for each learner with regard to open versus closed types of tasks (See Tables 7.3 and 7.4, pp 107 - 108). This enabled me to answer question 2(b), regarding how each of the different ability groups fared in the open-ended tasks versus the more closed types of tasks. Incorporated in this discussion is the analysis of the tasks from the perspective of the cognitive demand involved in each task. The cognitive demand of the tasks chosen for this portfolio varied from low cognitive demand (in the routine exercise-type worksheets) to high cognitive demand (evident in the Hide the Spies Investigation).

Lastly, the different ability groups were used to answer question 2(c), regarding the proficiency (or not) of each ability group in each of the mathematical competencies. Using Table 7.1 (pp 97 - 98) (i.e. identifying each competency/category of competency in each task), Appendix C (Tables C1 – C6, pp 185 - 198) reflect the initial steps towards the analysis, where I assigned a ‘1’ to the learner if I was confident that that category/competency had been displayed, a ‘0’ if I was unsure and a ‘–1’ if the category was definitely not displayed. The following are some examples of what I considered as a competency either ‘clearly demonstrated’, where I was ‘unsure’ or where the competency was ‘not clearly demonstrated’ (taken from the Towers of Hanoi task):

6.2 Examples to illustrate the competency or not demonstrated by the learners (exemplars are for Competencies 2, 3 and 4):

[Extracts are taken from the Towers of Hanoi Task.]

6.2.1 Competency 2: Thinking and reasoning mathematically:

Category 2b): Extending the scope of a concept by abstracting some of its properties, generalising to larger classes of objects.

i) Competency 2b clearly demonstrated: Reference Lesley:

Table 6.2.1

Number of rings	Number of towers	Number of moves
1	3	1
2	3	3
3	3	7
4	3	15
5	3	31
R	3	$2^R - 1$

2 (to the power of the number of rings) - 1 = Number of moves

e.g. $M6 = 2^6 - 1 = 64 - 1 = 63$ moves

i.e. $M1 = 2^1 - 1 = 2 - 1 = 1$

$M2 = 2^2 - 1 = 4 - 1 = 3$

:

$MR = 2^R - 1$

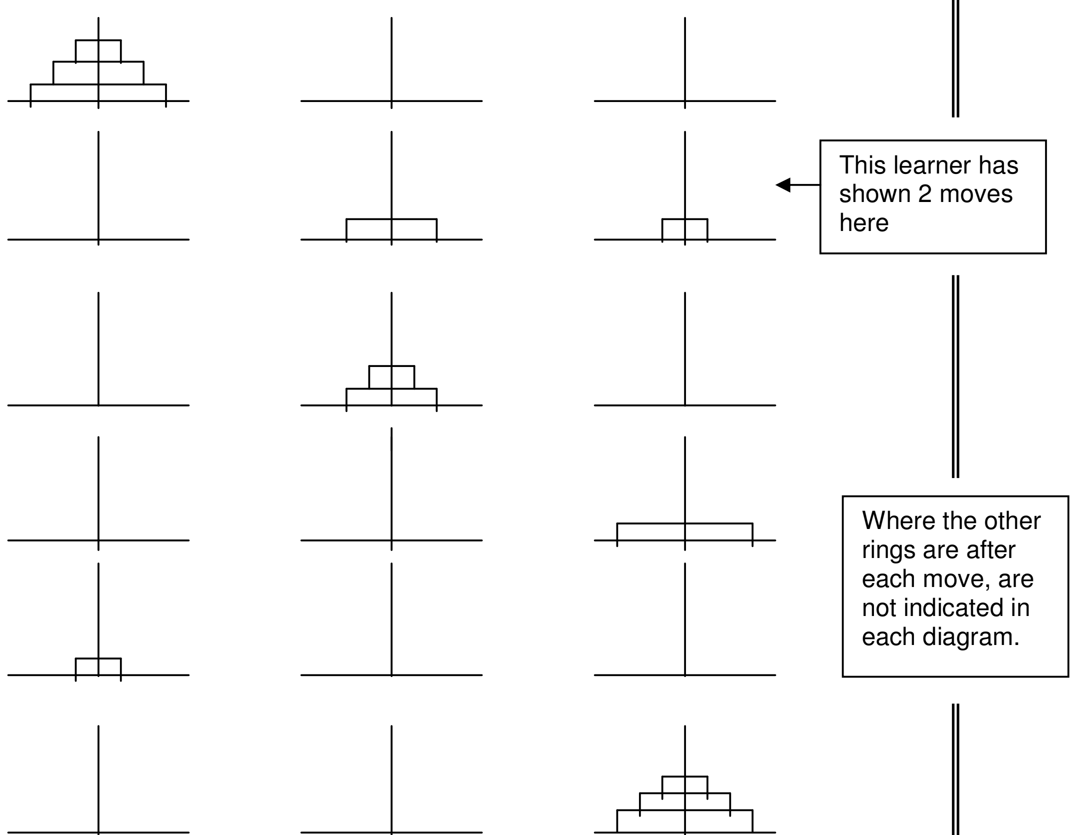
One can see that this learner has demonstrated this competency of abstracting and generalising to some larger class of objects.

ii) Competency 2b, not clearly demonstrated: e.g.1: Reference: Ana

"2 rings = 3, 3 rings = 7, 4 rings = 15, 5 rings = 35
4 X 2 = 8 X 2 = 16 ∴ formula = double the amount."

iii) Competency 2b, not clearly demonstrated: e.g.2: Reference: Sam

This learner's diagrams do not clearly illustrate the number of moves made, e.g.: This is her answer to moving three rings:



After using diagrams to illustrate her moves for the different number of rings, she writes:

"3 + 3 + 1 = 7	The formula goes as follows:
7 + 7 + 1 = 15	the number must be doubled and
15 + 15 + 1 = 31	then you add one."

6.2.2 Competency 2c: Being able to distinguish between different kinds of statements (such as definitions, assumptions, quantifiers, theorems, cases and conjectures).

i) Competency 2c clearly demonstrated: Reference Lesley:

If one refers back to Table 6.2.1 (p 83) above and the excerpt from Lesley's work (6.2.1 (i)), we can see that she has clearly demonstrated each case in the form of a table and then generalised to $2^R - 1$.

Also, her answer to the question of when the world will end, is written clearly as

"M64 = $2^{64} - 1$ = 18 446 744 073 709 600 000 – 1
= 18 446 744 073 709 599 999 moves."

Thus I felt that this learner could distinguish between different kinds of statements.

ii) Competency 2c demonstration unsure: Reference Ana:

"2 rings = 3, 3 rings = 7, 4 rings = 15, 5 rings = 35
4 X 2 = 8 X 2 = 16 $\therefore$ formula = double the amount."

As is used to demonstrate competency 2b above, Ana's solution to each question, added to her 'formula' do not clearly demonstrate her ability to differentiate between cases, generalisations and conjectures.

She however, follows this statement with the answer $2^{64} - 1$. It is unclear from where this solution originates and whether it is legitimately her own solution.

iii) Competency 2c <u>not clearly demonstrated</u>: Reference Ruth:

Her solutions for each question are: 2 rings - 3 moves
3 rings - 6 moves
4 rings - 18 moves
5 rings - 34 moves.

She states the correct generalisation, as $2^R - 1$, although it cannot follow from the above solutions. This generalisation is obviously not her own legitimate work.

iv) Competency 2c <u>not clearly demonstrated</u>: Reference Thandi:
She provides a 'generalisation' of "$2^5 - 1 = m$" and then predicts 2^{64} as when the world will end. There is no differentiation between generalisations and specific cases.

6.2.3 <u>Competency 2h: Self-monitoring</u>.

i) Competency 2h <u>clearly demonstrated</u>: Reference Lesley:

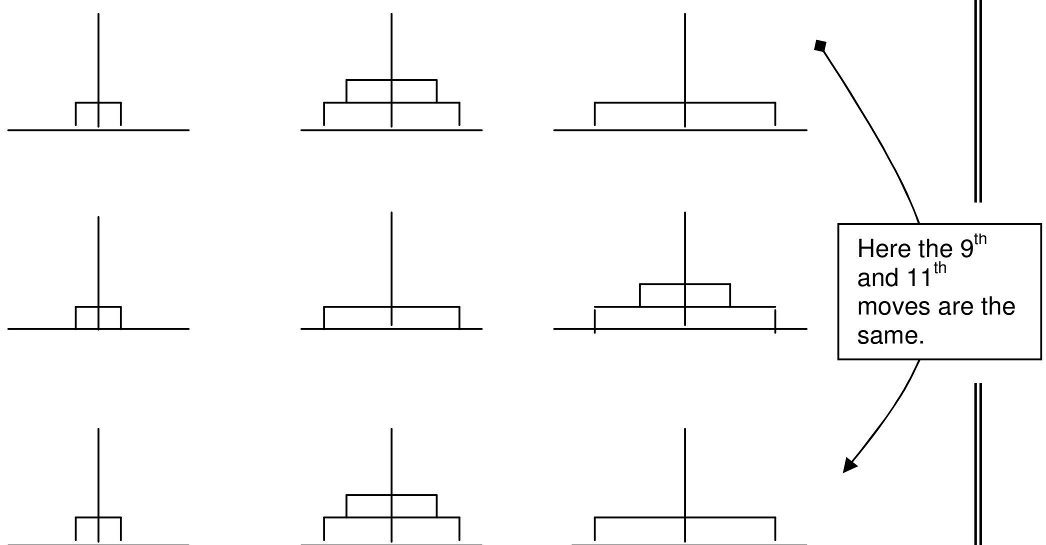
This was demonstrated when the correct moves were shown on the diagrams, with no repeats or unnecessary moves e.g. see Table 6.2.1 (p 83) above for correct number of moves for each case.

ii) Competency 2h <u>not demonstrated</u>: e.g.1: Reference: Ruth:

The following diagrams show Ruth’s 9^{th}, 10^{th} and 11^{th} moves for her solution to 4 rings:

:

:



:

:

There is thus no referring back to previous diagrams to ascertain the ‘minimum’ number of moves required.

iii) Competency 2h <u>not clearly demonstrated</u>: e.g. 2: Reference: Sam:

As mentioned above in 6.2.1(iii) above, she writes:

“3 + 3 + 1 = 7

7 + 7 + 1 = 15

15 + 15 + 1 = 31”

and even though she has solutions of 5, 8, 7 and 38, her solution to when the world would end is “1,844674407 - 1 = 1,844674406”.

She has not taken the decimal place into account, neither considered her answer of being less than 38 moves. Thus the competency of self-monitoring is not evident. This solution has been read off from the calculator, yet she has failed to realise that the 19 (or the 10^{19}) on the right-hand side of the screen, multiplies this number by 10^{19}.

6.2.4 Competency 2i: Using one's generalisations to predict some other case/conjecture:

i) Competency 2i clearly demonstrated: Reference: Lesley:

If one refers back to Table 6.2.1 (p 83) above and the excerpt from Lesley's work, we can see that she has clearly demonstrated each case in the form of a table and then generalised to $2^R - 1$. Which is then followed by her answer to the question of when the world will end, written clearly as "M64 = $2^{64} - 1$ etc." She has clearly used her previous formula and the table, to predict this solution.

Even if the learner's formula/generalisation, was incorrect in question 5 of the task, if she used that formula to predict when the number of rings was 64, I accepted this competency as demonstrated.

ii) Competency 2i not clearly demonstrated: Reference: Sam:

As mentioned above in 6.2.3 (iii) (p 86) with regard to self-monitoring, Sam has final answers of 5, 7, 8 and 38, but answers the prediction (without having provided a generalisation) with the solution 1,84474406. She has not used a 'formula' (or her previous work) to make this prediction.

iii) If the learner did provide a generalisation for question 5, but failed to provide an answer to the prediction, I interpreted this competency category then as not clearly demonstrated.

6.2.5 Competency 3: Posing and solving mathematical problems.
Competency 3b: Solving different kinds of mathematical problems:

i) Competency 3b clearly demonstrated: Reference Lesley:
All her solutions were correct (see Table 6.2.1 (p 83) above).

Note: If most of the solutions were correct, I allocated a “1” to that learner.

ii) Competency 3b not clearly demonstrated: Reference Sam:
As mentioned in 6.2.4 (ii) (p 88), Sam’s solutions for each question were incorrect, thus implying that the competency has not been demonstrated.

6.2.6 Competency 4: Representing and explaining mathematical entities.
Competency 4a: Being able to explain procedures of approach used:

i) Competency 4a clearly demonstrated: Reference Lesley:
See Table 6.2.1(p 83) above and her explanation (6.2.1) to explain her given formula.

ii) Competency 4a unsure: Reference: Kristi:
Although she provided the correct generalisation, she failed to provide any explanation of how this formula was derived. Added to the fact that she failed to use this generalisation to predict when the world would end. Thus I felt that I was unsure whether this competency was clearly demonstrated or not.

iii) Competency 4a <u>not clearly demonstrated</u>: Reference: Ruth:

Although the teachers required an explanation for each question, Ruth summarised her moves for 5 rings as follows:

> "I moved 5 towers around, up and down, left and right and in the centre, to try and get it on the last tower with all the pieces."

This explanation is definitely not clear.

6.3 Generation of initial tables of analysis

The tables in Appendix C (pp 185 – 198) provided me with the initial results, from where I then calculated the percentages of which competencies were displayed, and which not by each learner and as ability groups.

All averages calculated in the tables are means; and all percentages are rounded off to the nearest percent. The initial intention was for a qualitative approach, however once I began the analysis of the tasks and the learners' competencies, these calculations tended more towards a quantitative approach.

Maintaining reliability in my research was an issue, since no matter how explicit one is in providing explanations of acceptable demonstrations of each competency, assigning a '1', a '0' or a '-1' is ultimately still a subjective decision, one where slight differences in opinion may occur between researchers. However, by rereading each learner's work a number of times in order to make sure of these allocations, I hope that I was as accurate as can be expected in this type of interpretative analysis.

6.4 Limitations to this research

This research was restricted to one school, a case study of the portfolios developed for the Grade 9's during 2003 in order to satisfy the promotion requirements for the General Education and Training Certificate for Grade 9 learners. Secondly, of the 54 learners, I was only able to use 29 of their portfolios, as the others either did not respond to my request for its use as research, or refused use thereof. Thus the results of this study have to be accepted without generalisation until more portfolios are analysed across different grades and also across different schools. I did initially intend including the Grade 12 portfolios in my data as well, but subsequently decided that it would become too vast a project for my current needs. It may be interesting to do a similar analysis of those portfolios in order to compare results for the two grades.

McMillan and Schumacher (1993) mention two major limitations with regard to the use of a convenience sample:

(1) That such a sample of learners is not representative of the larger population of learners in public schools and thus generalizability is restricted to schools with similar characteristics to that which the target school had; and

(2) That this sample of voluntary learners may be biased in that they were probably those learners who were most confident with regard to their mathematical ability and performances on the portfolios and more extroverted than others in the same grade

(Rosenthal and Rosnow (1975), cited in McMillan and Schumacher (1993)). With regard to the first point mentioned, it was not the intention of this research project to generalise and quantify the results, but rather to illuminate the results of this sample of learners within the context of mathematical competencies displayed or not displayed. The second limitation may apply to my sample, since learners who were perhaps concerned about the standard of their work in the tasks, whose portfolios were not complete or who considered themselves very weak at mathematics, could have opted not to take part in this research. It is perhaps for this latter reason that I had only one learner who was classified as a Level 1 learner in my study (i.e. who obtained between 0 and 39 % for the promotion results). This research thus only discusses learners who were classified as belonging to the ability levels 2, 3 or 4 (see p 81 for the percentages obtainable for these levels), as all results for the one level 1 learner were disregarded.

There is, according to Parker and Rennie (1998), much research on the differences in performance between males and females on timed, competitive, external tests and on un-timed, school-based tests. These research findings reveal that males tend to perform better on the former tests and females perform better on the latter assessments. According to these two researchers, this is due to the females experiencing more anxiety on the timed tests and males portraying more confidence in themselves academically. Since my research is in the context of a single-sex girls private school, it may not be possible to generalise my results to males, since the items studied were exclusively classroom-based tasks, although some time restrictions for the completion of tasks were given. Similar research using males should be undertaken before any generalisations are made.

Another limitation to my research project is that I analysed only seven tasks from the total portfolio. In choosing which tasks to incorporate into my study, I selected those tasks that were the most open-ended or investigative in nature or simply involved working in some everyday context instead of only concentrating on very abstract mathematical exercises. Since the portfolio consisted of 19 pieces, many of which were tests and examinations, I chose to exclude these, as I wanted to gain more insight into the use of more reform-based open-ended tasks and what competencies these items alone covered. Of course, the tests and examinations do cover some of the competencies listed in my table, but it is fairly widely assumed that these items would reflect little of the higher-order thinking skills included in my table of competencies.

Chapter 7. Analysis of tasks and discussion of results.

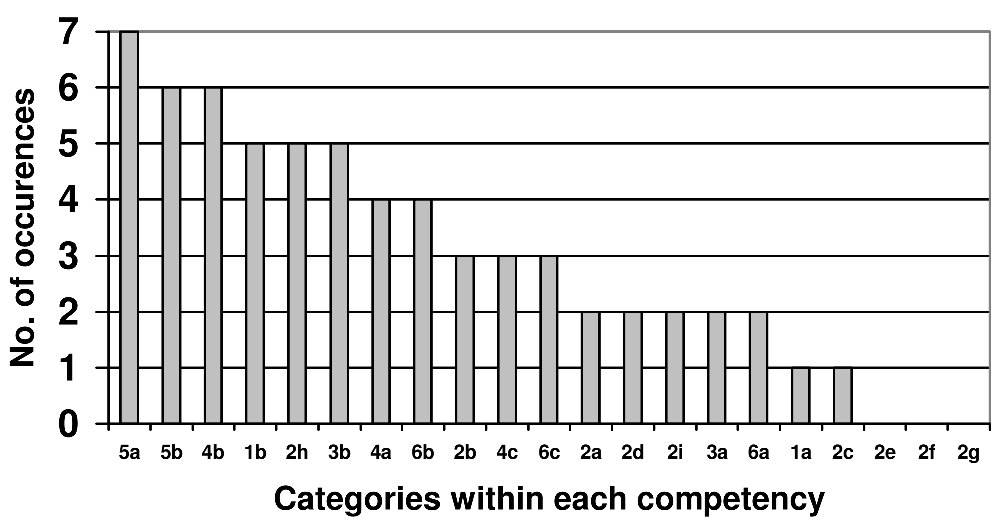
As was discussed in Chapter 2, as the classification and framing (Bernstein, 1996) in pedagogy weaken, it is interesting to note how these new codes and rules are put into practice in the classroom. The portfolio developed for this research, was the teachers' and the learners' interpretations of these new rules. The extent to which these learners benefited from class discussions and scaffolding, the way in which they interpreted the expectations of the teachers in terms of level of investigation expected for each task and the way in which these tasks were assessed, all form part of the new codes in operation as the model changes from a performance- to a competence-based model. Using the portfolio as a new form of assessment implies new functions of assessment being satisfied. Yet what is the reality in the classroom? This portfolio is the result of the weaker framing with regard to the 'selection of the communication', where the teachers had to select tasks that satisfied certain given criteria and it reveals that which the teachers valued most. This chapter attempts to answer the research questions set by this project in Chapter 1, beginning first with an analysis of the tasks in terms of competencies covered and moving on to an analysis of the learners' performances on these tasks, the extent of apparent benefit of their use how the different ability groups have fared across the tasks and across the competencies.

7.1 Question 1: What mathematical competencies were assessed by the tasks used in this research project.

<u>Analysis of tasks from the teachers' perspectives: that is the tasks as initially presented to the learners</u>.

In order for me to begin my analysis of the competencies, I needed to ascertain which competencies were covered by the tasks used for this research. I thus used the list of competencies drawn up (see Table 5.1, p 61) and attempted to identify the competencies (or categories) incorporated in each task (see Table 7.1, pp 97 – 98 for exemplars). The degree of coverage (i.e. the extent to which each learner satisfied the descriptions of this competency) (Niss, 2002) is what I as researcher had to decide on in order to assign a '1', a '0' or a '-1' in the initial tables. I then counted the number of occurrences of each category within each competency for all the seven tasks and totalled these up (see Table 7.2, p 99). These totals are illustrated in Figure 7.1 below.

Figure 7.1 Number of occurences of each competency



It needs to kept in mind however, that every competency will not be included or reflected in all seven tasks due to the nature of each task, varying from investigative to exercise-type. This table analyses the *opportunity* had by the teachers in these tasks to assess these competencies and the reality of the findings.

Referring to Figure 7.1 (p 95) above, it is noted that the highest occurrence is that of competency 5a (interpreting others' mathematical texts), followed closely by 5b (i.e. using natural language to express oneself) and 4b (i.e. being able to use different forms of representation). Interpreting others' mathematical texts is the essence of problem solving, since one cannot begin to solve any problem unless the task has been read and interpreted. This is the starting point of any mathematical activity and thus it is expected that it represent the greatest number of occurrences. The range of contexts for this category includes 'interpreting questions correctly, following someone else's work, interpreting mathematical notation, interpreting graphs and interpreting simple mathematical costing calculations (see Table 7.1, pp 97 - 98). These tasks provide ample opportunity for the learner to demonstrate the radius of action of this competency (i.e. the range of contexts and situations that the learner can apply this competency to) (Niss, 2002) in order for the teacher to infer competency to some acceptable degree of accuracy.

