

WHAT CAN WE LEARN FROM TIMSS 2003?

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South Africa participated in the Trends in Mathematics and Science Study (TIMSS) in 1995, 1999 and 2003, but not in 2007. Critics have accused the National Department of Education (DoE) of opting out because of previous poor results (Business Day 25th April, 2007). The defense from the DoE is that the interventions in place have not had time to take effect. The major question guiding this paper is “What can teachers learn from South Africa’s participation in TIMSS 2003?”

The purpose of the TIMSS study is the improvement of teaching and learning through evaluating different aspects of the education system from educational policy to implementation in schools and finally to learner attainment. One of the biggest limitations of large-scale international studies such as TIMSS is that the information obtained does not reach teachers in a form, which enables them to interpret the evidence and take action.

In this paper I describe how the conceptual resources from the TIMSS study were used to investigate the performance of a sample of South African children on ratio and proportional reasoning.

INTRODUCTION

South Africa participated at the Grade 8 level in the Trends in Mathematics and Science Study (TIMSS) in 1995, 1999 and 2003, but not in 2007. There has been strong criticism from the press and other interested watchdogs accusing the National Department of Education (DoE) of opting out because of poor results (Blaine, 2007). The defense from the DoE has been that the interventions that have been put in place have not had time to take effect. The questions the general public may ask is what interventions have been put in place, how effective are the interventions and what time period are we envisaging for the interventions to take effect.

Teachers and teacher educators may ask, “What have we learnt from the TIMSS study?” Our answer could be “Not very much”, as our results have remained largely the same over a period of eight years. The responsibility for the poor performance is generally attributed to teachers. The role of the teacher, however, is critically affected by the education system that is in place. A responsibility therefore lies with the policy makers, the curriculum planners and educational officials, who decide on curriculum and make resources available to schools. The TIMSS studies are designed specifically to tell us about the overall system and not to per school and within a school.

There are both benefits and pitfalls to participating in large-scale international studies

for all stakeholders in the system (Howie, 2001). For the policy makers, curriculum planners and educational officials, external evaluation provides objective benchmarking of aspects of the education system and comparative information regarding the effectiveness of educational practices and learner performance. Problem areas are highlighted so that funds and resources can be redistributed to these areas. A problem that arises is that instead of reflecting on the system as a whole a scapegoat is targeted and this is nearly always the teacher or the study itself. The problem of lack of adequate understanding of the conceptual, methodological and technical underpinnings of studies like TIMSS leads to a disregard of the results, and so loss of an opportunity for learning.

For schools and teachers the results may lead to professional development and improved instruction. A problem may of course be that the unmediated release of bad results can result in unthinking and shortsighted decision making about what should be done. The direct value of large-scale evaluation for individual teachers is questionable as only a small percentage of mathematics teachers have access to the details of the study, which could inform classroom practice. The major question guiding this paper is “What can teachers learn from the Trends in Mathematics and Science Study (TIMSS) 2003?”

In this paper I describe how a research study, using TIMSS 2003 data, and related conceptual and technical resources, was designed to investigate the performance of a sample of South African learners on ratio and proportional reasoning. Description of the responses on selected items, analysis of the concepts underpinning the items and the predominant errors made by learners give deeper insight into the mathematical topic, but also into aspects of the TIMSS research design thereby placing educational officials, teachers and researchers in a position to give a reasoned response as to whether participation in the TIMSS studies could assist in the improvement of mathematics and science teaching and learning.

THE TIMSS STUDY

The purpose of large scale testing in countries around the world is to improve the quality of educational outcomes. Four purposes have been described by Nasser Abu-Alhija: to monitor educational systems for public accountability, assure quality control, provide information to teachers about teaching and learning and to “identify needs and allocate resources” (2007:52). The TIMSS study, one of many studies conducted by the International Association for the Evaluation of Educational Achievement (IEA), performs the function of monitoring educational systems for the purpose of improving education systems, through a carefully constructed research design that compares the intended curriculum, the implemented curriculum and attained curricula of education systems across the world with regard to mathematics and science.