The technical level (i.e. how conceptually and technically advanced the tools are that the learner can apply within this competency (Niss, 2002)) varies across the tasks, depending on the cognitive level of difficulty of each tool. These tools vary from low cognitive demand ('interpreting co-ordinate notation'), to high cognitive demand ('interpreting Thomas Saint's work' in order to correctly assess his test). Although this competency implies the *interpretation* of the concept of co-ordinates and their notation in order to draw the picture, it nevertheless expects less cognitive thought than that required for the procedures involving factorisation/multiplying out,

Table 7.1 Identifying characteristics each of competencies within each task.

COMPETENCIES		TOWERS OF HANOI	THOMAS SAINT'S TEST & MEMO	HIDE THE SPIES	CARTESIAN PLANE
1. Memorisation	a				a) plotting points in general
	b		b) all algorithmic questions		b) drawing own diagram from given co-ordinates
2. Thinking & reasoning mathematically	a		a) understand when to stop/carry on with the factorisation process		
	b	b) generalising to $2^n - 1$		b) extension expected plus some generalisation	
	c	c) differentiating between cases (qu's. 1 – 4), generalisations (qu. 5) and conjectures (qu. 6)		c) note the difference between cases vs. conjectures	
	d		d) following and assessing Thomas Saint's Test		d) following a given order of points to be plotted, linking and colouring areas correctly
	e				
	f				
	g				
	h	h) self-monitoring: finding the *lowest* no. of moves (with no repeats)		h) self-monitoring expected for extension part of the investigation	h) self-monitoring to draw own appropriate picture, using appropriate scale

COMPETENCIES		TOWERS OF HANOI	T.S. TEST & MEMO	HIDE THE SPIES	CARTESIAN PLANE
3. Posing and solving mathematical problems	a		a) knowing the difference between simplification and factorisation	a) qu.2 extension: identifying a problem	
	b	b) solving this problem	b) solving each question	b) solving extension problem	
4. Representing and explaining mathematical entities	a	a) explanation of procedure needed	a) providing help for Thomas Saint with regard to procedures	a) explanation of procedures needed	
	b	b) use of diagrams		b) using different forms	b) using co-ordinate form correctly
	c			c) switching between forms	c) switching between co-ordinates and diagrams
5. Communicating mathematically and interpreting mathematical statements	a	a) interpreting the question correctly	a) following Thomas Saint's work	a) extrapolate maths from text	a) interpreting notation of co-ordinates
	b	b) using appropriate language for explanations	b) providing appropriate and clear advice for Thomas Saint	b) providing explanation, using appropriate language	
6. Handling mathematical symbols and formalisms	a				
	b	b) working with the formulae (i.e. substitution)	b) being able to manipulate expressions and products		
	c	c) decoding patterns generated, in order to generalise			

Table 7.1 continued.

COMPETENCIES		GRAPHS EX.	SHOPPING EX.	STATISTICS EX.
1. Memorisation	a			
	b	b) being able to calculate average speed and highest average speed (qu's. 2.7, 2.8 and 2.9), given the formulae	b) procedural: being able to convert to same unit price/item for comparison purposes	b) being able to calculate simple percentages
2. Thinking & reasoning mathematically	a	a) understand scope and limitations of graphs 3.1., 3.6. & 2.2.		
	b	b) Determining the period of highest average speed from the graphs		
	c			
	d			
	e			
	f			
	g			
	h		h) self-monitoring to find biggest saving	h) self-monitoring to make sure angles add up to 360˚
	i			
3. Posing and solving mathematical problems	a			
	b		b) Task 1 & Task 2, solving problem	b) being able to convert amount for each item into degrees in order to draw pie chart

COMPETENCIES		GRAPHS EX.	SHOPPING EX.	STATISTICS EX.
4. Representing and explaining mathematical entities	a	a) Task 1: explanations of milkshake graph		
	b	b) use graph to represent milkshake situation	b) Task 2: using the concepts of price versus saving, price versus quantity to make conclusions	b) use graphs and tables
	c	c) being able to switch between graphs and calculations		
5. Communicating mathematically and interpreting mathematical statements	a	a) interpreting graphs: Task 1: qu's 3.1. - 3.5.	a) Task 3: assessing R4,40/person quote in relation to current prices	a) interpreting statistical graphs
	b	b) explanation of graphs	b) Task 2: providing an explanation of saving, using natural language	b) question1c: deducing which kind of family is not represented, from frequency table above
6. Handling mathematical symbols and formalisms	a		a) Task 3: translating from formal recipe to natural language to make final conclusion	a) translating graphs to natural language
	b		b) Task 2: Calculating price & saving; Task 3: Calculating Latest price/person for menu	
	c		c) Task 2: interpreting monetary calculations in terms of overall saving; Task 3: Decoding statements involving price/person	c) could learner decode explanation for converting an angle to a percentage, in order to draw pie chart?

Table 7.2 Number of occurrences of competencies in original tasks.

MATHEMATICAL COMPETENCIES	
1. Memorisation	a) Memorisation of definitions, concepts and proofs without expectation of any application, interpretation, analysis or synthesis. (1) b) Recall of algorithmic procedures without any expectation of application, interpretation, analysis or synthesis (e.g. solving simple equations, factorising, products). (5)
2. Thinking and reasoning Mathematically	a) Understanding the scope and limitations of a given concept. (2) b) Extending the scope of a concept by abstracting some of its properties, generalising to larger classes of objects. (3) c) Being able to distinguish between different kinds of mathematical statements (such as definitions, assumptions, quantifiers, theorems, cases, conjectures). (1) d) Following and assessing chains of thought by others. (2) e) Knowing how a mathematical proof differs from other kinds of mathematical reasoning. (0) f) Being able to identify the main lines in an argument. (0) g) Proving statements. (0) h) Self-monitoring. (5) i) Using one's generalisations to predict other cases. (2)
3. Posing and solving mathematical Problems	a) Identifying different kinds of mathematical problems. (2) b) Solving different kinds of mathematical problems. (5)
4. Representing and explaining mathematical entities	a) Being able to explain procedures of approach used. (4) b) Being able to use different forms of representation of mathematical objects, phenomena and situations. (6) c) Being able to switch between different forms of representation. (3)
5. Communicating mathematically and interpreting mathematical statements	a) Interpreting/decoding others' written, visual or oral texts about issues of a mathematical nature (including open-ended tasks). (7) b) Expressing oneself in oral, visual or written form, using nat. language. (6)
6. Handling mathematical symbols and formalisms	a) Translating from formal/symbolic language to natural language (and visa -versa). (2) b) Handling and manipulating statements and expressions containing symbols and formulae. (4) c) Decoding and interpreting statements in the form of symbolic or formal mathematical language. (3)

since the former concept involves more memorisation and the latter some algorithmic procedure. This introduces a dimension of competency analysis that needs to be kept in mind when inferring the competency of our learners. The high occurrence of the categories 5b (i.e. 'using natural language to express oneself') and 4b ('being able to use different forms of representation'), indicates what the teachers valued most with regard to the development of the portfolios of 2003, i.e. the ability to provide explanations in terms of natural language and the ability to use different forms of representation such as diagrams, graphs and tables. The high occurrence of these latter two competency categories also reveals that the teachers are attempting to address new functions of assessment, exposing their learners to new experiences, expecting not only the ability to perform calculations, but being able to communicate within the mathematical domain using natural language. As these competencies are classified as being of high cognitive demand, it is encouraging to see these competencies being assessed often.

On the other hand, the competency memorisation with its recall of simple algorithmic procedures without any expectation of application, interpretation, analysis or synthesis (1b), is next highest (with a count of 5 out of a maximum of 7 occurrences). This is assessed in the tasks by examining factoring and multiplying out procedures, listing co-ordinates from a diagram, doing simple conversions to unit prices, doing simple percentage calculations and substituting into a given formula. This still reveals the ever-present dominance of the more traditional forms of assessment, with the assessment function being the attainment of correct answers and the use of previously taught 'algorithmic' procedures. It is possibly difficult for teachers who were themselves taught in a paradigm heavily dependent on the use of algorithms and routine procedures; to shift totally towards a more constructivist approach, with the use of more open-ended and investigative type tasks. Also, basic procedures and concepts do still need to be practised and assessed at some time, although the more expected forum of such assessments would be class tests and examinations. Being present in the open-ended types of tasks is an issue that may need further consideration. The high occurrence of memorisation in terms of the recall of simple algorithmic procedures, may be attributed to the following factors:

- the actual characteristics of the tasks chosen for this research (seeing as Tasks 4 to 7 did tend more toward exercise-type items anyway);
- there may be some unconscious resistance from the teachers to move completely into the realm of using purely investigative and more open-ended type tasks without some inclusion of scaffolding;
- the strong framing with respect to criteria, that the teachers needed to abide by, stating the types of tasks needed for the portfolio.

In comparison, what is also of interest with regard to the competency involving 'memorisation', is the low occurrence of memorising definitions, concepts and proofs (1a) (with 1 out of seven occurrences). This is as it should be when dealing with more open-ended tasks. The one occurrence of this competency was found in the Cartesian Plane exercise, where the learners were expected to know how to plot co-ordinates on a Cartesian plane. It would be expected that this category have a higher occurrence in test-type items, where recall of definitions and other theory is examined more often.

Also with a count of 5 out of 7 occurrences are 'thinking and reasoning mathematically by self-monitoring one's own work' (2h) and 'solving different kinds of problems' (3b). Self monitoring is a skill that needs to be developed in our learners, if they are to succeed in the ever-changing world that they live in. By developing the self-discipline to evaluate and assess one's own work realistically, could aid in the assessment process, by empowering the learners to become involved in the teaching and learning process in an active manner and by developing their abilities to work efficiently and apply their theoretical knowledge to the problems at hand. This category involving self-monitoring, is reflexive in nature (Kraak, 1999), since it expects the ability to integrate or connect own performances with the *understanding* of those performances so that learners learn from their actions and are able to adapt to change. The analysis of this category should reveal those learners who at that time possessed the new realisation and recognition rules now in operation in the classroom. The practical competence (Kraak, 1999) of 'solving mathematical problems' (3b) is also one of the main goals of any mathematician's activities and one of the characteristics of the outcomes-based educational system that we in South Africa are using, that of demonstrating the ability to perform a set of tasks in order to solve the problems at hand.

Note also the lower occurring categories on Figure 7.1 (p 95), those that only occurred once, twice or not at all. That of competency 2a (i.e. 'understanding the scope and limitations of a given concept'), 2d (i.e. 'following and assessing chains of thought by others'), 2i (i.e. 'using one's generalisations to predict other cases'), 3a (i.e. 'identifying different kinds of mathematical problems') and 6a (i.e.' translating from formal/symbolic language to natural language and visa-versa') all occurred 2 out of 7 possible times. These competencies can all be considered cognitively challenging and difficult to assess. They also tend more toward new forms of assessment, not usually evident in exercise-type tasks. This is evident from Question 3.1 from the exercise on Graphs (Task 5) [i.e." How is it that we can still interpret (in general), what is happening even though no vertical scale or units are given?"]. This question seeks a verbal explanation about what the learners' mathematical thoughts are from the graph, not simply a traditional type question requiring drawing a graph from some given data. Added to this, is the problem of errors of inference, when so few occurrences are used to conclude competency. When we consider 2d (i.e. 'following and assessing chains of thought by others'), Table 7.1 (pp 97 - 98) notes that this category was reflected in Thomas

Saint's Test and Memo and in the Cartesian Plane Exercise. Following instructions regarding plotting points and colouring areas is of lower cognitive challenge than following someone else's solutions and being expected to provide helpful hints, thus introducing the possibility for potential errors of inference of competency occurring. Also, if learners are expected to become critical thinkers of today, then this competency of being able to follow others' thoughts and suggestions and to critique them in a useful manner, needs to be practised and assessed and shown to be an important aspect of each learner's education. With only two occurrences of this category, this importance is not reflected.

As with the competency 1a (i.e. 'memorisation of definitions etc.'), the category 2c, (i.e. 'being able to distinguish between different kinds of mathematical statements'), was also only reflected once throughout, in the Hide the Spies Task. Here learners were expected to investigate an extension of the original question, analyse different cases of this extension and then make some type of conjecture. Only those learners who possessed the realisation rules (Bernstein, 1996) required, would be able to extend their questions appropriately and subsequently make informed conjectures.

As was mentioned in the development of my list of competencies from the original list drawn up by the Danish KOM Project (Niss, 2002), I removed the competencies of 'making use of aids and tools' and 'modelling mathematically' as they did not occur at all in the portfolio used for this research. The competency 2 (thinking and reasoning mathematically, with its categories 2e (i.e. 'knowing how a mathematical proof differs from other kinds of mathematical reasoning'), 2f (i.e. 'being able to identify the main lines in an argument') and 2g (i.e. 'proving statements'), also did not occur in the tasks selected for this research. All of these categories mentioned here, are important for the overall experience of any mathematician, although admittedly not all need to be covered in every task undertaken.

However, it reveals a weakness in the exposure we give to our learners, one that needs to be addressed if we are to develop critical thinkers.

Thus, in summary, these teachers valued highly the ability to communicate mathematically and interpret mathematical statements (i.e. Competency 5) by being able to interpret others' work (5a) and being able to express oneself using different forms (5b) and also being able to use different forms of representation (i.e. Competency 4b). These reformist functions reveal an attempt by the teachers to include new functions into their assessment practices. They allow for the analysis of each learner's competence of the realisation rules (Bernstein, 1996) in operation at that time, allow some insight into their ability to verbalise mathematical concepts in different ways and reveal their understanding of certain mathematical concepts used within each task. However, memorisation of simple algorithmic procedures (i.e. competency category 1b) was also often assessed, indicating the ever-present dominance of the more traditional function for which these tasks were used, i.e. that of achieving correct answers. Although self-monitoring (competency category 2h) was assessed often, the categories least often assessed were from the competency involving thinking and reasoning (i.e. Competency 2). This highlights an area of concern for mathematics teachers attempting to develop portfolios, where new forms of assessment are being used, but the functions to which they are being applied are still more traditional in emphasis.

Even though the framing with regard to the development of portfolios is weaker in comparison to the previously examination-oriented approach, there is unevenness with regard to the extent to which different competencies have been incorporated into the portfolio. Is this lag in the assessment of thinking and reasoning characteristic of most portfolios being developed for Grade 9 at this time, or is it characteristic just of this specific portfolio? If one regards these teachers as 'acquirers' (of an outcomes- and competency-based model of pedagogy), they definitely do possess the recognition rules to produce such a portfolio, but the realisation rules to produce legitimate tasks that span all the competencies, still needs attention.

7.2	Question 2a: How do mathematics portfolios affect the learners' academic results? In particular, do the results of different ability groups of learners reflect differing apparent benefits?

<u>Analysis of percentages obtained by the learners across the seven tasks. This is done according to ability groups</u>.

[Refer to Tables 7.3 and 7.4 (pp 107 – 108) for this section.]

The percentages obtained for the seven research tasks were combined into one average and compared to the final portfolio result and to the final promotion mark (see Table 7.4, p 108). It is evident that the average percentage for the research tasks is higher across all the levels of learners, compared to either of the other two marks. This difference between the average obtained for the seven research tasks compared to the final portfolio and promotion marks, may be due to a number of factors:

1. some of the research tasks may still be too easy, i.e. where the cognitive demand is still low;
2. for these specific research tasks, the learners involved in this study may have recognised the changes in the rules and thus been able to produce the legitimate text expected by the teachers;
3. the learners involved in this study could have found the seven tasks very predictable;
4. the marking schemes for these seven tasks may have been too easy, making it relatively easy for the learners to achieve good results;
5. too little guidance from the department of education regarding the level of difficulty expected for such tasks;

6. by providing more opportunity for discussion and collaboration, all the learners are actually benefiting from it; and
7. more facilitation and mediation from the teachers, who are operating successfully in the zone of proximal development.

The items that were not used in the research exercise were the six tests/examinations, four other homework exercises, one individual assignment on geometry and one group project on designing a quad. This implies that the learners fared much worse on the rest of the portfolio items compared to the seven tasks chosen for this research, especially the lower ability learners. Especially noticeable in the lower ability groups of learners, the inclusion of the more time-restricted test and examination types of tasks indicate that these learners did not fare well in this form of assessment. The inclusion of reformist forms of assessment thus gives these learners the opportunity to engage with their peers, learn from them in groups, operate in the ZPD with some success and develop some sense of achievement in solving the problems at hand. The scaffolding allowed when using the more open-ended types of tasks and the different strategies that these tasks encourage, enable each learner to at least begin engaging with the tasks at hand. This scaffolding as mentioned earlier, may result in some dependency of the learner on the teacher, however, if appropriately done for each individual learner, it should provide opportunity for each one to experience the concept of ‘generalisation’, applying each learning experience to more general thinking strategies (Jaworski, 1990). It also reveals times when the learner makes intuitive leaps in his/her thinking, times when the learner is struggling with the concepts at hand; and provides opportunity for the teacher to gain experience in making decisions about whether to withhold information or to provide more help. These are all valuable experiences for both the teacher and the learner, experiences not often exposed to while doing the more traditional forms of time-restricted assessments.

By calculating the range between the average obtained for the seven

Table 7.3.

Percentages per task:

			Task 1	Task 2	Task 3	Task 4	Task 5			Task 6	Task 7
			Towers of Hanoi	T. Saint's test & memo	Hide the Spies	Cartesian plane Ex.	Interpreting graphs			Going shopping	Statistics Ex.
							Graph 1	Graph 2	Ave.%		
Lev1	0 – 39 %	Catherine	36	35	a	85	45	60	53	91	78
Lev2	40 – 59 %	Kristi	62	48	65	75	80	53	67	77	91
		Ann	48	69	50	a	75	73	74	95	78
		Ruth	67	35	55	90	70	73	72	100	87
		Thandi	81	67	90	100	80	73	77	100	84
		Sam	17	50	40	95	25	67	46	32	75
Lev3	60 – 79 %	Kim	90	85	60	95	90	93	92	95	87
		Lesley	100	72	a	95	80	53	67	95	95
		Ana	43	33	55	90	30	73	52	100	a
		Kathy	100	72	65	95	75	67	71	95	95
		Marie	100	82	95	75	80	13	47	73	91
		Thumi	86	91	95	90	65	93	79	91	95
		Tessa	91	74	65	80	85	60	73	86	97
		Pat	95	43	65	100	90	73	82	95	93
		Lee	76	48	40	100	85	60	73	68	73
		Jane	52	91	60	80	40	33	37	86	a
		Candice	100	61	65	95	85	73	79	68	85
		Tammy	100	87	95	100	80	60	70	100	95
		Nicky	95	74	80	95	90	73	82	100	100
		Jacky	81	63	70	85	67	80	74	91	91
		Laura	81	80	65	100	a	a	a	82	76
		Tatum	95	70	90	85	80	40	60	82	97
		Jessy	86	84	70	95	90	87	89	86	88
		Shana	100	78	65	90	80	47	64	86	95
Lev4	80 – 100%	Karen	71	72	70	85	70	87	79	91	98
		Juan	100	74	95	85	90	80	85	86	100
		Mandy	76	90	95	95	85	53	69	91	95
		Loren	100	96	100	95	95	86	91	91	100
		Peta	91	92	75	55	85	87	86	73	93
Level 1 %'s		No. of learners: 1	36	35	a	85	45	60	53	91	78
Level 2 Ave. %'s		No. of learners: 5	55	54	60	90	66	68	67	81	83
Level 3 Ave. %'s		No. of learners: 18	87	72	71	91	76	63	70	88	91
Level 4 Ave. %'s		No. of learners: 5	88	85	87	83	85	79	82	86	97
Group ave. % per task		No. of learners: 29	80	70	72	89	75	67	71	86	90

Table 7.4.

Final percentages:							
			Ave. % for tasks 1 – 3	Ave. % for tasks 4 – 7	Ave. % for seven research tasks put together	Final portfolio mark	Final promotion mark
Lev1	0 – 39 %	Catherine	36	77	69	47	39
Lev2	40 – 59 %	Kristi	58	77	69	54	48
		Ann	56	82	69	58	52
		Ruth	52	87	72	57	45
		Thandi	79	90	86	61	58
		Sam	36	62	51	53	49
Lev3	60 – 79 %	Kim	78	92	86	76	75
		Lesley	86	88	87	76	76
		Ana	44	81	62	64	62
		Kathy	79	89	85	67	66
		Marie	92	71	80	80	76
		Thumi	91	89	90	75	67
		Tessa	77	84	81	79	78
		Pat	68	92	82	72	63
		Lee	55	78	68	60	65
		Jane	68	68	68	65	69
		Candice	75	82	79	71	75
		Tammy	94	91	92	71	62
		Nicky	83	94	89	76	76
		Jacky	71	85	79	72	64
		Laura	75	86	81	63	65
		Tatum	85	81	83	78	77
		Jessy	80	87	84	74	77
		Shana	81	84	83	74	78
Lev4	80 – 100%	Karen	71	88	81	79	80
		Juan	90	89	89	87	85
		Mandy	87	88	87	87	82
		Loren	99	94	96	94	94
		Peta	86	77	81	83	86
Level 1 %'s		No. of learners: 1	36	77	69	47	39
Level 2 Ave. %'s		No. of learners: 5	56	80	69	57	50
Level 3 Ave. %'s		No. of learners: 18	76	85	81	72	71
Level 4 Ave. %'s		No. of learners: 5	86	87	87	86	85
Group ave. % per column		No. of learners: 29	74	84	80	71	69

research tasks and the final portfolio mark, one can see that this range decreases as mathematical ability increases

i.e. 69 – 57 = 12 % for level 2,

81 – 72 = 9 % for level 3, and

87 – 86 = 1 % for level 4 learners.

The Level 4 learners' performance is fairly consistent across all the results, whereas the other learners' results do vary considerably. The exception occurs when considering the average obtained for the three open-ended tasks and the final portfolio results (in Table 7.4). The average obtained for Tasks 1 to 3 used for this research and the final portfolio result are relatively close, implying that these tasks could be a good indicator of each learner's portfolio mark (only 7 out of 29 learners had a difference of 10 or more percentage points between the two averages). One should then ask whether it is feasible to expect the teachers to produce a portfolio consisting of 19 items, when three open-ended tasks resulted in a similar mark. Thus, as the framing (Bernstein, 1996) of mathematical assessment weakens, decisions about the number of tasks that need to be included, plus the forms of assessment that would clearly illustrate where each learner is at that time (i.e. the competency of each learner as compared to the list of competencies used for this study), could possibly be left up to each individual teacher or department within each school. Clear guidelines as to minimum numbers of tasks, would have to be provided, but setting absolute criteria regarding the number of tasks to be included, contradicts the aspect of weaker framing within a competency-based model of education. Guidelines explaining the competencies that are expected to be assessed in this portfolio would possibly have been of more use. Since many of the teachers involved in this grade felt that the number of items expected by the IEB was not practical in terms of time available to produce all the items, one could, after further research has been done, suggest reducing the criteria to a fewer number of 'open-ended' tasks and leave the teachers to examine the rest of the content taught in whatever manner they deem appropriate.

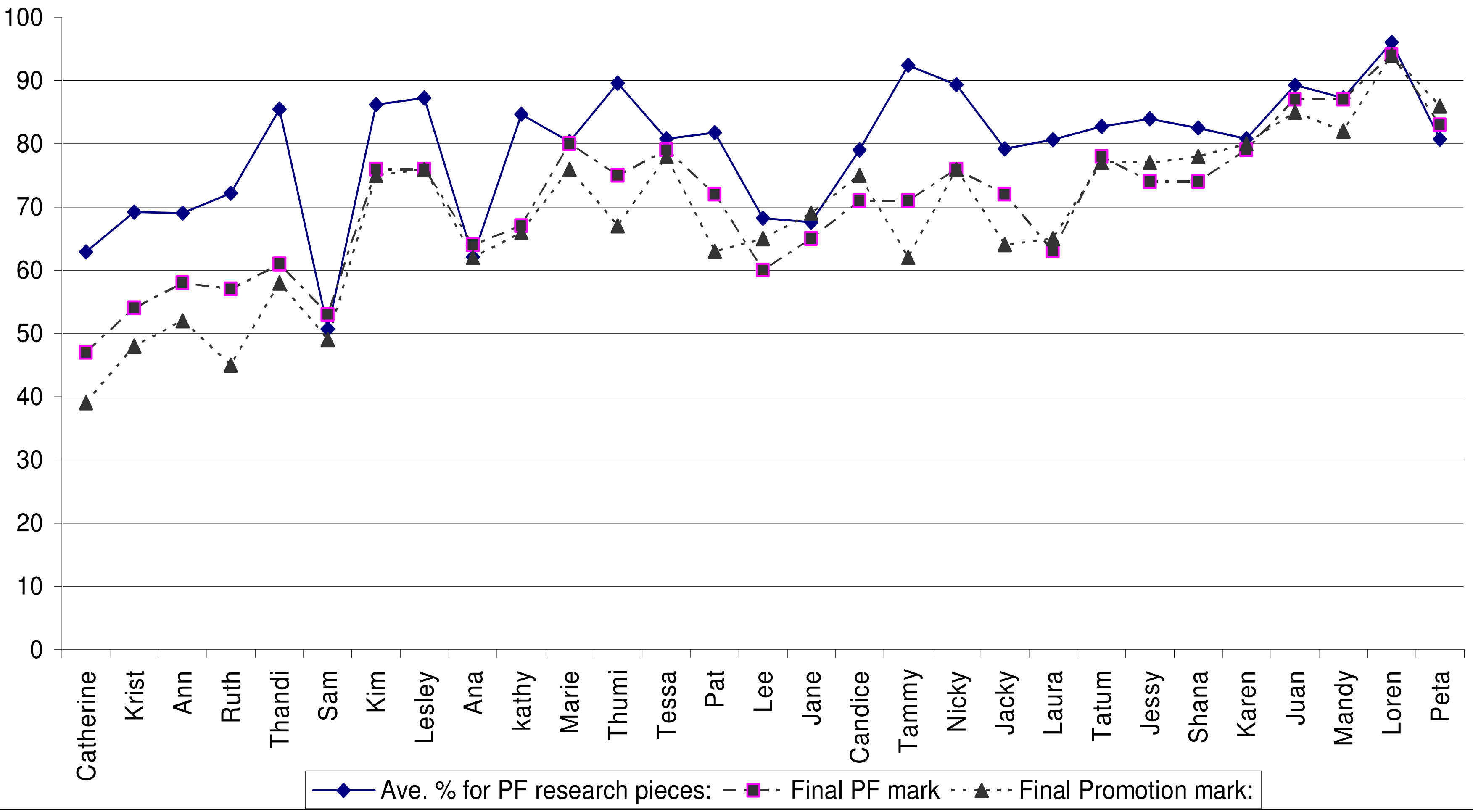
As can be seen from Figure 7.2 (p 111) below and the percentages shown in Tables 7.3 and 7.4 (pp 107 - 108), the lower ability learners seemed to benefit most from the use of this portfolio. As to why this has happened, may be due to more class or group discussions with the teacher and/or peers occurring regarding the task/s and possible strategies to be used, working in groups or from one of the factors 1 to 7 mentioned in the previous paragraph (p 105), i.e. the mediation that is occurring between the different parties involved. Since it is not possible to ascertain any group dynamics that occurred or analyse any discussions that took place while the tasks were being introduced to the class from the data used for this research, it is not possible to determine the actual reasons for the lower ability learners benefiting most from the use of these tasks and can thus only be surmised at. However, since 18 of the 29 learners (i.e. 62 %) obtained a final portfolio mark higher than the final promotion mark, the portfolio is achieving two of its purposes, i.e. to benefit our learners with regard to their overall promotion results and to provide varying experiences of mathematics, not just tests and examinations. There is always the danger that discussions with the teacher/peers and working in groups has served to obscure the actual competence in performance for these weaker ability learners. Errors of inference need to be kept in mind here too.

7.2.1 What then was the dominating purpose of producing such a portfolio?

In practice (i.e. in this school), the promotion mark was determined as follows:

> All the items in the portfolio (referred to as the School Based Assessment part), were added together, producing two totals, one the maximum possible mark obtainable from the sum of all the tasks and also the sum of each learner’s total for all the tasks. The maximum total was divided into the learner total and then converted

Figure 7.2 **A comparison of learners' selected PF mark versus final portfolio mark and final promotion marks**



> to a mark out of 75. The Continuous Assessment Task* (CTA) Part A was converted to a mark out of 15 and the CTA Part B was converted to a mark out of 10. These produced the promotion mark for each learner. The weighting of the tasks within the portfolio in order to calculate the portfolio mark, was not done according to any guidelines, but on the totals for each of the 19 tasks. This method is problematic, since tasks that had a high total obviously dominated this calculation. There was thus little or no consideration of the types of tasks that were weighted the most. Although examinations and tests have a high total, they tend to be dominated by more procedural types of questions with a lower cognitive demand, than investigations and more open-ended tasks that require extensive analysis, synthesis, self-monitoring and generalisation and involve more time in class.

[* The CTA is a compulsory module of lessons and assessments set externally by the IEB consisting of two sections: Part A is a set of lessons that incorporates a series of continuous assessments, then culminating in a summative examination-type Part B assessment task.]

This still means that this new form of assessment (i.e. the portfolio) is being used for old purposes, i.e. to provide a percentage indicative of each learner’s mathematical proficiency during the Grade 9 year, in order to judge whether the learner should be promoted or not. The teachers in my research project have obviously used an analytical approach, implying a summative purpose to the use of the portfolio. However, Pahad warns:

> To assume that an aggregate of marks collected throughout the year is a suitable indicator of competencies at the end of the year is (even more) problematic (Pahad, 1999: 250).

Teachers need to be more aware of the mathematical competencies that they have exposed their learners to and which they have not covered at all. As mentioned earlier, the final assessment of each learner is only as good as the tasks to which we have exposed our learners. The manner in which the aggregate is determined is also important in making deductions about each learner's competency and performance levels, where the number of 'exposures' to each competency, should be taken into account and not a simple average taken. There should therefore be a cautionary awareness about assessing portfolios using this analytical approach.

7.3 Question 2b: How do each of the different ability groups of learners fare with regard to

i) the more 'open-ended' types of tasks compared to the more closed types, and

ii) tasks that are considered to be of 'high cognitive demand' versus those that are classified as being of 'low cognitive demand'?

Analysis of percentages obtained by the learners on the tasks, according to the open-endedness or not of each task.

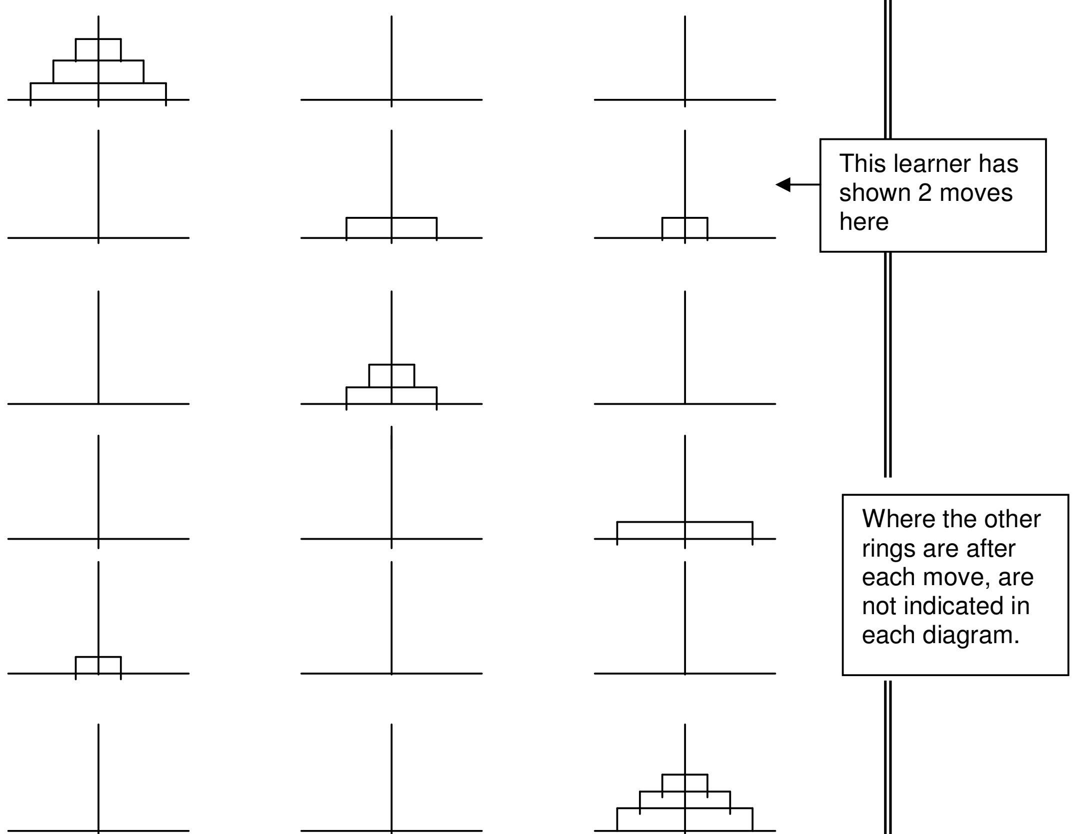
[Refer to Tables 7.3 and 7.4 (pp 107 - 108) for this section.]

As can be seen from Table 7.3 (p 107), the five Level 2 learners performed the worst on Thomas Saint's Test and Memo, achieving 54 % as a group, as opposed to the stronger learners (Level 3 and Level 4), who fared worst (in the Interpreting Graphs Exercise). This indicates a difference in the abilities of these learners with regard to mathematical competency, plus a difference in the possession of Bernstein's (1996) 'recognition and realisation rules'. The weaker learners probably possessed the recognition rules expected for Towers of Hanoi and Thomas Saint's Test and Memo, but with regard to the explanations required, did not possess the realisation rules to be able to produce legitimate text appropriate for those tasks (Bernstein, 1996).

The following is an example of a learner who realised the intention of the question, but did not produce the legitimate text in order to answer the question appropriately: Taken from Towers of Hanoi, competency 2b (‘extending the scope of a concept by abstracting some of its properties, generalising to larger classes of objects’). The task expected each of the moves to be shown, showing all relevant information to illustrate the minimum moves necessary to move the 3 rings from the first tower onto the last tower (as is shown in 6.2.1 (83) above):

<u>Competency 2b, not clearly demonstrated: e.g.2: Reference: Sam</u>

[This learner’s diagrams do not clearly illustrate the number of moves made, e.g.: This is her answer to moving three rings:



With regard to the Hide the Spies Task, many of the learners could not structure an appropriate pathway to solving question 2 and the extension expected, i.e. they couldn't pose appropriate questions to investigate other extensions of this task. For instance, one such learner changed the shape of the park to a heart shape and could then not make any predictions of a possible formula relating the number of booths and spies involved. Thus again, the realisation rules are problematic for the whole group.

The Level 3 learners fared only slightly better on the Interpreting Graphs exercise (with an average of 70 %), compared to the Level 2 learners (with a 67 % average). Most of the learners lost marks on this task from incorrect calculations for questions 2.7., 2.8. and 2.9, this occurring across all four levels.

Also from Table 7.3, one can see that the whole group fared best on the Cartesian Plane and Statistics Exercises. Cognitively, these had the lowest demand, where plotting points and drawing simple statistical graphs was tackled well by all the learners. These two tasks had the highest averages by far, for the group as a whole and for each ability level.

From Table 7.3, we can see that the learners as a group, performed the worst on Thomas Saint's Test and Memo, the Hide the Spies Investigation and Interpreting Graphs. With regard to Thomas Saint's Test and Memo task, being asked to mark someone else's work, having to provide explanations about misconceptions and providing helpful advice, demands a good understanding of the processes involved in factorisation and multiplying out. Although these processes are algorithmic in nature, the explanations expected increase the cognitive demand (Stein et al, 2000) of the task. The investigative nature of the Hide the Spies task, places this task in the high cognitive demand category, excluding then those learners who do not possess the recognition and realisation rules (Bernstein, 1996) from achieving good results. The open-endedness of this task immediately sets it apart from the other tasks, making it inaccessible to those learners who do not have access to the new rules.

From Table 7.4 (p 108) above, when I combined the results for the three more open-ended tasks (i.e. Tasks 1 to 3) and compared this to the average for the more closed exercise-type tasks (i.e. Tasks 4 to 7), one can clearly see that most of the learners fared much better on the more traditional exercise-type tasks (23 of the 29 (i.e. 79.3%) of the learners) obtaining higher results for these tasks compared to the more open-ended tasks. Also the range between these two averages for each level decreases as mathematical ability increases

i.e. 80 – 56 = 36 % for level 2,
85 – 76 = 9 % for level 3 and
87 – 86 = 1 % for level 4.

These ranges indicate that the higher ability learners are coping better with the different tasks compared to the weaker learners who fared much better with the exercises compared to their performance on the open-ended tasks. This is what I had envisaged with regard to the use of open-ended tasks, as it is expected that the lower ability learners may not possess the realisation and/or the recognition rules demanded by these tasks.

7.4 Question 2c: With regard to the mathematical competencies assessed in this portfolio, do the different ability groups of learners fare differently within each one? If so, how? That is, which groups are proficient (or not) in the different mathematical competencies assessed in these portfolios?

Analysis of learners' mathematical competencies

[Refer to Appendix C (p 185 – 198) for the initial tables of competencies.]

With regard to Tables C1 to C6, the numbers '–1' and '1' represented whether the learner couldn't or could show the mathematical competency as explained in Table 7.1(pp 97 - 98) for each task. The '0' represented the case where I was unsure whether the learner did actually represent the relevant competency. Where no figure is filled in, that learner's portfolio did not include that specific task. It is for that reason, that the totals at the bottom of each column do not all add up to 29. The following table represents the number of learners whose tasks were analysed for each task:

Table 7.5 Table showing the number of learners per task

Tasks used for research	***Number of learners***
Towers of Hanoi	29
Thomas Saint's Test and Memo	29
Hide the Spies Investigation	29
Cartesian Plane Exercise	20
Interpreting graphs exercise	28
Shopping Exercise	29
Statistics Exercise	28

The totals from Table 7.5 are reflected in Tables C1 to C6 underneath the row labelled 'TOTALS". Underneath these totals, the number of learners in each ability level, reflected as a percentage, are those learners who did/did not display each competency in each task. Then to obtain Tables C7 through to C12, a summary of each competency was made. The number of occurrences for each category within each competency were counted (a = 1 for competency 1 means that there was only one occurrence of this category over all seven tasks). Underneath each column, is a total of the maximum number of occurrences for each competency category. Then, to obtain the percentages right at the bottom of each table, I took the total for each column and divided this by the

Table 7.6 Whole sample learner performance within each sub-category of competency:

		% L's who couldn't display competency	% Unsure of competency	% L's who did display competency
Competency 1:	(a)	0	0	100
	(b)	18	1	81
Competency 2:	(a)	32	10	58
	(b)	28	3	69
	(c)	7	21	72
	(d)	16	2	82
	(h)	25	4	71
	(i)	30	10	60
Competency 3:	(a)	15	7	78
	(b)	15	3	82
Competency 4:	(a)	26	9	65
	(b)	14	4	82
	(c)	26	3	71
Competency 5:	(a)	11	3	86
	(b)	21	6	73
Competency 6:	(a)	19	0	81
	(b)	7	6	87
	(c)	14	5	81

Key to shading:

- Strongest competency(s)

_ Weakest competency

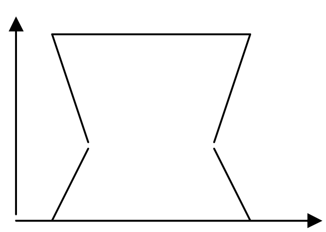
maximum total, to obtain a percentage of how the levels and also the group as a whole, fared per category within each competency. The percentages for each level of ability are shown at the bottom of Tables C7 to C12 and rewritten into Tables 7.7, 7.8, and 7.9. Table C13 (a) and C13 (b) represent the percentages of each learner's demonstration of each competency. The group's final percentages are summarised in Table 7.6 (p 118) above.

7.4.1 Reflection as a group:

Table 7.6 (p 118) above shows that the competencies of 'memorisation' and 'handling mathematical symbols and formalisms' (i.e. competencies 1 and 6), are strongest in this group of learners. This is to be expected with regard to the competency of memorisation where no understanding and application of these algorithmic procedures is expected. These are questions that the learners are used to seeing in past papers. Competency 6b 'handling and manipulating statements and expressions containing symbols and formulae', is what many consider the dominant activity of a mathematics class, i.e. 'doing sums'. The competencies 6a and 6c, i.e. 'translating from formal/symbolic language to natural language' (and visa-versa) and 'decoding and interpreting statements of the form of symbolic or formal mathematical language', were also well handled by these learners.

In comparison, the weakest categories occur within competency 2 ('thinking and reasoning mathematically') and competency 4 ('representing and explaining mathematical entities'). Competency 2a, that of 'understanding the scope and limitations of a given concept', was the weakest in this group of learners. As is indicated in Table 7.1 (p 97 - 98), this category was reflected in the two tasks (i.e. Thomas Saint's test and memo and the Graphs Exercise) by analysing the learners' solutions to the factorisation questions in Thomas Saint's memo and test; being able to interpret graphs with no vertical axes labelled, being able to represent a situation graphically and interpret a given graph. With regard to Thomas Saint's test and memo, a number of the learners did not complete the question 2 (c), i.e. to factorise a(x – y) – b(y – x), since they left their solution in the form ax – ay – by + bx; and also used inappropriate language to explain mistakes, e.g. with regard to the question 121 – m^2, which Thomas Saint answered as follows: 121 – m^2 = (121 – m)(121 + m), one learner wrote "You didn't simplify the 12, but you did simplify the m^2." The word "simplify" should have been "square root". This learner possessed the recognition rules (Bernstein, 1996) in operation here, but not the realisation rules. These learners did not understand the full procedure involved for factorisation and some could also not explain the mathematics involved using the correct terminology. Many could solve the algorithmic problems, but could not explain the mathematics in an acceptable manner.

With respect to the Graphs Exercise, some learners did not understand the scope of the graphs depicted, since their answers for Question 3.1. (i.e. "How is it that we can still interpret (in general) what is happening even though no vertical scale or units are given?") were sometimes inappropriate. For example, one learner wrote: "We can still interpret what is happening because we can see the lines." Another learner drew an inappropriate graph in answer to Question 3.6 ("Now draw your own graph of the level of milkshake in a glass when you and your friend have gone out. …"), shown as follows:



And yet another learner answered the Question 2.2. regarding the length of the trip as “100 km + 150 km + 250 km + 300 km + 300 km + 450 km + 450 km + 500 km + 550 km = 3050 km.” Clearly, these learners did not understand the concepts involved in graphing different situation. They may possess the recognition rules to distinguish what the question is asking, yet may not possess the realisation rules (Bernstein, 1996) to produce an appropriate answer.