Information on the attained curriculum, the aspect of the study that gets the most publicity in the media, is obtained through an extensive battery of items based on the mathematical frameworks that incorporate the “goals of mathematics and science education regarded as important in a significant number of countries” (Mullis, Martin,

Smith, Garden, Gregory and Gonzales, 2003). These results can be found in the TIMSS 2003 International Report (Mullis, I. V.S., Martin, M.O., Gonzalez, K.M. & Chrostowski, S.J. 2004) as well as in the national report (Reddy, 2006).

The extensive cross-country comparisons in the TIMSS 2003 Report (Mullis et al., 2004) show differences in the *intended curriculum*¹ among countries. The *implemented curriculum* is reported to have the least overlap with the TIMSS mathematical framework (Reddy, 2007). This is cause for concern as the TIMSS mathematical framework was constructed from the “goals of mathematics and science education regarded as important in a significant number of countries” (Mullis et al., 2003).

The South African national report (Reddy, 2006) gives results by province and by former department. The Western Cape, the Northern Cape and Gauteng performed better than the national average, with the other provinces lagging behind. Former Model C schools performed around the international average, while schools formerly under the control of other departments scored lower. Results are also given for individual content domains and cognitive domains. The performance overall was relatively better in the content domain of measurement and data, but poor in geometry.

General information of this sort is critically important for education officials, but for teachers what is of greater value is providing information that can inform them about their practice. This third purpose listed above is “the most controversial function attributed to large scale assessment” (Nasser Abu-Alhija, 2007). The argument is made that while the information provided by large-scale external evaluation might result in motivation for teachers it does not necessarily provide the means to improve, especially in a conceptually complex subject like mathematics.

It is widely acknowledged that it is formative assessment, which provides feedback on teaching and learning to both teachers and learners, that leads to the improvement of learning (Black & Wiliam, 1998). This feedback has to be informed by a detailed knowledge of the curriculum and indeed a deep knowledge of the mathematical field. The situation at present is that not all teachers of mathematics have an adequate knowledge of the field. External evaluations such as the TIMSS study bring the expertise of the international community together in the design of mathematical frameworks and the construction of items (Mullis et al., 2003). Access to both the framework and the items alert the teachers to the need for more knowledge in a particular area. The research study reported below offers a model for using the conceptual and technical resources provided by the TIMSS study to investigate the mathematical domain of ratio and proportional reasoning.

¹ Problems with the South African *intended curriculum* and the reporting thereof have been reported elsewhere (Long, 2006a)

RATIO AND PROPORTIONAL REASONING²

This study forms part of a larger research study into the epistemological and conceptual underpinnings of ratio and proportional reasoning and related subtopics within the multiplicative conceptual field (MCF) (Vergnaud, 1988). From a conceptual perspective MCF includes multiplication and division, ratio, rate, fractions and rational numbers. It also includes the mathematical processes required to solve problems associated with this domain. Vergnaud argues that the reason for mathematics education researchers to study conceptual fields is that concepts develop in relationship with other concepts rather than in isolation (Vergnaud, 1988). Mastery of these concepts, processes and ability to engage with associated problems, form the basis of more advanced mathematics topics in secondary school. Failure to engage with this field, which is generally agreed to be complex and to be cognitively challenging, undermines the mathematical progress of learners.

The theoretical focus of this research involves a conceptual analysis using the work of Vergnaud and others. An added dimension is the investigation of pivotal changes in the historical development of concepts within this field. A requirement from an empirical perspective was to understand the present level of attainment of South African learners in this field. The identification of learners mathematical processing and significant errors provided an empirical link towards the broader understanding of this mathematical domain.

The performance of the South African sample on the TIMSS items designed to test this content domain and aligned cognitive processes within this field confirmed that South African learners in general found these items difficult. Much of the low performance can be attributed to lack of properly functioning schools and associated poor teaching, but a large measure of difficulty can be attributed to the complexity of the field. In order to assess the complexity of the topic apart from adverse school factors, it was decided to use the same items to test a sample of learners from two well functioning schools. In addition to testing Grade 8s, the grade on either side, the Grade 7s and 9s, were included in order to track the progression of cognitive development across this phase.