The next weakest category within competency 2 is that of 2i, ‘using one’s predictions to predict other cases’. If the learner couldn’t produce some formula for the initial given question, then she couldn’t predict some formula for another case. With regard to Towers of Hanoi, if the learner didn’t obtain the formula $2^n - 1$, then she couldn’t predict when the world would end, i.e. $2^{64} - 1$ days. This is not to say that these learners could not predict, but that their prediction was dependent on them obtaining some general formula that could then be used for further prediction. Judging the competency of these learners may have lead to ‘false negatives’ (Cooper and Dune, 2000).

Competency 4a, ‘being able to explain different procedures of approach used’, was only displayed by 65 % of the group of learners (Table 7.6, p118). For example, one learner solved the question $(a - 2)^2 + 2(a + 1)^2$ from Thomas Saint’s Test and Memo correctly as follows:

$$
\begin{aligned}
& (a - 2)^2 + 2(a + 1)^2 \\
&= (a - 2)(a - 2) + 2(a + 1)(a + 1) \\
&= a^2 - 2a - 2a + 4 + 2(a^2 + 1a + 1a + 1) \\
&= a^2 - 4a + 4 + 2a^2 + 4a + 2 \\
&= 3a^2 + 6
\end{aligned}
$$

but when providing help for Thomas with regard to his attempt at this question, wrote:

"Always look at how many terms there are. When you are battling always write out the whole sum and show all working out, don't skip any steps out."

This was clearly not going to help Thomas correct any errors he had made or correct any misconceptions he may have harboured regard the procedures involved in factorising and simplifying products. Another learner provided the following help for Thomas (written in bulleted form as below) for the same question as shown above:

- "You must do BODMAS.
- Brackets first.
- Must learn foil.
- Look at mark allocation.
- Practise your factorising.
- Don't make silly mistakes.
- Check your answers.
- Make sure you multiply your brackets.
- Try harder.
- Well tried."

These points are very general hints and advice that all teachers mention in class at some point during the lessons involving factorising and simplifying terms, but as presented above, they would not help Thomas with specific errors that he made in individual questions.

When we consider how the learners handled each of these competencies separately in each task, we can see that although competency 1, i.e. that of 'memorisation', was handled well as a group, obtaining an average of 100% and 81 % for each of the categories in competency 1 in Table 7.6 (p 118), there is differentiation with respect to the percentages obtained for each individual task. Although this competency reflected a 100 %, a 90 % and an 85 % group proficiency with regard to competency 1b for Thomas Saint's Test and Memo, Going Shopping and the Cartesian Plane tasks respectively (see Table C1), it was not as well displayed in the Interpreting Graphs and Statistics tasks (i.e. only 64 % and 68 % of the group positively displayed this competency in these tasks). The calculations expected for 'average speed' (Questions 2.7, 2.8 and 2.9 in the Graphs Exercise), definitely have a higher cognitive demand compared to that necessary for factorising and simplifying algebraic expressions since some reading from the graphs is necessary. Nevertheless, I classified these calculations as 'memorisation of algorithmic procedures without any expectation of application, interpretation, analysis or synthesis', because the formula was provided on the question paper and because the teachers had done similar examples with the learners just prior to handing out this task. This overlap of competencies between performing simple percentage calculations and some language interpretation was also evident in the Statistics Exercise, thus increasing the cognitive demand for these questions (Stein et al., 2000). It does thus happen in an assessment of competencies, that they are intertwined within each other, where, in order to display one mathematical competency, one needs to be proficient in another. Also, the context in which a competency is assessed or the form in which it is asked, may affect the overall display of such competencies; and any assumptions regarding the proficiency or not of learners, must take into account the issue of 'transfer' of competency across task and across context.

This differentiation of percentages reflecting demonstration of competency across tasks, also occurs for the other competencies. With regard to competency 2a 'understanding the scope and limitations of a given concept', only 48 % of the group displayed this competency in Thomas Saint's Test and Memo (see Table C2 for these percentages), compared to 68 % in the Interpreting Graphs task. Both of these percentages are low, indicating a general weakness with regard to the display of this category. Only 52 % of the group displayed competency 2b, ‘extending the scope of a concept by abstracting some of its properties, generalising to larger classes of objects’, in the Hide the Spies Investigation, compared to an 83 % and a 71 % display in the Towers of Hanoi and Interpreting Graphs tasks. The cognitive demand expected in order to extend a question into an appropriate investigation, is higher than deducing the formula $2^n - 1$ (since pattern recognition can be practised whereas extensions to investigations can take any direction). With regard to competency 2h, that of ‘self-monitoring one’s own work’, the group percentages vary from 55 % (in the Hide the Spies investigation) to 90 % in the Shopping task. The more open-ended a task becomes, the higher the cognitive demand for self-monitoring one’s own work.

With regard to competency 3b, i.e. ‘solving different kinds of mathematical problems, only 48 % of the group displayed this competency in the Hide the Spies investigation, compared to a 93 % display in the Towers of Hanoi task, Thomas Saint’s Test and Memo and the Statistics Exercise and an 83 % display in the Going Shopping task. As discussed earlier, for those learners who extended the task in an inappropriate manner, solving the extension became almost impossible. This investigation also resulted in the lowest percentage obtained for the group for competencies 4 and 5 (i.e. a 48 % display for category 4a (i.e. ‘being able to explain procedures of approach used’) and a 55 % for category 5b (i.e. ‘expressing oneself in oral, visual or written form, using natural language’) (see Tables C4 and C5 for these percentages). Percentages for the whole group recorded for Thomas Saint’s Test and Memo (Table C4 and C5) also indicate lower than average displays of these competencies.

Thus there is a clear indication that caution needs to be exercised when making deductions about the competency of our learners, since successful display varies quite widely per task. An obvious statement here then is that the greater the number of exposures to each competency, the better one's conclusions for an overall assessment. Also, as mentioned above, the cognitive demand for each task, the amount of scaffolding needed per learner and the cognitive demand for each competency assessed within the task, needs to be taken into consideration prior to making any deductions about the learners' competency. The radius of action (Niss, 2002) of each competency needs to be varied enough to allow for ample opportunities for each learner to display his/her competency. This all in the context of an acceptable social base (Bernstein, 1996) established between both the teacher and the learners.

7.4.2 Reflection in terms of levels of ability

i) Level 2 ability learners:

With regard to these five learners, as was for the group as a whole, Table 7.7 (p 127) below indicates that competencies 1and 6 are strongest and categories 2a, 2c, 2i, 5b and 4a are weakest.

Although category 1a indicates a 100 % display, this category was only assessed once within the seven tasks used for this research and only three out of the five Level 2 learners had submitted the Cartesian Plane Exercise as a portfolio task. Thus little more can be said about this category for this level of learners, other than that it is expected that most learners do well at the memorisation questions, especially when the formulae are provided (see the average speed questions in the Graphs Exercise). Most of these learners could perform the mathematical calculations required in the Shopping and Statistics Exercises, their strength lying in performing actual calculations. It was in the interpretation of these calculations (i.e. competency 5) however that identified weaknesses in these learners' work. See Table C5 Competency 5b for the Statistics Exercise, where the question to be answered was “What kind of family could not be represented in the data and why not?" One of these Level 2 learners wrote: "5 got the least amount." This learner clearly does not possess the realisation rules in operation here in order to interpret the frequency table in that task, not realising that children only come from families who have at least one child anyway. A couple with no children will not be reflected in this frequency table at all. Of these learners, 80 % (i.e. 4 out of 5 of them) could not answer this question.

Although the average display percentage for this group of learners is 30 % for competency 2a ('understanding the scope and limitations of a given concept'), this percentage was obtained by determining the average between 0 % for Thomas Saint's Test and Memo and 60 % for the Interpreting Graphs exercise (see Table C2, row L2 below the Totals row). From Thomas Saint's Test and Memo:

1) three of the five learners in this level, left question 2 (b) as follows:

$$a(x-y) - b(y-x)$$
$$= ax - ay - by + bx$$

not completing this factorisation to its fullest; and

2) one of these learners left it as:

$$a(x-y) - b(y-x)$$
$$= a(x-y) + b(x-y)$$

3) the fifth learner left this question out in the memo and then did not provide comments for Thomas.

These four learners did not understand the scope of the process of factorization; what it means to express an expression as a product of its simplest factors.

[This resulted in 0 % of these level 2 learners displaying this competency category]; and from the Graphs Exercise, three of the five learners answered Questions 3.1, 3.6 and 2.2 correctly, resulting in the 60 % demonstration for this category, whereas the other two learners did not attempt to draw the graph of the level of milkshake (i.e. Question 2.2) at all, hence the 40 % unsure result. These learners thus possessed the recognition rules in operation in order to start the factorisation process, but

Table 7.7 Level 2 learner performance within each sub-category of competency:

		% L's who couldn't display competency	% Unsure of competency	% L's who did display competency
Competency 1:	(a)	0	0	100
	(b)	26	0	74
Competency 2:	(a)	40	30	30
	(b)	26	7	67
	(c)	20	60	20
	(d)	38	0	62
	(h)	43	0	57
	(i)	80	0	20
Competency 3:	(a)	40	10	50
	(b)	28	4	68
Competency 4:	(a)	50	10	40
	(b)	14	11	75
	(c)	31	0	69
Competency 5:	(a)	18	6	76
	(b)	40	13	47
Competency 6:	(a)	20	0	80
	(b)	15	25	60
	(c)	20	20	60

Key to shading:

- Strongest competency(s)

_ Weakest competency

do not possess the realisation rules to complete these questions appropriately.

With regard to competency 2i (‘using generalisations/formulae to predict other cases’), only one out of the five learners could display this competency in both occurrences of this category. As discussed for the group as a whole, for those learners who could not generalise their work from previous cases, they could then not predict other cases. However, any conclusion made about this competency could be erroneous, since it may be the case that these learners would have been able to predict other cases, had they actually reached the correct generalisation/formula needed from their previous work (i.e. errors of inference may have occurred here).

For competency 4a, (‘being able to explain procedures of approach used’), these learners achieved a 40 % display of this category (Table 7.7, p 127), however this average is obtained from the average of the following percentages: 20 %, 0 %, 60 % and 80 %, achieved for different tasks (see APPENDIX C, Table C4 Row L2 for these percentages). When the assessment forms change, the recognition and realisation rules (Bernstein, 1996) begin to change, as is noticeable from the different performances in the first three more open-ended tasks compared to those recorded for the more closed exercise-type tasks (i.e. Tasks 4 to 7). Where explanations were clearly asked for, as in the graphs exercise (where an explanation of the graph illustrating the drinking of a milkshake was asked for), these learners fared very well, yet where this instruction became more implicit (as in the Towers of Hanoi task, indicated in the rubric provided to the learners, indicating how the task would be assessed) or when mathematical procedures had to be explained (Thomas Saint’s Test and Memo), they fared much worse.

As the forms of assessment change, so too does the cognitive demand then placed on the learners change. One can see that these learners fared worse on the higher cognitive demand tasks with regard to competency 4 than on the more closed tasks (see Table C4 for all the percentages obtained for this competency). This competency is closely linked to that of ‘communicating mathematically and interpreting mathematical statements’ (competency 5), since both rely on the use of language to display the competence. Learners who are weak at language, but who are strong mathematically, may not be able to express themselves using the appropriate terminology. On the other hand, learners who have a strong demand of the language, but do not possess strong mathematical skills, may be able to learn some procedures by rote and thus display a false competence. These are similar to the false negatives and false positives discussed by Cooper and Dunne (2000). These possibilities need to be kept in mind at all times. The average achieved for the level 2 learners for competency 5b, ‘expressing oneself in oral, visual or written form, using natural language’, is low (47 %), very similar to the 40 % achieved for 4a (Table 7.7, p 127). Both these results indicate a low ability with regard to language skills, an area that needs to be developed further for these learners if they are to become more successful in the new forms of assessment to be used now and in the near future.

With regard to competency 1b, ‘the recall of algorithmic procedures’, this group of learners achieved a 74 % competency rate (Table 7.7), yet when one considers the achievements per task (APPENDIX C, Table C1), we notice that these learners were weakest at the Statistics Exercise (obtaining 40 % competence in this task), where simple percentages were to be calculated. This type of analysis reveals a weak area for these five learners, one that could have been used to inform the teaching/learning process of those involved, if such an analysis had been done during the year. Knowing from previous discussion (7.3, p 113 above), that these learners benefited the most from the inclusion of these tasks in their

Table 7.8 Level 3 learner performance within each sub-category of competency:

		% L's who couldn't display competency	% Unsure of competency	% L's who did display competency
Competency 1:	(a)	0	0	100
	(b)	16	2	82
Competency 2:	(a)	34	9	57
	(b)	33	2	65
	(c)	0	17	83
	(d)	10	0	90
	(h)	23	6	71
	(i)	22	14	64
Competency 3:	(a)	14	3	83
	(b)	16	2	82
Competency 4:	(a)	27	7	66
	(b)	17	2	81
	(c)	28	2	70
Competency 5:	(a)	10	2	88
	(b)	20	3	77
Competency 6:	(a)	26	0	74
	(b)	7	1	92
	(c)	19	0	81

Key to shading:
- Strongest competency(s)
_ Weakest competency

portfolios, we need to help these learners develop this competency further, in order to improve their own performances. These learners also confirm the point that although they may have benefited from the discussions that should have occurred, i.e. from any mediation that may have taken place, they still may not possess the recognition nor the realisation rules to perform sufficiently well within these open-ended types of tasks.

ii) Level 3 ability learners:
[Refer to Table 7.8, 130 above]

The strongest competencies for this group of learners was competency 1 (memorisation), competency 3 (‘posing and solving mathematical problems’) and competency 6 (‘handling mathematical symbols and formalisms’). Again memorisation and performing mathematical calculations is strongest, although one begins to see strength in posing mathematical problems within these learners. The weakest competency is once again competency 2, where percentages of 30 % for 2a and 20 % for both 2c and 2i were obtained for these learners.

With regard to the Hide the Spies Investigation, these learners also fared very badly in displaying categories from competency 2, 3 and 4: 2b recorded 33 %, 2h 44 %, 2i 33 %, 3b 39 % and 4a 39 % display rate) (see APPENDIX C Tables C2, C3 and C4 for these percentages). This again indicates the difficulty that these learners experienced with regard to this more open-ended type of task. By expecting an extension of the first problem within this task, one would expect an environment where each learner feels confident to explore different possibilities, an environment that would encourage and support one’s efforts and suggestions. This demands strong control on the part of the teacher, where all suggestions are encouraged and where operation in the zone of proximal development (Vygotsky, 1979: 86) is maintained for all learners, not just the higher achievers. However, even amongst these higher achieving learners, inappropriate extensions to the investigation were seen, where learners did not provide appropriate paths for extension of the investigation.

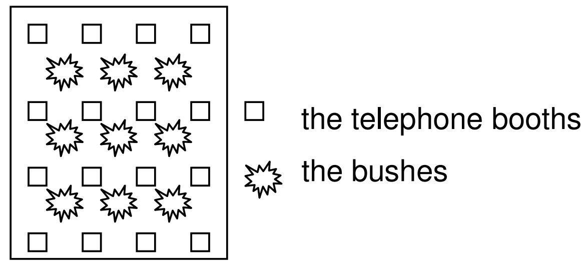
One such learner extended her investigation by reducing the number of spies in the question to three and then to two, keeping the size of the square and the number of booths constant. However, she explains her solution as follows:

> "for 3 spies I found 96 different answers.
> for 2 spies I found 72 different answers.
> So what I found out is if I times the answer for the 4 spies times the amount I got the answer for the next amount of spies.
> 24 X 4 = 96 which is the answer for 3 spies
> 24 X 3 is the answer for 2 spies."

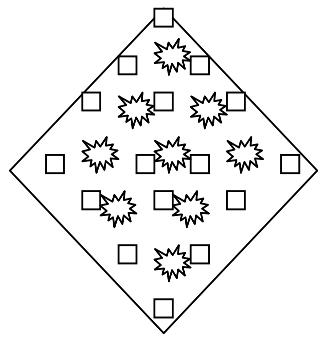
[This extension would have been fine, had she calculated the number of permutations for both of these situations correctly, which she did not. Since for a 4 by 4 square with 3 spies, there are 96 possibilities but if there are two spies, there are 288 possibilities.] This learner had extended the question appropriately, yet not performed some checks with regard to her solution. Self-monitoring her answer would have revealed an incorrect solution.

Another inappropriate extension is illustrated below, where this level 3 learner drew her ‘new’ shape as a diamond, i.e.

the square park



was redrawn as a diamond, i.e.



From Table C2 (APPENDIX C), one can see that of the 18 learners in this ability group, only 8 of the 18 learners (i.e. 44 %) showed evidence of self-monitoring. So too, only 6 of the 18 learners (i.e. 33 %) showed clear evidence of an appropriate extension and then some generalisation from their extension. Following this, only 33 % of these learners provided a prediction from some formula that they had provided. This task thus reveals an area of concern with regard to investigations, where providing more opportunity for these learners to practice investigations, self-monitor their work, generalise and predict, should serve to improve their investigative skills. These level 3 learners are more able to perform the productive aspect of competency 2, providing appropriate paths for investigation, the beginnings of self-monitoring, generalisation and prediction (by performing the mathematical processes required to solve the problems), but the analytical aspect of the competency (i.e. the ability to analyse and interpret the problem) (see 'dual nature of competencies' (Niss, 2002) 5.2.2, p 53 above) still requires attention.

Although the level 3 learners recorded an 82 % average for competency 1b ('the recall of algorithmic procedures') (Table 7.8, p 130), only 10 of the 17 learners (i.e. 59 %) displayed this competency in the Interpreting Graphs Exercise (Table C1). Being able to calculate average speed and highest average speed, although given the formula, obviously challenged these learners as well. Since this calculation required the implicit assumption of calculating speeds across intervals where the speeds remained constant (i.e. from O to A, A to B, B to C, etc.), in order to compare, or else to determine the steepest interval along the graph (see Graph 2 in this task), there are other factors that affected the success of these calculations, not just the simple action of substituting into a given formula. Only the top achievers all managed to calculate these speeds correctly.

iii) <u>Level 4 ability learners</u>:

[Refer to Table 7.9, p 136 below]

Although this group of learners performed very well across all seven research tasks, they nevertheless displayed the lowest percentages within competencies 4 and 5. Per task, this group of learners obtained the lowest percentages in the Cartesian Plane Exercise for competency 2h and 4c (60 % for both) (Tables C2 and C4) and in the Hide the Spies Investigation for competency 5b (60 %) Table C5). Self-monitoring is again highlighted added to which switching between forms and providing explanations using appropriate language is sometimes problematic even for these learners. These learners obviously possess the ability to demonstrate these 6 competencies, both from the productive and the analytical aspect of each competency. These learners thus possess both the realisation and recognition rules in operation within these tasks, producing work that is appropriate and applicable, using language that is effective and mathematically correct.

7.4.3 Reflection in terms of competencies and tasks

As can be seen from the previous paragraphs, the percentages achieved for the display of each competency for each of the tasks (see Tables C1 to C6), vary widely from the averages calculated for each competency in Tables 7.6 to 7.9. Table 7.10 (p 137) below, lists the task/s that displayed some of the lowest percentages for each level and as a group.

As can be seen from Table 7.10 (p 137), the one common task that consistently produced low (if not the lowest) percentages across competency, was that of the Hide the Spies Investigation, followed closely by the Towers of Hanoi and Thomas Saint's Test and Memo. With the changes in the forms of assessment occurring, towards the use of more investigative and open-ended types of assessment tasks, all the learners, especially the lower ability learners, need more opportunities to develop the skills necessary to produce work acceptable for such tasks. The control over the social base (Bernstein, 1996) also changes when we begin to introduce these new forms of assessment, taking time and effort from both the teachers and learners to develop and evolve. Those learners with higher than average mathematical ability, seem to have adjusted quicker than those of lower mathematical ability to these changes, as indicated by the competencies in Table 7.10 (p 137) below.

Table 7.9 Level 4 learner performance within each sub-category of competency:

		% L's who couldn't display competency	% Unsure of competency	% L's who did display competency
Competency 1:	(a)	0	0	100
	(b)	4	0	96
Competency 2:	(a)	0	0	100
	(b)	0	0	100
	(c)	0	0	100
	(d)	0	10	90
	(h)	8	0	92
	(i)	0	0	100
Competency 3:	(a)	0	0	100
	(b)	0	0	100
Competency 4:	(a)	5	5	90
	(b)	3	0	97
	(c)	20	0	80
Competency 5:	(a)	3	3	94
	(b)	7	7	86
Competency 6:	(a)	0	0	100
	(b)	0	0	100
	(c)	0	0	100

Key to shading:

- Strongest competency(s)

_ Weakest competency

Table 7.10 Table depicting the task/s that displayed some of the lowest percentages for each level and as a group.

Competency:	*Level*	*Task that displayed low percentages*
Competency 1 (see Table C.1)	Level 2:	Statistics Exercise
	Level 3:	Interpreting graphs
	Level 4:	*
	Group	Interpreting graphs
Competency 2 (see Table C.2)	Level 2:	Towers of Hanoi, T. S.'s Test and Memo, Hide the Spies Inv., Cartesian Plane Ex.
	Level 3:	Hide the Spies Inv.
	Level 4:	Cartesian Place Ex.
	Group	T. S.'s test and Memo, Hide the Spies Inv.,
Competency 3 (see Table C.3)	Level 2:	Hide the Spies Inv.
	Level 3:	Hide the Spies Inv.
	Level 4:	*
	Group	Hide the Spies Inv.
Competency 4 (see Table C.4)	Level 2:	Towers of Hanoi, T.S.'s Test & Memo, Hide the Spies Inv.
	Level 3:	Hide the Spies Inv.
	Level 4:	Cartesian Plane Ex.
	Group	T. S.'s test and Memo, Hide the Spies Inv.
Competency 5 (see Table C.5)	Level 2:	Towers of Hanoi, T. S.'s Test and Memo, Cartesian Plane Ex.
	Level 3:	Hide the Spies Inv.
	Level 4:	Hide the Spies Inv.
	Group	T. S.'s Test and Memo, Hide the Spies Inv.
Competency 6 (see Table C.6)	Level 2:	Towers of Hanoi
	Level 3:	Going Shopping
	Level 4:	*
	Group	*

* indicates no problematic tasks for that competency

[T.S.'s refers to Thomas Saint's Test and Memo.]

7.5 Conclusion

This chapter serves to provide some analysis of the seven research tasks from the perspective of the competencies that are assessed by them. From Graph 7.1 above, it is clear that ‘communicating mathematically and interpreting mathematical statements’ (competency 5) was assessed the most, in comparison to ‘thinking and reasoning mathematically’ (competency 2) which had the least occurrences across these seven tasks. A portfolio should emphasis the importance of communication and interpretation in all different forms and the high occurrence of competency 5 reveals what the teachers valued most with regard to the development of the portfolios of 2003, i.e. the ability to provide explanations in terms of natural language. The use of different forms of representation (competency 4b), was also assessed often in these tasks. Although memorisation of definitions does not feature often in these tasks, that of memorisation of procedures does. This indicates the tensions that the teachers are facing with regard to the use of more traditional types of assessments versus those that are more open-ended in nature.

From an analysis of the percentages obtained for the final portfolio compared to that obtained for the final promotion mark, it is evident that the lower ability learners have benefited more than their higher achieving peers from the use of this portfolio. However, all the learners across the whole group, achieved a higher result for their overall portfolio in comparison to their final promotion result. Most of the learners also fared much better on the more traditional exercise-type tasks, obtaining higher results for these tasks compared to the more open-ended tasks. With regard to the seven research tasks used for this report, these learners definitely found the investigation task most problematic, indicating a weakness that needs to be improved if we are to use more investigative types of tasks for high stakes assessments, assessments that may in the long run have a critical influence on the lives of each learner in the future.

By providing mathematics teachers with an initial set of open-ended and investigative type exemplar tasks, tasks that cover the required Specific Objectives (now referred to as LOs) in the required ratios, may serve to improve the standard of portfolios being developed. Also, by providing examples illustrating the levels of difficulty expected and rubrics for assessing such tasks, may prevent assessment sheets from becoming window dressing for the overall result. Teachers should be made more aware of how many times each competency (or Specific Objective/Learning Outcome) needs to be assessed and also be provided with appropriate examples of each competency.

The developmental nature of the portfolios has not been discussed and has also not been evident within the seven tasks used for this portfolio. Tasks that require initial drafts (such as a research project or assignment) may lead to some evidence of developmental progress across time. Since the learners had only one attempt at each task, they were then treated as summative assessments. The formative nature of educational assessment is not clearly evident in this portfolio.

Thus in summary, from the above analysis of each of the tables, we can see that the calculations to determine the mean (i.e. the average) of each group of tasks (i.e. the more open-ended versus the more closed types of tasks), hide important variations that occur within each set of percentages obtained. This means that any deductions made about the competency of learners requires the consideration of a number of different factors:

1. Firstly, the cognitive demand of each task needs to be taken into account when making such deductions.
2. The cognitive demand of different questions involved in each task, varies, and may influence the final results that the learner obtains. Also, the recognition and realisation rules (Bernstein, 1996) that each learner possesses at that time, have an over-riding influence on how the learners answer individual questions within each task

and then also on the final result obtained. This may negatively affect his/her result, if he/she has not been able to complete previous work on which any questions that follow, depended.

3. The level of ability of the learners needs to be taken into account, since different ability groups in this study, performed differently across the different mathematical competencies.
4. The learners involved in this study have performed better at the exercises and other lower order thinking tasks involved in this study, than the investigation and other open-ended tasks. Thus deductions about the competency of each learner, needs to take into account the form of assessment being used, added to the cognitive demand of each task. Different forms of assessment demand differing levels of cognitive demand, which need to be considered when making deductions about the competency or not of each learner.

With regard to the competencies, across all the ability groups, ‘thinking and reasoning mathematically’ (competency 2) and ‘representing and explaining mathematical entities’(competency 4) were weakest and ‘memorisation’ and ‘handling mathematical symbols and formalisms’ (competencies 1 and 6) the strongest. This indicates how the mediation has taken form in practice. Competency 2 was also assessed the least across the seven tasks. If we as mathematics teachers want to develop learners who can think and reason mathematically, then we need to provide more opportunity for this competency to be developed.

Chapter 8. Conclusions and discussion.

8.1 Discussion

The study reported, takes place in the context of curriculum change, in particular from a performance-based model to a ‘competence-based’ model of curriculum. It has studied the impact that this change has had on the forms of assessment used. Within the outcomes-based, competence model now being applied in South Africa, a learner-centred approach to teaching, learning and assessment, is advocated. The changes in assessment are a direct result of the weakening classification and framing with regard to the selection of the communication, the sequence and pace of the work and the control over the social base which makes this transmission possible (Bernstein, 1996: 27), aspects that are characteristic of this model of approach. Although there is weaker framing with regard to the factors mentioned above, there is still strong framing in terms of the criteria stipulated for the development of the portfolios. The introduction of a portfolio into the Grade 9 year, has allowed teachers much freedom of choice with regard to task selection and content for their learners, yet this research report reveals a number of concerns with regard to the use of this new form of assessment in mathematics.

This research report, while focussing on assessment of the Grade 9 portfolios, contributes in two ways to the field of Mathematics education. Firstly, it provides a composite list of mathematical competencies that can be used to analyse one’s teaching and learning in all mathematics classrooms. Added to this, some exemplars of tasks analysis against this list of mathematical competencies are provided. This is a contribution, since there is very little detail on this from a South African perspective. The mathematical competencies used for this research include:

1. Memorisation (of definitions, concepts and proofs without the need for application, plus the recall of simple algorithmic procedures).

2. Thinking and reasoning mathematically, which incorporates the ability to understand the limitations of certain concepts, generalising, recognising different mathematical statements, following other's chains of thought, differentiating 'proof' from other mathematical statements, identifying main thoughts in an argument, self-monitoring and predicting.
3. Being able to pose and solve mathematical problems.
4. Being able to represent and explain mathematical entities, using different approaches, different forms of representation and switching between them.
5. Being able to communicate mathematically and interpret mathematical statements. And
6. Being able to handle mathematical symbols and formalisms.

As was discussed, this list of mathematical competencies was derived from the Danish KOM Project (Niss, 2002), but was altered in certain discussed ways. This list is by no means a complete list of mathematical competencies, but will provide important starting points from which one's tasks can be analysed. For instance, this list does not include modelling and the use of computers and other tools. These competencies also need to be added in so as to provide a more comprehensive list.

The second contribution of this study is the analysis and subsequent interpretation of actual learner performance in new forms of assessment. These forms of assessment have been introduced into the classroom, in line with the changes expected from the new competence-based model of curriculum and pedagogy. The move away from a performance-based model, towards one advocating an outcomes-based approach, where learner-centredness is assumed, has resulted in the introduction of a portfolio of work. This has steered the assessment forms away from purely examination and test driven assessments, to the introduction of investigations, open-ended tasks, projects and assignments; i.e. tasks that cannot be completed in time-restricted environments.

The framework of this research was based on a selection of concepts introduced by Basil Bernstein (1996). His concepts of ‘classification’ and ‘framing’ have been useful when considering the current pedagogy being advocated at this time in South Africa. The weakening in classification and framing (Bernstein, 1996) that has occurred with the change from a performance to a competence model, has resulted in the recognition and realisation rules changing. Learners need to adapt to these changes in order to operate successfully in this new model. However, which learners have adapted and which not? The successful act of teaching and learning in the zone of proximal development (Vygotsky, 1979) is dependent on learners possessing these new realisation rules and on appropriate scaffolding by the teacher. Those who are successful have also realised the change in the control over the social base (Bernstein, 1996) that takes place between teacher and learners. Although all of these concepts form part of Bernstein’s framing (1996), it is because of the weakening of the framing, that these have taken new form. The portfolio developed for the Grade 9 learners of 2003, at the school at which I am currently teaching, is just one indicator of this weaker framing. It is the manner in which the teachers and learners involved in that Grade 9 year, interpreted and mediated the expectations of a new curriculum and the assessment thereof.

In order to provide an alternate gaze (one not reliant on the Specific Outcomes as stated in the Curriculum documents) to the analysis of the portfolios used for this research, the list of mathematical competencies discussed above, was derived. While the portfolio for these learners was being developed, actual mathematical competencies were not considered. Other factors such as the time each task would take to complete and then mark, plus the type of assessment it included (for example peer or group assessment) were often the dominating factors influencing the tasks chosen. Deductions about the mathematical competency or not of our learners in the past I feel, have thus been skewed. An awareness of mathematical competencies included in tasks, may serve to inform the teaching and learning of mathematics, by improving task selection processes and increasing the cognitive demand of most of the tasks that we would then use. Only by starting with tasks that have a high cognitive demand, can learners be challenged to produce work of a high standard, and thus take true ownership of their work.

Proponents of OBE advocate that this competence- and outcomes-based approach to education will introduce the potential firstly to provide for the needs of all students, regardless of their circumstances (i.e. become more learner centred), and secondly that it will enable "teachers and educationists to … be able to develop better instructional procedures, and assess learners' achievement with exactitude, clarity and validity" (Baxen and Soudien, 1999: 133). This point claims then that all students will benefit from this approach and secondly that teachers will be able and willing to choose and develop tasks that will be relevant to the learners in that specific community of practice. It is also assumed that the tasks chosen will reflect the critical and specific/learning outcomes for each learning area adequately and in some correct ratio of importance. In my research, this assumption is seen to be problematic, in that not all the students really benefit from the use specifically of portfolios (or seem to benefit to different degrees) and also that the teachers involved in my study, although highly trained and qualified and extremely proficient in their subject, have not been able to cover all of the competencies listed in Table 5.1 (p 61) above. If this is the situation in a small private single-sex school, then what is happening in the government schools where teachers have much bigger classes and larger numbers of portfolios to assess? The assumption is that teachers at privileged schools with vast resources, are most likely to succeed in implementing innovative principles, but is this assumption not too generalised? It is not enough that these teachers have recognised that the rules of pedagogic practice have changed and are attempting to apply the new assessment policies to their teaching.

Teacher support in terms of developing and selecting appropriate tasks in order to cover all outcomes needs to be tackled, in order to provide the teachers with the skills required to teach and assess proficiently within an OBE system.

There are a number of purposes that a portfolio could be used for, i.e. accountability, selection, promotion, appraisal and formative assessment (used to improve and inform the teaching and learning processes) (Klenowski, 2003), which is considered a continuous form of assessment, yet it seems that the dominant use of the portfolio in the GETC year in South Africa, is that of a summative assessment and for certification. It is supposed to serve a reformist function, by giving teachers and learners more control over selection, sequencing, pace and social base. However with all tasks being converted to a percent-correct mark and the formation of a 'portfolio mark' used as part of the promotion mark, it is summative in nature. A continuous, formative assessment approach is supposed to be used, yet due to the very nature of the tasks selected, it at the moment offers only one opportunity for the learners to display their competence per task. There is thus no opportunity for improvement and self-reflection within a task once it has been handed in (although there is opportunity for improvement from task to subsequent task). As was mentioned in Table 4.1 (p 34), open-ended and investigative tasks can be used to study learners' insights into methods of problem solving and levels of understanding of certain mathematical concepts, reveal misconceptions and encourage discovery. The manner in which these portfolios was assessed and the number of tasks that were required, has not allowed for much discussion regarding misconceptions revealed by the learners, insights into unusual methods of solution, nor much development of the metacognitive processes involved in selecting, critiquing and monitoring one's own work. The learners should not be assessed on the results of the investigation task, but more so on the quality of the mathematical processes as work, i.e. of working systematically, conjecturing, generalising, explaining and communicating, i.e. the mathematical competencies that our learners are exposed to.

8.2 Tensions with regard to the development of successful portfolios

This research has identified a number of tensions that teachers and learners need to overcome in order to perform successfully in this model. The first is that the quantity of items required for completion of the portfolio, takes time away from further analysis of misconceptions and problems that would serve to enrich the teaching/learning practise. This time management is not unique to portfolio work, but one that mathematics teachers constantly grapple with.

The second tension highlighted from these portfolios, is that there is still a predominance of exercise-type tasks included in the portfolio, which is still an old form of assessment. Of the seven tasks chosen for this research, only three of the seven were actually open-ended. Although the rest were context-based, they still resembled exercise-type tasks, 'closed' in that they only required one correct answer for all the questions.

The third involves decisions about the overall cognitive demand of the tasks used. We need to keep in mind that individual questions may vary according to cognitive demand, and so require differing amounts of time for completion. Enough time must be provided to enable the learners to produce work that will be considered as that exemplifying a high standard; by becoming really involved in those high cognitive demand type questions. We also need to begin with cognitively challenging questions, in order to provide opportunity for these types of assessments. We cannot expect our learners to become proficient at solving investigative tasks and extending open-ended types of tasks in appropriate directions, without practicing these competencies in class prior to assessments taking place. Although we may begin with a cognitively challenging task, this may be reduced in cognitive demand due to actions by the teacher, i.e. by providing formulae for the learners to use, providing too much scaffolding, not operating correctly in the zone of proximal development.

Another tension that exists, is the tension between the use of 'old' versus' new' forms of assessment. Instead of encouraging formative assessments, these tasks have been assessed in a summative manner. By using only old forms of assessment to evaluate learner performance (Saxe et al., 1999), i.e. by using only percentages to mark the tasks, this portfolio tends towards a summative assessment of each learner's performance, instead of promoting the use of rubrics that do not use percentages and marks, with words such as 'achieved', 'partially achieved', 'not achieved', etc. Thus the manner in which these open-ended and investigative tasks are assessed, is still problematic. Also, within the more open-ended types of tasks included in this portfolio, there is still a high occurrence of questions requiring memorisation of algorithmic procedures without any expectation of application, interpretation, analysis or synthesis (i.e. competency 1b). These were revealed analytically and by studying the tasks themselves. This new form of assessment still has an old function, i.e. for certification, by means of time-restricted summative tasks.

Lastly, there is also a tension with regard to cost. This being since this competence model that we are applying, has high costs with regard to economy, in terms of the resources required to create such a portfolio demanding much time and effort on the part of the teachers to create appropriate tasks, develop rubrics to assess them and then time to mark such tasks. Again, the issue of time is mentioned.

8.3 Results from the learners' actual performances

As a group, these learners performed worst on the Thomas Saint's

Test and Memo, the Hide the Spies Investigation and Interpreting Graphs Exercise and best on the Cartesian Plane and Statistics Exercises. Almost 80 % of the group fared much better on the more traditional type of tasks compared to the more open-ended types of tasks.

When one compares the average obtained for the seven research tasks compared to that obtained for the final promotion mark and the final portfolio marks, the mark for the seven research tasks is much higher across all levels of learners than either of the other two. However, after calculating the average obtained for only the three open-ended tasks, this result is extremely close to that mark obtained for the whole portfolio. This the highlights the importance of producing enough evidence to enable the teachers to make informed decisions about the competency or not of our learners, but to find the balance right between the number of tasks that should be used to make such informed decisions.

With regard to the apparent benefits of using a portfolio, these learners have revealed that those belonging to the lower ability groups, seemed to have benefited most from the introduction of this portfolio. This is when one compares their results obtained for the final portfolio compared to the final promotion marks. When considering, however, the different types of tasks included, the learners in the level 2 ability group, fared worst on Thomas Saint’s Test and Memo, compared to those in levels 3 and 4 who fared worst on the Interpreting graphs exercise. There is thus a differentiation with regard to the different ability groups and how each group fared within each task. The amount of scaffolding and mediation that took place, would also have an effect on the overall performances.

It is also clear that these learners as a group, could demonstrate the competencies of ‘memorisation’ (competency 1) and ‘handling mathematical symbols and formalisms’ (competency 6), but found those of ‘thinking and reasoning mathematically’ (competency 2) and ‘representing and explaining mathematical entities' (competency 4) difficult. 'Thinking and reasoning mathematically' and 'representing and explaining mathematical entities', obviously have a higher cognitive demand compared to that expected for 'memorisation' and 'handling mathematical symbols and formalisms'. This also indicates a weak area in the teaching/learning process. If we are going to expect our learners to produce explanations for work and not just solve problems, we as mathematics teachers must expose them to such competencies more and more, developing these competencies prior to assessing them. The learners need time to develop these competencies before they are assessed on them.

8.4 Competencies assessed in these portfolios

The teachers involved in this study, clearly valued the ability of the learners to provide explanations of work and make use of different forms of representation. From the high occurrence of the competency categories 'interpreting other's mathematical texts' and 'using natural language to communicate' (competencies 5a and b) and 'using different forms of representation' (competency 4b), these indicate a move by the teachers towards using new forms of assessment.

The occurrence of the competency communicating mathematically and interpreting mathematical statements, is a huge step forward in the use of new forms of assessment. Expecting our learners to explain their working and not just to be able to perform the mathematical manipulations, helps the learners to realise that there are other aspects of doing mathematics, not just solving the problem using numbers/formulae. Added to this is the point that being able to verbalise one's approach reveals many misconceptions that us as mathematics teachers may not be aware of if only considering the symbolic forms more often examined. Being able to represent mathematical entities using different forms, is a skill that needs to be developed within our learners, since problems in life do not appear in only one format. Learners need to be able to decide which form/s of representation would be best in different situations, which form/s would be most economical and appropriate. These skills cannot be developed unless we as teachers expose our learners to them. We also cannot assess them fairly, unless we have provided the learners with enough opportunities to practise these skills sufficiently.

What has also been evident from the analysis of this portfolio, is the intertwined nature of the competencies, where the demonstration of one competence often depends on the mastery of another.

8.5 Recommendations for practice

This research reveals that these portfolios are being used to provide a school-based assessment, referred to as the CASS mark, which ultimately takes the form of a percentage mark. The manner in which the tasks included in these portfolios were marked, i.e. converting to percentages, reflects a more performance-based model of education, where norm-referencing and not criterion-referencing is used. There is little evidence in this research project of some developmental nature of the portfolios, where improvements over time can be realised and highlighted and where opportunities for reassessment and improvement are provided. Teachers should thus be made aware of the purposes for which the portfolio will be used, which in turn would then influence the tasks/pieces chosen for that portfolio and the assessment used to evaluate that portfolio. If the portfolio is claimed to have a purely formative learning function, then feedback that can be used by the learners for improvement is imperative. Assigning a grade only to these tasks, would then not suffice. In comparison, if the purposes are purely that of a summative nature and for accreditation, then the assigning of grades done analytically is appropriate.

In order to improve the tasks selected for a portfolio, exemplars of tasks and actual learner performances within those tasks may be of immense benefit o the teachers. The competencies assessed by each task needs to be mentioned in order to ensure an even spread of the assessment of the competencies. Also, teachers should then be provided with minimum recommendations (from the Department of Education) for ensuring this even spread of competency assessment. Teachers should become more aware of the mathematical competencies that they are assessing and the cognitive demand involved in each one, as this awareness will only serve to improve the mathematics that we are exposing our learners to. We also need to begin working in such a manner as to increase the number of exposures of each competency, but not to increase the number of tasks that we need to use.

This research has resulted in my becoming more concerned with all the procedures and algorithms that we teach our learners, since the value of investigations and open-ended tasks cannot be highlighted enough. It may be interesting to study other schools' portfolios and to come up with some recommendations that would improve the quality of mathematics learning that we are providing for our learners. As was mentioned in the methodology chapter, it was decided to restrict my research only to an analysis of the Grade 9 portfolios and so it would be an option to extend this research to the senior classes, exposing the competencies that dominate those portfolios and reveal which competencies those learners are proficient at. A developmental study over time, one that studies the improvement (or not) of the proficiency of mathematical competencies, may enlighten problems in the current mathematical 'curriculum', making suggestions for improvement.

With regard to the performance of these learners in terms of mathematical competency, unsuccessful demonstrations of these competencies may have resulted from the learner lacking the recognition and/or the realisation rules necessary for appropriate completion of that task. As Morgan (1998: 125), stated: “different social classes have differentiated access to certain forms of language”. Teachers assess in relation to often unspoken assumptions about what they regard as appropriate language, and unless these assumptions are made clear to the learners, some learners may be disadvantaged because of their inability to express themselves adequately, and which in turn may be interpreted as a lack of ‘understanding’ (Morgan, 1998). Where necessary, time should allow for the teacher to provide more opportunities for the learners to demonstrate some degree of competency, although at some point it is expected that the teacher will have to make an informed decision to move on with new work.

By being aware of the competencies that we are frequently exposing our learners to and which need more attention, the quality of mathematics learnt will also be improved. It is often said, that teacher teach to the test, and if we are provided with the appropriate guidelines for assessment, enough resources and much in-service training, plus enough time to spend analysing our learners’ works in detail, teachers may be won over to the principles of a truly outcomes-based approach to education.

8.6 Experience as a researcher

As an inexperienced researcher, there were instances where I became very disillusioned with myself and with others involved in my research project. With regard to the use of the Grade 9 portfolios for my research, I fully expected that all the learners would allow me to use their work, and was initially disappointed with the poor response of the consent forms. I also became discouraged when I began working through the tasks, since I had expected to have more open-ended types to analyse. Having conducted interviews with some of the learners involved in my study, I would have liked to analyse the comments made by the learners in the interviews regarding their experiences with portfolio work. This would have added another dimension to my interpretation. This however was not to be. The data that I had was sufficient to illuminate problems and concerns with regard to the assessment of mathematical competencies, but as can be seen, there is always room for extension.

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Portfolio Research Project Consent Form.

Dear Grade 12 and Grade 9 learners, 2003

Re: Consent for participation in M.Sc. research project

In order to complete my Master of Science in Mathematics Education, I have had to complete a number of courses plus do some research of my own. In this latter regard, I am interested in the new forms of assessment that we now have to administer and also the forms that these new forms of assessment take, specifically what tasks have been selected as part of a portfolio for each learner. I am interested in whether these new forms of assessment actually benefit our students or hinder them. I will be attempting to discover what competencies these new forms of assessment are really measuring, what contradictions emerge and what our learners experiences are around these portfolios.

My research will occur in three phases, i.e. the first being an analysis of all the portfolios of all the learners in grades 9 and 12, a questionnaire for all the learners in both grades and then some interviews with learners from each grade (I envisage interviewing 6 grade 9 learners and 6 grade 12 learners). These interviewees will be selected from all/both of the represented classes, where the interview will take the form of an informal discussion about the portfolio pieces, reasons for specific selections of pieces, the learner's experiences with regard to the portfolio and a general discussion of the portfolio as continuous form of assessment.

In order for me to do the above research, I plan do:

- photocopy all portfolio pieces of all the grade 9 and grade 12 learners
- ask all the learners to complete a questionnaire, and
- to interview 6 grade 9 learners and 6 grade 12 learners, by arrangement with the persons involved.

APPENDIX A

The purpose of this letter is

- to inform you about my research
- to request your participation in the research process
- provide you with procedures for your written consent that I gather the information as described above
- provide written guarantee to you that all data will be treated confidentially, and all participants will be treated anonymously
- inform you that participation in this research is entirely voluntary.

All data captured (copies of individual pieces, interview responses and questionnaires) will only be used for research purposes. The research report and all data will be archived and kept at the University of the Witwatersrand, only to be used to verify my research, and, depending on request from other academics, be reported/discussed at conferences and be published in academic journals. In all written reports confidentiality and anonymity will be protected. It is important to make clear that your participation in my research is entirely voluntary. If you do not wish to participate in any aspect of it, you can indicate this on the consent response sheet attached. In addition, if at any point during my research analysis you would wish to withdraw your consent, you are entirely free to do so.

Hence I am asking that you and your parents/guardians (if under the age of 18 years at date of signing) complete the attached consent form and return it to me, i.e. Mrs. L. Rodwell, at Holy Rosary School at your earliest convenience. I will be happy to deal with any questions or queries that you may have now or at any stage during my research.

I am looking forward to your participation in my research and anticipate your responses keenly. On the following page there is a consent form that, if you agree, needs to be completed and signed by you and your parents (if you are under 18 years of age).

Yours truly,

……………………………..

CONSENT FORM

I, ………………………………………………….., (please print your full name), as a student in Grade 9/ 12 (please circle correct grade), currently studying at S.J. Secondary School * for the year 2003, am aware of all the data collection processes in this research project as listed in the letter above.
I give consent to the following:

- copies of all my assignments, tests and other portfolio pieces that I have produced as part of my portfolio for this grade being made

  Yes / No (*Please circle your response*)

- completing a questionnaire at some time during or immediately after completion of the work for this year

  Yes / No (*Please circle your response*)

- being interviewed at some point during or after completion of the school work for this year

  Yes / No (*Please circle your response*)

- the future use of results generated from this research for academic purposes

  Yes / No (*Please circle your response*)

Signed:………………………………………… (Learner)

…………………………………………(Parent/guardian, if learner is under the age of 18 years at date of signing)

Date: …………………………………………

(* Name changed)

Tasks used for analysis.

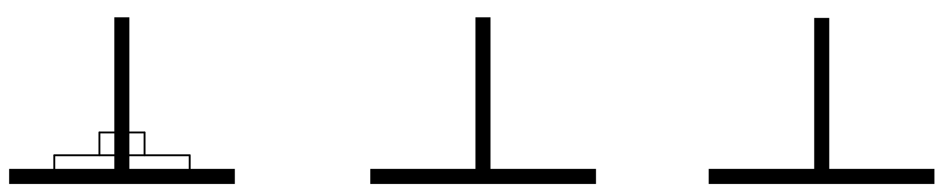
Task 1: Towers of Hanoi.

In the city of Benades, in northern India, the priests of the temple of Brahma have been set a task that will take from the beginning until the end of the world….or so creator of the "Towers of Brahms" puzzle would have believed. The original tower consisted of three diamond needles. Each needle the height of an adult and set below the great dome of the temple of Brahma in the city of Benades. They had been placed there, along with sixty-four golden discs, by the god Brahma when he created the world. The golden discs were of differing size and were mounted on the central needle. The temple priests had been set the task of transferring the discs from the central needles to one of the others according to laws laid down by Brahma.

The laws stated that only one disc could be moved at a time and that it must be placed on a needle before another could be moved. Also a larger disc could never be placed on a smaller disc. When the priests completed the task, then Brahma would end the world with a clap of thunder.

THE TOWERS OF HANOI.

The towers of Hanoi is a game of logic.
Three vertical towers and a series of different sized rings are involved.
Initially, all the rings are arranged on one tower, in ascending order of size - as below.



A B C

The object is to move all the rings from one tower to another - keeping them in ascending order. You may move one ring at a time to another tower, provided you never put a larger ring on top of a smaller ring. The winner is the person who can do it in the fewest number of moves.

1) Verify, by drawing your own diagrams that the rings can be moved to tower B in a minimum of three moves.
2) What is the minimum number of moves for 3 towers and 3 rings. Draw all your diagrams.
3) What is the minimum number of moves for 3 towers and 4 rings. Draw all your diagrams.
4) What is the minimum number of moves for 3 towers and 5 rings. Draw all your diagrams.
5) Come up with a rule for calculating the minimum number of moves for 3 towers and R rings.
6) Predict how many moves need to be made before the world would end.

RUBRIC FOR TOWERS OF HANOI.

	Solving the problem (SOLVE)	Mathematical communication (COMMUNICATE)	Mathematical reasoning (EXPLAIN)
1	Solve 2 ring problem (1)	Show correct logic on diagrams (1)	Written explanation (1)
2	Solve 3 ring problem (1)	Show correct logic on diagrams (1)	Written explanation (1)
3	Solve 4 ring problem (1)	Show correct logic on diagrams (1)	Written explanation (1)
4	Solve R ring problem (1)	Show correct logic on diagrams (1)	Written explanation (1)
5	Solve 2 ring problem (1)	Show correct logic on diagrams (1)	Written explanation (1)
6	Solve 'end of world' problem (1)	Use of correct logic (1)	Written explanation (1)

TEACHER ASSESSMENT	FINAL ASSESSMENT
	Teacher + $\frac{\text{own + peer + peer}}{7}$ = $\frac{\quad}{30}$

Task 2: Thomas Saint's Test and Memo.

Thomas Saint wrote a Maths test. Below is a copy of the test, followed by his solutions. Your teacher asks you to set up a memorandum for the test, mark Thomas' work, and to give him full, constructive advice on how to avoid the mistakes he has made.

Your effort will be assessed according to the rubric shown overleaf.

TEST.

1. Simplify:

a)	$(a - 2)^2 + 2(a + 1)^2$	(4)
b)	$5 - 3(2x - 3)^2$	(3)

2. Factorise fully:

a)	$3a^2b + 3b$	(1)
b)	$x(x - 7) + 6$	(2)
c)	$a(x - y) - b(y - x)$	(2)
d)	$121 - m^2$	(2)
e)	$\pi R^2h - \pi r^2h$	(3)
f)	$- x^2 + 5x + 84$	(3)

TOTAL: 20 marks

Thomas Saint's Grade 9 Maths Test.

1a) $(a - 2)^2 + 2(a + 1)^2$

$= a^2 - 4a + 4 + (2a + 2)^2$

$= a^2 - 4a + 4 + 4a^2 + 8a + 4$

$= 5a^2 - 4a + 8$

b) $5 - 3(2x - 3)^2$

$= 2(2x - 3)^2$

$= 2(4x^2 - 12x + 9)$

$= 8x^2 - 24x + 18$

2a) $3a^2b + 3b$

$= 3b(a^2 + b)$

b) $x(x - 7) + 6$

$= x^2 - 7 + 6$

$= x^2 - 1$

$= (x - 1)(x + 1)$

c) $a(x - y) - b(y - x)$

$= (x - y)(a - b)$

d) $121 - m^2$

$= (121 - m)(121 + m)$

e) $\pi R^2 h - \pi r^2 h$

$= \pi h(R^2 - r^2)$

f) $- x^2 + 5x + 84$

$= (- x + 12)(x - 7)$

<u>Assessment for Thomas Saint's Test and Memo.</u>

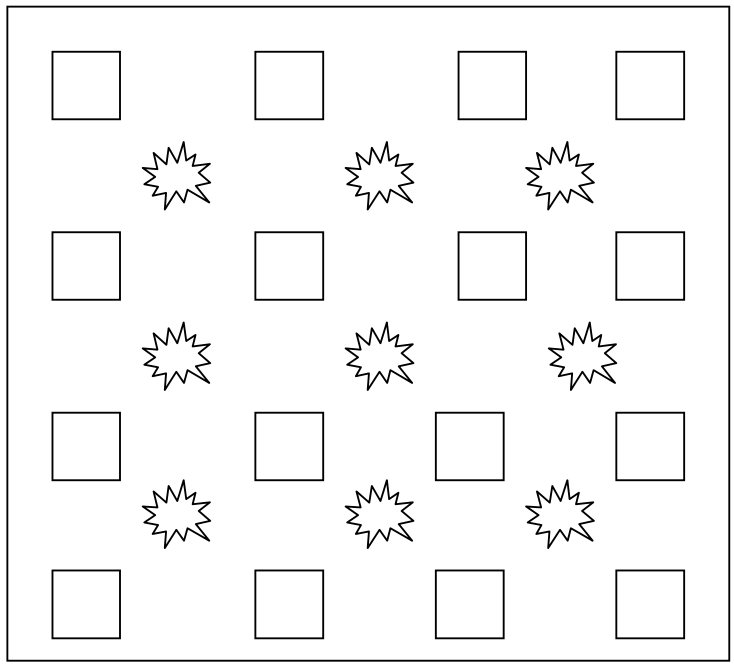
We will be assessing three things:

1) Your memo for the test.
2) Your marking of Thomas's test.
3) The help you have provided for Thomas.

MARKING RUBRIC	Possible mark	Actual mark	Key:
Memo for test:			0 - no help provided
1. Correctness of memo	15		1 - numerical help
2. Presentation.	5		2 - numerical help and explanations
3. Allocation of marks.	5		
Marking			3 - numerical help and good, clear explanations that help him identify problems and correct his thinking
1. Accuracy of marking, taking methods into account.	16		
2. Identification of mistakes.	10		
Help for Thomas:			
1 a) 0 1 2 3	3		
b) 0 1 2 3	3		
2 a) 0 1 2 3	3		
b) 0 1 2 3	3		
c) 0 1 2 3	3		
d) 0 1 2 3	3		
e) 0 1 2 3	3		
TOTAL:	50		
PERCENTAGE			

Task 3: Hide the Spies.

Hide the spies.[1]



A park has 16 telephone booths and 9 very tall bushes. The telephone booths have glass sides.

Four spies want to make secret phone calls from the park, at the same time.

Question 1:

a) Which telephones should the four spies use so that none of the spies can see each other?

b) How many different answers can you find.

APPENDIX B

Question 2:

By extending the question in any direction, i.e. by changing some aspect of the question, investigate other situations.

[For example, one could study other sized parks, other shaped parks, or even consider the following:

By numbering the booths as follows:

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

and adding the booth numbers together in each result that you found, what do you notice?]

Note:

When writing up your work, try to use different ways of representing the results. Make use of tables, diagrams, headings and extensive explanations regarding your work, wherever necessary.

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[1] Reference: University of London Examinations and Assessment Council 1992. *Hide the Spies*. GAIM. Thomas Nelson and Sons Ltd. p 38.

Assessment sheet for Hide the Spies.

A	Approach to solving this investigation: 4 - Approach was sophisticated, efficient and logical; appropriate for this investigation. 3 - Approach would work for this investigation, but could have been extended. 2 - Approach would only lead to solving part of this investigation. 1 - Approach was inappropriate for this investigation.	4	
B	Mathematical knowledge: 4 - Shows understanding of all mathematical concepts involved in this investigation. 3 - Shows understanding of some of the concepts involved in this investigation. 2 - Shows limited understanding of the concepts involved in this investigation. 1 - Shows no understanding of the concepts involved in this investigation.	4	
C	Communication skills: 4 - Response is clear, unambiguous and logically sound, includes examples wherever necessary. 3 - Response is generally clear, yet has areas where explanations are slightly ambiguous or unclear. 2 - Response is satisfactory, although there are many places where explanations are unclear or ambiguous. 1 - Ineffective communication. Explanation does not reflect the investigation at hand.	4	
D	Presentation (e.g. Diagrams, tables, pictures): 4 - Presentation is distinguished, clear and appropriate for this investigation. All means of communication complement the discussion and clarify points/conclusions made. 3 - Some diagrams, tables etc. have been used, however there are sections where they should have been used. Alternatively, tables, etc. have been used, but there are some errors. 2 - Some tables, diagrams etc. have been used, but there serious flaws in their calculations, display etc. 1 - Used no other means of presenting their work, other than written form.	4	
E	Outcomes: 4 - Solved the problem and provided a general rule about the solution, or extended the investigation correctly to other similar situations. 3 - Solved the initial problem and connected the solution to other mathematical concepts. Some possible extensions of the investigation are mentioned and studied, but there are some minor flaws in the solution to the extension. 2 - Solved the initial problem and connected the solution to other mathematical concepts. Some possible extensions of the investigation are mentioned and studied, but there are some serious flaws in the solution to the extension. 1 - Solved the initial problem and stopped. Provided no extension to the question.	4	
F	Group evaluation (See attached sheet)	5	
	TOTAL:	25	

Task 4: Cartesian Plane exercise.

Instructions:

1. Plot the following co-ordinates on the graph paper provided. Colour in the areas as indicated.
2. Now draw your own diagram on a new sheet of graph paper, writing down the co-ordinates for your own diagram.

Part 1: Bugs Bunny.

Start here and follow the co-ordinates in a vertical manner:

Join the following points:	(9; 32)	(21; 13)	(23; 32)	(12; 17)	(10; 15)
(7; 1)	(11; 28)	(20; 13)	(25; 34)	(12; 17)	(11; 12)
(10; 5)	(13; 23)	(18; 10)	(23; 30)	(11; 19)	(13; 10)
(8; 10)	(15; 28)	(15; 8)	(21; 28)	(12; 21)	(15; 10)
(5; 12)	(18; 31)	(14; 5)	(15; 24)	(13; 22)	(16; 11)
(4: 14)	(22; 33)	(15; 1)	Lift pencil	(14; 19)	(13; 11)
(3; 14)	(26; 36)	Lift pencil	Start again	Lift pencil	(13; 15)
(4; 16)	(26; 34)	Start again	(13; 17)	Start again	(10; 15)
(3; 16)	(25; 32)	(11; 23)	(14; 19)	(15; 18)	Start again
(5; 17)	(23; 29)	(7; 26)	(13; 19)	(15; 22)	(13; 15)
(4; 17)	(21; 27)	(5; 29)	(12; 18)	(16; 21)	(15; 14)
(6; 18)	(18: 25)	(2; 35)	(13; 17)	(17; 18)	(15; 11)
(8; 18)	(14; 23)	(5; 33)	Colour in the fol. area	Lift pencil	(16; 11)
(10; 22)	(16; 22)	(9; 27)	(16; 17)	Start again	(17; 15)
(9; 24)	(17; 19)	(11; 23)	917; 18)	(16; 15)	(15; 14)
(6; 26)	(18; 18)	Lift pencil	(16; 19)	(15; 14)	Lift pencil and join the fol.:
(5; 27)	(22; 16)	Start again	(15; 18)	(14; 15)	(14; 15) to (9; 18)
(1; 35)	(20: 16)	(15; 24)	(16; 17)	(16; 15)	(14; 15) to (6; 17)
(1; 36)	(21; 14)	(16; 26)	Start again	Lift pencil	(14; 15) to (7; 15)
(3; 36)	(20; 15)	(20; 30)	(13; 17)	Start again	(16; 15) to(23;13)
					(16; 15) to(24;17)
					(16; 15) to(22;18)

Assessment sheet for Cartesian plane exercise.

SO7: Shape, space and time:

	1	2	3	4
Accuracy of Bugs Bunny				
General appearance				
Accuracy of co-ordinates				
Complexity				

_______ = %

16

SO9: Use of mathematical language:

	1	2	3	4
Communication				

_______ = %

4

TOTAL: _______ = %

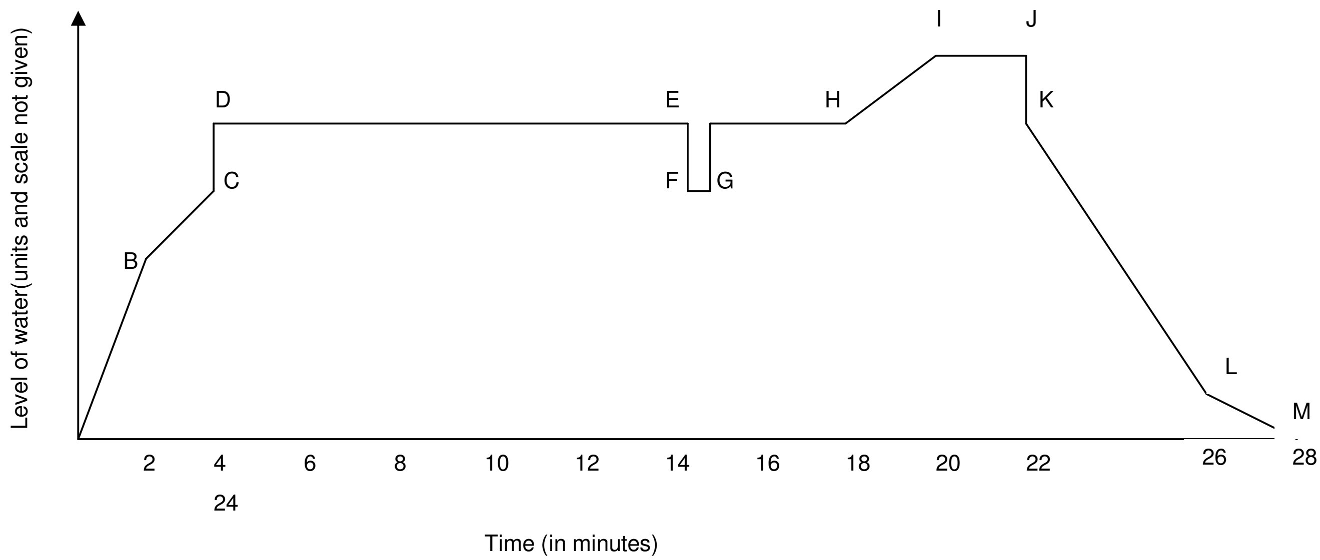
20

Key: 1 - Poor
2 - Average
3 - Good
4 - Excellent

Task 5: Homework exercise on graphs.

Graph 1:

Below is a graph which represents the level of water in a bathtub, as time passes (in minutes), when someone takes a bath.



Study the increases, decreases and level sections carefully, noting how much time passes at each stage. Now answer the following questions:

3.1. How is it that we can still interpret (in general) what is happening even though no vertical scale or units are given? (2)

3.2. Give a reasonable and likely explanation for what is happening from A to B to C to D. (3)

3.3. Line DE is horizontal. This means that the level of water did not change for a while.
a) For how long did the water level not change? (1)
b) Why might this have happened? (1)

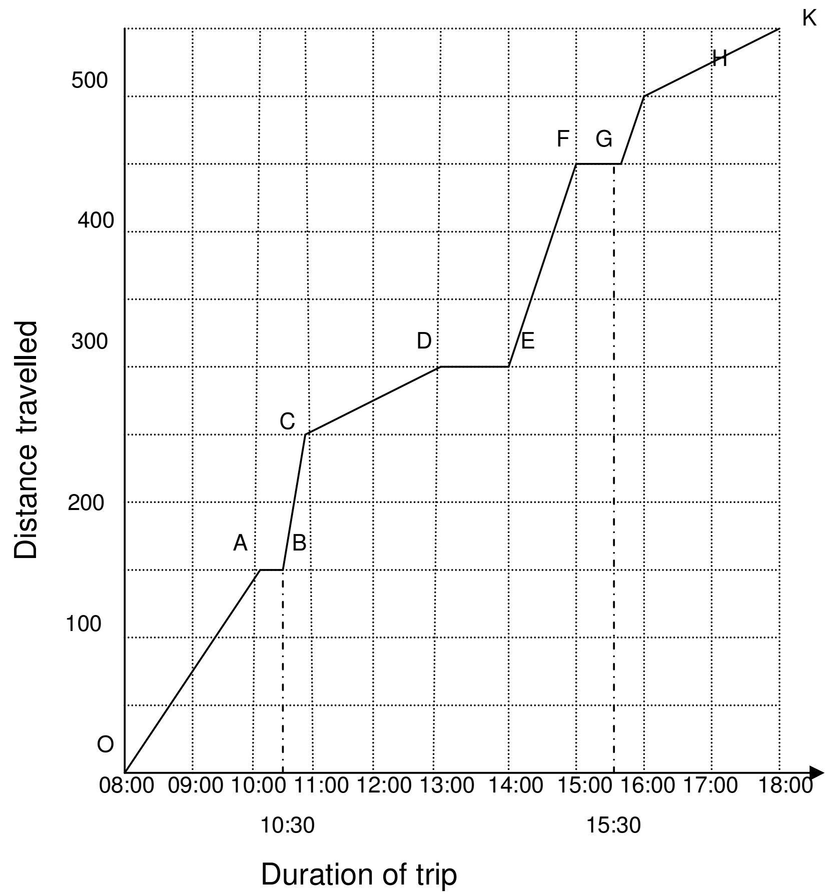
3.4. Give a plausible reason for what is happening from E to F to G to H to I. (3)

3.5. Account for what might have happened from L to M. (1)

3.6. Now draw your own graph of the level of milkshake in a glass when you and your friend have gone out. Use minutes horizontally and level of milkshake vertically. Include an explanation of the changing level of liquid. Be creative. (9)
[20]

Graph 2:

Pumla and Angie went on a tour through Europe. This is a graph of one of their daily trips. It shows the tour group's distances travelled, including stops for morning tea, lunch and afternoon tea.



Use the graph above to answer the following questions:

2.1.	How long did the trip last?	(1)
2.2.	How far was the trip?	(1)
2.3.	After how many hours did they stop for the first time?	(1)
2.4.	How long did they stop for lunch?	(1)
2.5.	How far did they drive between lunch and afternoon tea?	(1)
2.6.	For how long was the tour group actually travelling?	(2)
2.7.	During which time interval were they travelling at the highest average speed?	(2)
2.8.	What was their average speed between 08:00 and 10:00?	(3)
2.9.	What was their average speed for the whole journey?	(3)

$$\boxed{\text{Average speed} = \frac{\text{distance}}{\text{time}}}$$

[15]

<u>Task 6: Going shopping.</u>

[Not complete task as given to learners, as diagrams were not clear.]

Task 1:

Questions 1 - 5 had the following question plus some pictures of different products advertised given:

A series of advertisements from various newspapers appear below. By determining the price per unit of an item, decide which product is better value for money in each case. Calculators may be used and all answers must be rounded off to two decimal figures. All calculations must be clearly shown in the work you hand in.

Qu. 6: I want to paint my roof green. Which option is the better option, the 5 l or the 20 l tin? (……picture of advert)

Qu. 7: In the advertisements below, is it better for me to buy

(a) Handy Andy or the other Household Cleaner?

(b) Sta-Soft or Saubermann Fabric Softner?

(……pictures of adverts)

<u>Task 2:</u>

You are asked to help with the budget for the Conservation Club Camp. A list of items required appears below. You must visit two different shops and price each of the items. (Where no brand is specified, take those that are cheapest). Represent your information in a table and determine the total cost of the shopping at each store. Which shop should we buy the goods from and how much do we save in the process?

Shopping required:

5 l Oros squash	2 kg Tastic Rice	750 ml washing up liquid
4 l Milk	3 dozen bread rolls	2 kg mince meat
750 g Ricoffy	2,5 kg sugar	2 bars of soap
1 kg Vienna sausages	3 dozen eggs	9 toilet rolls
4 packets of bacon	2 l oil	

Task 3:

The following Budget meal appeared in the You magazine on 26 December 2002. The meal is sufficient for 4 people and the author claims that the cost averages out at R4,40 per person. By pricing the relevant ingredients, see of you agree with this claim or not.

Recipe …….. R4,40 pp

In this assignment, the following specific outcomes will be addressed:

SO 1: Use of Numbers:

	AC4.2.	Significant digits
	AC4.5.	Use of a calculator
	AC5.1.	Ratio problems
SO4:	Social, political and economic relations	
	AC2.1.	Budgeting
	AC5.3.	Use of advertisements
SO5:	Measurement	
	AC2.6.	Millilitres to litres
	AC2.7.	Comparison of masses
SO6:	Use of data	
	AC1.1.	Data collection
SO9:	Language	
	AC6.2.	Real life situations

Assessment sheet for 'Going Shopping'.

Task 1:

	Not yet achieved	Achieved	Achieved beyond
SO1: Use of numbers			
Accuracy of rounding			
Correct use of calculator			
Use of ratio (price/item)			
SO4: Social, political and economic relations			
Decisions about products			
SO5: Measurement			
ml to l (or visa-versa)			

Task 2:

	Not yet achieved	Achieved
SO4:Social, political and economic relations		
Total price		
Which shop to use		
Savings incurred		
SO6: Data		
Price lists		

Task 3:

	Not yet achieved	Achieved
SO1: Use of numbers		
Accuracy of rounding		
Correct use of calculator		
Use of ratio (price/item)		
SO4: Social, political and economic relations		
Total cost of meal		
Cost per person		
SO6: Data		
Price list		
SO9: Language		
Validity of statement (X 2)		

Breakdown of marks:

SO1	9	
SO4	7	
SO5	2	
SO6	2	
SO9	2	

Total: _______ = %
22

Comment: ____

____

Task 7: **Homework exercise - Statistics**

Frequency tables and graphs in statistics.

A. Frequency tables.

Example: A die is thrown 30 times. The number on the upper face for each throw is given.

3	6	2	5	4	2	6	3	4	1
2	5	3	1	3	1	5	6	3	2
1	4	6	3	5	3	1	3	2	6

This data may conveniently be represented in a frequency table as follows:

Frequency table.

Number on die	Tally	Frequency
1		
2		
3		
4		
5		
6		

Exercise:

1. The number of children per family for each of the pupils in a certain grade 9 class is recorded in this set of data:

2	1	3	4	2	1	1	2	3	2
2	3	2	1	2	2	3	4	2	2
3	2	5	2	3					

a) Complete the following frequency table from this raw data:

Frequency table.

Number of children	Tally	Frequency
1		
2		
3		
4		
5		
6		

b) What is the most common number of children per family?

____

c) What kind of family could not be represented in the data and why?

____

____

d) What percentage of pupils are the 'only child' in a family?

____

2. There are five alternatives to a multiple choice question (A - E). The choices made by pupils answering the question were as follows:

A	B	A	E	B	A	A	A	B	C
E	A	A	A	E	A	C	A	A	A
C	A	E	B	E	A	A	C		

a) Draw up a frequency table for this data.

b) Which alternative do you think is the correct one? ___

1. A bag contained red, blue and green marbles. A boy was allowed to put his hand in the bag, withdraw one marble and then put it back. This was repeated 20 times. The colours of the marbles he took out were recorded (R = red, B = blue and G = green):

R	B	R	B	B	B	R	G	B	B
G	R	B	B	B	R	B	B	R	B

Make up a frequency table to show how often each colour was withdrawn.

B	<u>Statistics graphs</u>.

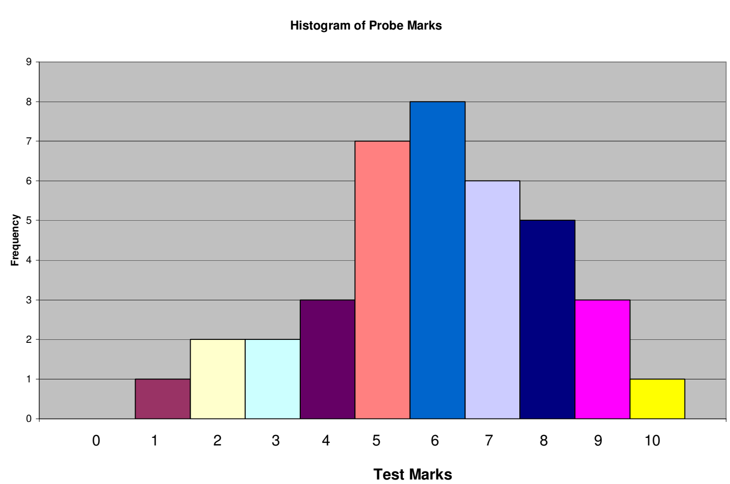
Once a frequency table has been completed, the relevant statistics can be represented graphically in various forms. We consider three of the most common representations.

1. <u>Histograms</u>.

<u>Example</u>: Consider the following frequency table of the scores obtained in a maths test (out of 10):

Score	0	1	2	3	4	5	6	7	8	9	10
Frequency	0	1	2	2	4	7	8	6	5	3	1

The following graph can be drawn:



APPENDIX B

Note:

1. The heights of the columns represent the frequencies.

2. Scores go across horizontally along the bottom of the histogram – numbers here apply to columns and not to points on the axes.

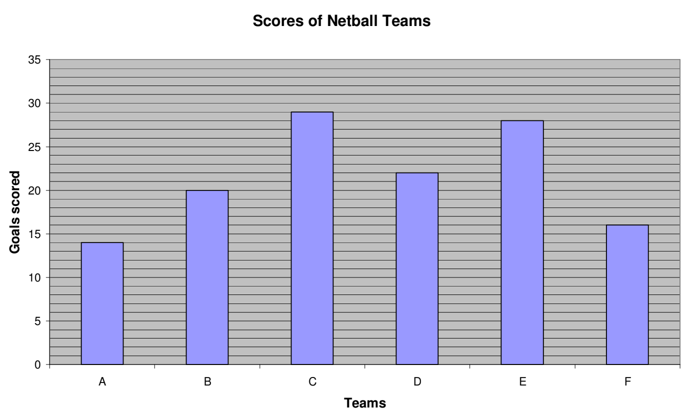
3. The columns follow immediately on next to each other. There are no spaces left between columns.

2. Bar graphs.

These are almost the same as histograms but in this case there are spaces left between the columns.

Exercise:

1. The following graph shows the scores of six netball teams:



a) Write down the scores of each team:

A: _____ B: _____

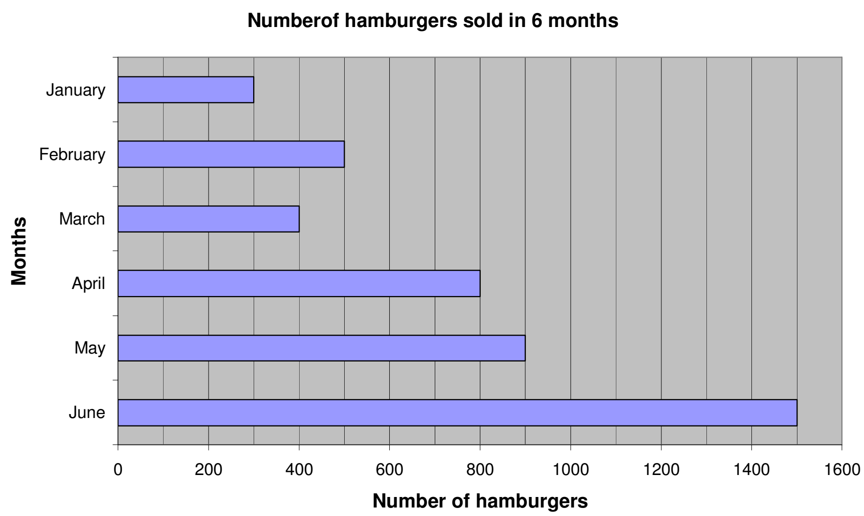
C: _____ D: _____

E: _____ F: _____

b) Which team has the lowest score? ______

c) What is the difference between the scores of teams D and B? ____

2. The graph below shows the hamburger sales figures of a new take-away food store which opened after Christmas.



a) The graph shows a 'general trend'. Explain.

____

____

b) The March figures do not fit the trend. Explain this statement.

____

____

c) What is the increase in sales in the six months?

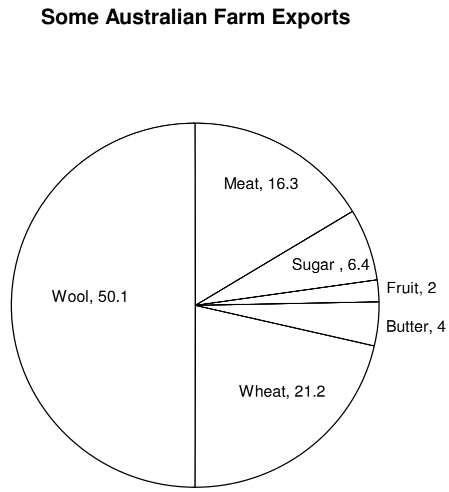
____

3. The table below shows the results of the survey on student traffic entering the school. Choose a suitable scale, and represent the information as a bar graph.

South gate	64
Main gate	146
North gate	85
Bicycle gate	55

3. Pie charts.

1.

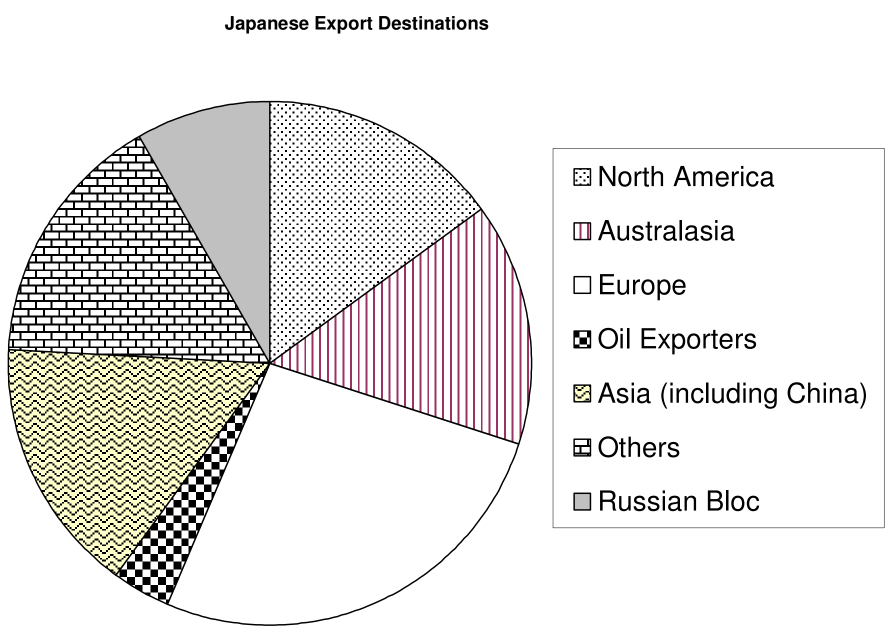


a) Add all the percentages on this farm export graph.
What is the total? ______

b) Are the sugar and meat sectors together larger than the wheat sector? _______

c) What commodity is more than half of Australian exports?
____

2. This pie chart shows the fractions of Japanese exports that go to different countries. No figures are given.



In order to find the figures for the different countries, measure the size of the sector in degrees and convert the measure to a percentage.

e.g. If we measure an angle of 18˚, then the

percentage = $\frac{18°}{360°} \times \frac{100}{1} = 5\,\%$

Complete the following table:

	Degrees	Percentage
North America		
Australasia		
Europe		
Oil Exporters		
Asia		
Others		
Russian bloc		

3. Construct a pie chart to illustrate how Johnny spends his R10 pocket money:

Sweets and eats:	R2,50
Entertainment:	R6,00
Charity:	R1,00
Savings:	R0,50

To find each angle, we say $\frac{\text{Amount spent}}{\text{Total amount}} \times \frac{360^\circ}{1}$

Homework exercise - Statistics: Assessment sheet.

SO1: Working with numbers.

AC5.1. Using algebraic techniques to solve problems involving percentages.

p2 Qu1d	Percentages	2		
p6 Qu2	Pie charts	14		
	Total:	16		%

SO6: Use of data in various contexts.

AC3: Organisation of data

AC5: Display of data

p1 % 1 Qu1 - 3 (not 1d)	Frequency tables	16		
p5 Qu3	Bar graph	4		
p7 Qu3	Pie chart	5		
	Total:	25		%

SO9: Use of mathematical language

AC4.1. Read and explain models.

p4 & 5 Qu 1, 2	Bar graphs	11		
p5 Qu1	Pie charts	3		
	Total:	14		%

TOTAL: ______ = __________%

55

INITIAL TABLES OF ANALYSIS

TABLES ACCORDING TO COMPETENCY.

Table C1: Competency 1: Memorization.

	Tasks:	T. St's tst & m			Going shop'g			Cartesian plane exercise						Int. Graphs			Stats. Ex.		
			b)			b)			a)			b)			b)			b)	
L1	Cathrine			1			1			1	-1			-1			-1		
	Kristi			1			1			1			1			1	-1		
	Ann			1			1									1	-1		
L2	Ruth			1			1			1			1			1			1
	Thandi			1			1							-1			-1		
	Sam			1	-1					1			1	-1					1
	Kim			1			1			1			1			1			1
	Lesley			1			1			1			1	-1					1
	Ana			1			1									1			1
	Kathy			1		0										1			1
	Marie			1			1			1			1	-1					1
	Thumi			1			1			1			1			1	-1		
	Tessa			1			1									1			1
	Pat			1			1							-1					1
	Lee			1	-1											1	-1		
L3	Jane			1			1			1			1			1			
	Candice			1			1									1			1
	Tammy			1			1			1			1	-1					1
	Nicky			1			1							-1					1
	Jacky			1			1			1			1			1			1
	Laura			1			1			1		0					-1		
	Tatum			1			1			1			1	-1					1
	Jessy			1			1			1	-1					1			1
	Shana			1			1			1			1	-1			-1		
	Karen			1			1			1			1			1			1
	Juan			1			1			1			1			1			1
L4	Mandy			1			1			1			1			1			1
	Loren			1			1			1			1			1			1
	Peta			1			1			1			1			1	-1		
	TOTALS:	0	0	29	2	1	26	0	0	20	2	1	17	10	0	18	9	0	19
			29			29			20			20			28			28	
	L1	0	0	100	0	0	100	0	0	100	100	0	0	100	0	0	100	0	0
	L2	0	0	100	20	0	80	0	0	100	0	0	100	40	0	60	60	0	40
	L3	0	0	100	6	6	88	0	0	100	9	9	82	41	0	59	24	0	76
	L4	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	20	0	80
	Group	0	0	100	7	3	90	0	0	100	10	5	85	36	0	64	32	0	68

DELETE

DELETE

DELETE

DELETE

DELETE

Table C2

TableC3: Competency 3: Posing and Solving mathematical problems.

Tasks:		Towers of Han.	Thomas Saint's test and memo		Hide the spies investigation		Going shopping	Statistics ex.
		b)	a)	b)	a)	b)	b)	b)
L1	Cathrine	1	0	0	0	0	1	1
L2	Kristi	1	0	1	-1	-1	0	1
	Ann	1	1	1	-1	-1	1	-1
	Ruth	1	-1	1	-1	-1	1	1
	Thandi	-1	1	1	1	1	1	1
	Sam	-1	1	1	1	1	-1	1
L3	Kim	1	1	1	1	1	1	-1
	Lesley	1	1	1	0	0	1	1
	Ana	1	1	1	1	-1	1	1
	Kathy	1	1	1	-1	-1	1	1
	Marie	1	1	1	1	1	1	1
	Thumi	1	1	1	1	1	1	1
	Tessa	1	1	1	1	-1	1	1
	Pat	1	1	1	1	1	1	1
	Lee	1	1	1	1	-1	0	1
	Jane	1	1	1	-1	-1	-1	
	Candice	1	-1	1	-1	-1	1	1
	Tammy	1	1	1	1	1	1	1
	Nicky	1	1	1	1	-1	1	1
	Jacky	1	-1	1	1	-1	1	1
	Laura	1	1	1	1	-1	1	1
	Tatum	1	1	1	1	1	1	1
	Jessy	1	1	1	1	1	-1	1
	Shana	1	1	-1	1	-1	1	1
L4	Karen	1	1	1	1	1	1	1
	Juan	1	1	1	1	1	1	1
	Mandy	1	1	1	1	1	1	1
	Loren	1	1	1	1	1	1	1
	Peta	1	1	1	1	1	1	1
	TOTALS:	2 0 27	3 2 24	1 1 27	6 2 21	13 2 14	3 2 24	2 0 26
		29	29	29	29	29	29	28
	L1	0 0 100	0 100 0	0 100 0	0 100 0	0 100 0	0 0 100	0 0 100
	L2	40 0 60	20 20 60	0 0 100	60 0 40	60 0 40	20 20 60	20 0 80
	L3	0 0 100	11 0 89	6 0 94	17 6 78	56 6 39	11 6 83	6 0 94
	L4	0 0 100	0 0 100	0 0 100	0 0 100	0 0 100	0 0 100	0 0 100
	Group	7 0 93	10 7 83	3 3 93	21 7 72	45 7 48	10 7 83	7 0 93

Table C4: Competency 4: Representing and explaining mathematical problems.

	Tasks:	Towers of Hanoi						T. Saints tst & m.			Hide the spies investigation									Going shopping			Cartesian plane exercise						Interpreting graphs exercises									Stats exercise		
		a)			b)			a)			a)			b)			c)			b)			b)			c)			a)			b)			c)			b)		
L1	Cathrine			1			1		0			0			0			0				1			1			1			1	-1					1			1
	Kristi		0				1	-1					1	-1			-1				0				1			1			1			1			1			1
	Ann	-1					1	-1					1	-1			-1					1									1			1			1			1
L2	Ruth	-1					1	-1			-1			-1			-1					1			1			1			1		0				1			1
	Thandi			1			1	-1					1			1			1			1									1			1			1			1
	Sam	-1					1	-1			-1					1			1	-1					1	-1				0			0				1			1
	Kim			1			1			1	-1			-1			-1			-1					1			1			1			1			1			1
	Lesley			1			1			1		0			0			0				1			1			1			1			1			1			1
	Ana			1			1		0				1			1			1			1							-1			-1					1			1
	Kathy			1			1	-1			-1					1	-1			-1									-1			-1					1			1
	Marie			1			1			1			1			1			1	-1					1			1			1			1	-1					1
	Thumi			1			1			1			1			1			1			1			1			1	-1			-1					1			1
	Tessa			1			1	-1					1	-1			-1					1									1			1			1			1
	Pat			1			1		0		-1			-1			-1			-1											1			1			1			1
L3	Lee			1			1	-1			-1			-1			-1			-1											1			1			1			1
	Jane			1			1	-1			-1					1			1			1			1			1	-1			-1					1			
	Candice			1			1	-1			-1					1	-1					1									1			1			1			1
	Tammy			1			1			1			1			1			1			1			1			1			1			1			1			1
	Nicky			1			1		0		-1					1			1			1									1			1	-1					1
	Jacky			1			1			1		0				1			1			1			1	-1					1			1			1			1
	Laura	-1					1			1	-1			-1			-1					1		0				1												1
	Tatum			1			1			1			1			1			1	-1					1			1			1			1	-1					1
	Jessy			1			1			1			1			1			1	-1					1	-1					1			1			1			1
	Shana			1			1			1	-1					1			1	-1					1			1			1			1	-1					1
	Karen			1			1			1	-1					1			1			1			1			1			1			1			1			1
	Juan			1			1			1			1			1			1			1			1	-1					1			1			1			1
L4	Mandy		0				1			1			1			1			1			1			1			1			1			1			1			1
	Loren			1			1			1			1			1			1			1			1			1			1			1			1			1
	Peta			1			1			1			1			1			1			1	-1			-1					1			1	-1					1
	TOTALS:	4	2	23	0	0	29	10	4	15	12	3	14	8	2	19	10	2	17	9	1	19	1	1	18	5	0	15	4	1	23	5	2	21	5	0	23	0	0	28
			29			29			29			29			29			29			29			20			20			28			28			28			28	
	L1	0	0	100	0	0	100	0	100	0	0	100	0	0	100	0	0	100	0	0	0	100	0	0	100	0	0	10	0	0	100	100	0	0	0	0	100	0	0	100
	L2	60	20	20	0	0	100	100	0	0	40	0	60	60	0	40	60	0	40	20	20	60	0	0	100	33	0	67	0	20	80	0	40	60	0	0	100	0	0	100
	L3	6	0	94	0	0	100	28	17	56	50	11	39	28	6	67	39	6	56	44	0	56	0	9	91	18	0	82	24	0	76	24	0	76	24	0	76	0	0	100
	L4	0	20	80	0	0	100	0	0	100	20	0	80	0	0	100	0	0	100	0	0	100	20	0	80	40	0	60	0	0	100	0	0	100	20	0	80	0	0	100
	Group	14	7	79	0	0	100	34	14	52	41	10	48	28	7	66	34	7	59	31	3	66	5	5	90	25	0	75	14	4	82	18	7	75	18	0	82	0	0	100

Table C5: Competency 5: Communicating mathematically amd interpreting mathematical statements.

	Tasks:	Towers of Hanoi a)	Towers of Hanoi b)	Thomas Saint's test & memo a)	Thomas Saint's test & memo b)	Hide the spies investigation a)	Hide the spies investigation b)	Going shopping a)	Going shopping b)	Cart. Pl. Ex. a)	Interpreting graphs a)	Interpreting graphs b)	Statistics exercise a)	Statistics exercise b)
L1	Cathrine	1	1	-1	-1	0	0	1	1	-1	1	1	1	-1
L2	Kristi	1	0	1	-1	-1	1	0	1	-1	1	1	1	-1
L2	Ann	1	0	1	-1	-1	-1	1	1		1	1	1	-1
L2	Ruth	1	-1	1	0	1	-1	1	1	-1	1	1	-1	-1
L2	Thandi	1	0	1	-1	1	1	1	1		1	1	1	-1
L2	Sam	0	1	1	-1	1	1	-1	-1	1	1	1	1	1
L3	Kim	1	1	1	1	1	1	-1	1	1	1	1	-1	-1
L3	Lesley	1	1	1	1	0	0	1	1	1	1	1	1	1
L3	Ana	1	-1	1	-1	1	1	1	1		1	1	1	1
L3	Kathy	1	1	1	-1	-1	-1	1	1		1	1	1	1
L3	Marie	1	1	1	1	1	1	1	-1	-1	1	1	1	1
L3	Thumi	1	1	1	1	1	1	1	1	1	1	1	1	1
L3	Tessa	1	1	1	-1	1	1	1	1		1	-1	1	1
L3	Pat	1	1	0	0	1	-1	1	1		1	1	1	1
L3	Lee	1	1	1	1	-1	-1	1	1		1	1	-1	-1
L3	Jane	1	1	1	-1	1	-1	-1	1	1	1	1		
L3	Candice	1	1	1	-1	-1	-1	1	1		1	1	1	1
L3	Tammy	1	1	1	1	1	1	1	1	1	1	1	1	-1
L3	Nicky	1	1	1	-1	1	-1	1	1		1	1	1	1
L3	Jacky	1	1	1	1	1	1	1	1	1	1	1	1	1
L3	Laura	1	0	1	1	1	-1	1	1	0			1	-1
L3	Tatum	1	1	1	1	1	1	-1	-1	1	1	1	1	1
L3	Jessy	1	1	1	1	1	1	-1	1	1	1	1	1	1
L3	Shana	1	1	1	1	-1	1	1	1	1	1	1	1	1
L4	Karen	1	1	1	1	1	-1	1	1	1	0	1	1	1
L4	Juan	1	1	1	1	1	1	1	1	1	1	1	1	1
L4	Mandy	1	0	1	1	1	1	1	1	1	1	1	1	1
L4	Loren	1	1	1	1	1	1	1	1	1	1	1	1	1
L4	Peta	1	1	1	1	1	0	1	1	-1	1	1	1	-1
	TOTALS:	0 1 28	2 5 22	1 1 27	11 2 16	6 2 21	10 3 16	5 1 23	3 0 26	6 0 14	0 1 27	1 0 27	3 0 25	10 0 18
		29	29	29	29	29	29	29	29	20	28	28	28	28
	L1	0 0 100	0 0 100	100 0 0	100 0 0	0 100 0	0 100 0	0 0 100	0 0 100	100 0 0	0 0 100	0 0 100	0 0 100	100 0 0
	L2	0 20 80	20 60 20	0 0 100	80 20 0	40 0 60	40 0 60	20 20 60	20 0 80	67 0 33	0 0 100	0 0 100	20 0 80	80 0 20
	L3	0 0 100	6 6 89	0 6 94	33 6 61	22 6 72	39 6 56	22 0 78	11 0 89	18 0 82	0 0 100	6 0 94	12 0 88	24 0 76
	L4	0 0 100	0 20 80	0 0 100	0 0 100	0 0 100	20 20 60	0 0 100	0 0 100	20 0 80	0 20 80	0 0 100	0 0 100	20 0 80
	Group	0 3 97	7 17 76	3 3 93	38 7 55	21 7 72	34 10 55	17 3 79	10 0 90	30 0 70	0 4 96	4 0 96	11 0 89	36 0 64

Table C6: Competency 6: Handling mathematical symbols and formalisms.

	Tasks:	Towers of Hanoi						T.St's tst & me.			Going shopping									Statistics exercise								
		b)			c)			b)			a)			b)			c)			a)			b)			c)		
L1	Cathrine		0			0				1			1			1			1			1			1			1
	Kristi			1	-1					1			1		0				1			1			1			1
	Ann		0			0				1			1			1			1			1	-1			-1		
L2	Ruth		0				1	-1					1			1			1	-1					1			1
	Thandi		0			0				1			1			1			1			1			1			1
	Sam		0			0				1	-1			-1			-1					1			1			1
	Kim			1			1			1	-1					1	-1					1	-1			-1		
	Lesley			1			1			1			1			1			1			1			1			1
	Ana	-1			-1					1			1			1			1			1			1			1
	Kathy			1			1			1			1			1			1			1			1			1
	Marie			1			1			1	-1					1	-1					1			1			1
	Thumi			1			1			1			1			1			1			1			1			1
	Tessa			1			1			1			1			1			1			1			1			1
	Pat			1			1			1	-1					1	-1					1			1			1
L3	Lee			1			1			1	-1					1	-1			-1					1			1
	Jane	-1			-1					1			1			1	-1											
	Candice			1			1			1			1			1			1			1			1	-1		
	Tammy			1			1			1			1			1			1			1			1			1
	Nicky			1			1			1			1			1			1			1			1			1
	Jacky	-1					1		0				1			1			1			1			1			1
	Laura			1			1			1	-1					1			1	-1					1			1
	Tatum			1			1			1	-1					1	-1					1			1			1
	Jessy			1			1			1			1			1			1			1			1			1
	Shana			1			1	-1			-1					1			1			1			1			1
	Karen			1			1			1			1			1			1			1			1			1
	Juan			1			1			1			1			1			1			1			1			1
L4	Mandy			1			1			1			1			1			1			1			1			1
	Loren			1			1			1			1			1			1			1			1			1
	Peta			1			1			1			1			1			1			1			1			1
	TOTALS:	3	5	21	3	4	22	2	1	26	8	0	21	1	1	27	7	0	22	3	0	25	2	0	26	3	0	25
			29			29			29			29			29			29			28			28			28	
	L1	0	100	0	0	100	0	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
	L2	0	80	20	20	60	20	20	0	80	20	0	80	20	20	60	20	0	80	20	0	80	20	0	80	20	0	80
	L3	17	0	83	11	0	89	6	6	89	39	0	61	0	0	100	33	0	67	12	0	88	6	0	94	12	0	88
	L4	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
	Group	10	17	72	10	14	76	7	3	90	28	0	72	3	3	93	24	0	76	11	0	89	7	0	93	11	0	89

TABLES SUMMARISING EACH CATEGORY WITHIN

	Table C7	Competency 1: Memorization.							
		a = 1				b = 5			
		-1	0	1		-1	0	1	
L1	Cathrine	0	0	1		0	0	0	
L2	Kristi	0	0	1		0	0	0	
	Ann	0	0	0		0	0	0	
	Ruth	0	0	1		0	0	0	
	Thandi	0	0	0		0	0	0	
	Sam	0	0	1		0	0	0	
L3	Kim	0	0	1		0	0	0	
	Lesley	0	0	1		0	0	0	
	Ana	0	0	0		0	0	0	
	Kathy	0	0	0		0	0	0	
	Marie	0	0	1		0	0	0	
	Thumi	0	0	1		0	0	0	
	Tessa	0	0	0		0	0	0	
	Pat	0	0	0		0	0	0	
	Lee	0	0	0		0	0	0	
	Jane	0	0	1		0	0	0	
	Candice	0	0	0		0	0	0	
	Tammy	0	0	1		0	0	0	
	Nicky	0	0	0		0	0	0	
	Jacky	0	0	1		0	0	0	
	Laura	0	0	1		0	0	0	
	Tatum	0	0	1		0	0	0	
	Jessy	0	0	1		0	0	0	
	Shana	0	0	1		0	0	0	
L4	Karen	0	0	1		0	0	0	
	Juan	0	0	1		0	0	0	
	Mandy	0	0	1		0	0	0	
	Loren	0	0	1		0	0	0	
	Peta	0	0	1		0	0	0	
	TOTALS:	0	0	20		0	0	0	
			20				134		
	L1	0	0	100		60	0	40	
	L2	0	0	100		0	0	0	
	L3	0	0	100		0	2	82	
	L4	0	0	100		0	0	0	
	Group	0	0	100	%	0	0	0	%

Table C8 **Competency 2: Thinking and reasoning mathematically**

		a = 2				b = 3				c = 1				d = 2				h = 5				l = 2			
		-1	0	1		-1	0	1		-1	0	1		-1	0	1		-1	0	1		-1	0	1	
L1	Cathrine	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Kristi	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Ann	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
L2	Ruth	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Thandi	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Sam	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Kim	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Lesley	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Ana	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Kathy	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Marie	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Thumi	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Tessa	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Pat	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
L3	Lee	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Jane	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Candice	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Tammy	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Nicky	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Jacky	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Laura	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Tatum	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Jessy	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Shana	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Karen	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Juan	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
L4	Mandy	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Loren	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Peta	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	TOTALS:	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
			57				86				29				49				135				58		
	L1	100	0	0		66	34	0		100	0	0		100	0	0		60	0	40		50	50	0	
	L2	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	L3	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	L4	0	0	0		0	0	0		0	0	0		0	0	0		0	0	0		0	0	0	
	Group	0	0	0	%	0	0	0	%	0	0	0	%	0	0	0	%	0	0	0	%	0	0	0	%

Table C9 **Competency 3: Posing and solving mathematical problems**

		a = 2				b = 5			
		-1	0	1		-1	0	1	
L1	Cathrine	0	0	0		0	0	0	
L2	Kristi	0	0	0		0	0	0	
	Ann	0	0	0		0	0	0	
	Ruth	0	0	0		0	0	0	
	Thandi	0	0	0		0	0	0	
	Sam	0	0	0		0	0	0	
L3	Kim	0	0	0		0	0	0	
	Lesley	0	0	0		0	0	0	
	Ana	0	0	0		0	0	0	
	Kathy	0	0	0		0	0	0	
	Marie	0	0	0		0	0	0	
	Thumi	0	0	0		0	0	0	
	Tessa	0	0	0		0	0	0	
	Pat	0	0	0		0	0	0	
	Lee	0	0	0		0	0	0	
	Jane	0	0	0		0	0	0	
	Candice	0	0	0		0	0	0	
	Tammy	0	0	0		0	0	0	
	Nicky	0	0	0		0	0	0	
	Jacky	0	0	0		0	0	0	
	Laura	0	0	0		0	0	0	
	Tatum	0	0	0		0	0	0	
	Jessy	0	0	0		0	0	0	
	Shana	0	0	0		0	0	0	
L4	Karen	0	0	0		0	0	0	
	Juan	0	0	0		0	0	0	
	Mandy	0	0	0		0	0	0	
	Loren	0	0	0		0	0	0	
	Peta	0	0	0		0	0	0	
	TOTALS	0	0	0		0	0	0	
			58				144		
	L1	0	100	0		0	40	60	
	L2	0	0	0		0	0	0	
	L3	0	0	0		0	0	0	
	L4	0	0	0		0	0	0	
	Group	0	0	0	%	0	0	0	%

Table C10 Competency 4: Representing and explaining mathematical problems.

		a = 4			b = 6			c = 3			
		-1	0	1	-1	0	1	-1	0	1	
L1	Cathrine	0	0	0	0	0	0	0	0	0	
L2	Kristi	0	0	0	0	0	0	0	0	0	
	Ann	0	0	0	0	0	0	0	0	0	
	Ruth	0	0	0	0	0	0	0	0	0	
	Thandi	0	0	0	0	0	0	0	0	0	
	Sam	0	0	0	0	0	0	0	0	0	
L3	Kim	0	0	0	0	0	0	0	0	0	
	Lesley	0	0	0	0	0	0	0	0	0	
	Ana	0	0	0	0	0	0	0	0	0	
	Kathy	0	0	0	0	0	0	0	0	0	
	Marie	0	0	0	0	0	0	0	0	0	
	Thumi	0	0	0	0	0	0	0	0	0	
	Tessa	0	0	0	0	0	0	0	0	0	
	Pat	0	0	0	0	0	0	0	0	0	
	Lee	0	0	0	0	0	0	0	0	0	
	Jane	0	0	0	0	0	0	0	0	0	
	Candice	0	0	0	0	0	0	0	0	0	
	Tammy	0	0	0	0	0	0	0	0	0	
	Nicky	0	0	0	0	0	0	0	0	0	
	Jacky	0	0	0	0	0	0	0	0	0	
	Laura	0	0	0	0	0	0	0	0	0	
	Tatum	0	0	0	0	0	0	0	0	0	
	Jessy	0	0	0	0	0	0	0	0	0	
	Shana	0	0	0	0	0	0	0	0	0	
L4	Karen	0	0	0	0	0	0	0	0	0	
	Juan	0	0	0	0	0	0	0	0	0	
	Mandy	0	0	0	0	0	0	0	0	0	
	Loren	0	0	0	0	0	0	0	0	0	
	Peta	0	0	0	0	0	0	0	0	0	
	TOTALS	0	0	0	0	0	0	0	0	0	
			115			164			77		
	L1	0	50	50	17	17	66	0	33	67	
	L2	0	0	0	0	0	0	0	0	0	
	L3	0	0	0	0	0	0	0	0	0	
	L4	0	0	0	0	0	0	0	0	0	
	Group	0	0	0 %	0	0	0 %	0	0	0 %	

Table C11 **Competency 5: Communicating mathematically and interpreting mathematical statements.**

		a = 7				b = 6			
		-1	0	1		-1	0	1	
L1	Cathrine	0	0	0		0	0	0	
L2	Kristi	0	0	0		0	0	0	
	Ann	0	0	0		0	0	0	
	Ruth	0	0	0		0	0	0	
	Thandi	0	0	0		0	0	0	
	Sam	0	0	0		0	0	0	
L3	Kim	0	0	0		0	0	0	
	Lesley	0	0	0		0	0	0	
	Ana	0	0	0		0	0	0	
	Kathy	0	0	0		0	0	0	
	Marie	0	0	0		0	0	0	
	Thumi	0	0	0		0	0	0	
	Tessa	0	0	0		0	0	0	
	Pat	0	0	0		0	0	0	
	Lee	0	0	0		0	0	0	
	Jane	0	0	0		0	0	0	
	Candice	0	0	0		0	0	0	
	Tammy	0	0	0		0	0	0	
	Nicky	0	0	0		0	0	0	
	Jacky	0	0	0		0	0	0	
	Laura	0	0	0		0	0	0	
	Tatum	0	0	0		0	0	0	
	Jessy	0	0	0		0	0	0	
	Shana	0	0	0		0	0	0	
L4	Karen	0	0	0		0	0	0	
	Juan	0	0	0		0	0	0	
	Mandy	0	0	0		0	0	0	
	Loren	0	0	0		0	0	0	
	Peta	0	0	0		0	0	0	
	TOTALS	0	0	0		0	0	0	
			192				172		
	L1	29	14	57		33	17	50	
	L2	0	0	0		0	0	0	
	L3	0	0	0		0	0	0	
	L4	0	0	0		0	0	0	
	Group	0	0	0	%	0	0	0	%

Table C12 Competency 6: Handling mathematical symbols and formalisms.

		a = 2				b = 4				c = 3			
		-1	0	1		-1	0	1		-1	0	1	
L1	Cathrine	0	0	0		0	0	0		0	0	0	
L2	Kristi	0	0	0		0	0	0		0	0	0	
	Ann	0	0	0		0	0	0		0	0	0	
	Ruth	0	0	0		0	0	0		0	0	0	
	Thandi	0	0	0		0	0	0		0	0	0	
	Sam	0	0	0		0	0	0		0	0	0	
L3	Kim	0	0	0		0	0	0		0	0	0	
	Lesley	0	0	0		0	0	0		0	0	0	
	Ana	0	0	0		0	0	0		0	0	0	
	Kathy	0	0	0		0	0	0		0	0	0	
	Marie	0	0	0		0	0	0		0	0	0	
	Thumi	0	0	0		0	0	0		0	0	0	
	Tessa	0	0	0		0	0	0		0	0	0	
	Pat	0	0	0		0	0	0		0	0	0	
	Lee	0	0	0		0	0	0		0	0	0	
	Jane	0	0	0		0	0	0		0	0	0	
	Candice	0	0	0		0	0	0		0	0	0	
	Tammy	0	0	0		0	0	0		0	0	0	
	Nicky	0	0	0		0	0	0		0	0	0	
	Jacky	0	0	0		0	0	0		0	0	0	
	Laura	0	0	0		0	0	0		0	0	0	
	Tatum	0	0	0		0	0	0		0	0	0	
	Jessy	0	0	0		0	0	0		0	0	0	
	Shana	0	0	0		0	0	0		0	0	0	
L4	Karen	0	0	0		0	0	0		0	0	0	
	Juan	0	0	0		0	0	0		0	0	0	
	Mandy	0	0	0		0	0	0		0	0	0	
	Loren	0	0	0		0	0	0		0	0	0	
	Peta	0	0	0		0	0	0		0	0	0	
	TOTALS	0	0	0		0	0	0		0	0	0	
			57				115				85		
	L1	0	0	100		0	25	75		0	33	67	
	L2	0	0	0		0	0	0		0	0	0	
	L3	0	0	0		0	0	0		0	0	0	
	L4	0	0	0		0	0	0		0	0	0	
	Group	0	0	0	%	0	0	0	%	0	0	0	%