The sample consisted of 330 learners from two schools. One of the schools serves learners from a lower socio-economic level, including street children, children from an orphanage, and boarders from rural areas. This is a private fee-paying school where 20% of learners are funded by bursaries. The second school catered for more affluent learners with a proportion of professional parents. The claim cannot be made that the sample is representative of the South African population, however as the purpose of the study was

² The title *ratio and proportional reasoning* is used in this paper as it embraces most of the constructs of interest in this study, and is familiar to teachers. It is however qualified as other related constructs are included in the study.

an investigation of a mathematical field it was felt that the range of abilities in these two schools would adequately support the purpose.

ASSESSING LEARNER ABILITY

Wright and Stone (1979) stipulate four steps to be taken in the process of measuring learners’ understanding. The first requirement in measuring is to get a clear idea of the domain to be tested. As mentioned above this included concepts, processes, and specific contexts which embody the problems associated with this field, as outlined in the conceptual framework (Long, in progress). The sub-components in the TIMSS mathematical framework were found to be a ‘good enough’ match for the relevant sub constructs in the multiplicative conceptual field, the focus of this study.

The second requirement in measuring constructs within a domain, is the use of items which “are believable realizations” of the particular mathematical domain and which can elicit signs of the variable in the person we want to measure (Wright and Stone, 1979:3). Items were initially selected from the mathematical domain *Number* and the subtopic *ratio, proportion and percent*. Additional items which included concepts, processes and contexts requiring multiplicative structures (Vergnaud, 1988) were selected from the mathematical domains Algebra, Measurement, Geometry and Data. The highlighted topics in the table below were selected as these included elements of the topic under investigation.

Table 1 : TIMSS 2003 Content domain (Mullis et al., 2003) showing subtopics

Number	Algebra	Measurement	Geometry	Data
whole numbers fractions and decimals integers ratio, proportion and percent	patterns algebraic expressions equations and formulas relationships	attributes and units tools, techniques and formula	lines and angles two- and three-dimensional shapes congruence and similarity locations and spatial relationships symmetry and transformations	data collection and organisation data representation and interpretation uncertainty and probability

In addition to the content domain, aligned cognitive processes are included in the TIMSS mathematical framework. To respond correctly to mathematical problems learners need to be familiar with the mathematics concepts being assessed, but they also need to draw on a range of cognitive skills. The first set of skills, *knowing facts, procedures and concepts*, covers what students need to know, while the second, *applying knowledge and conceptual understanding*, focuses on the ability of the learner

to apply what he or she knows to solve problems or answer questions. The third sub domain, *reasoning*, goes beyond solving of routine problems to encompass unfamiliar situations, complex contexts, and multi-step problems (Mullis, Martin and Foy, 2005: 65). The cognitive skills above, most notably the construct *reasoning* is critical for successful development of concepts within MCF.

Table 2 shows the extent of the content and cognitive domains from which the items were selected, indicating the complexity of the multiplicative conceptual field, of which the subtopic ratio and proportional reasoning is a part. Appendix A gives brief descriptions of the items. Detailed descriptions of the items and the items themselves can be found in the research report (Long, 2007).

Table 2: Items in content and cognitive domains

		Content domain				
		Number	Algebra	Measurement	Geometry	Data
Cognitive domain	Knowing facts, procedures and concepts	8	2		1	
	Applying knowledge and concepts	10	2	1		2
	Reasoning	2	5	1		5

The third and fourth requirements are essentially a test of the reliability of the test and the consistency with which learners respond to the items. This requires that we demonstrate that the items when taken by suitable persons are consistent with our expectations and that the patterns of learner responses are consistent with our expectations. Finding unexpected responses in either the items or the learners require an investigation of the *items* that we are using to measure the construct and an investigation of the *construct* we are aiming to measure. The process of converting both items and learner measures to the same linear units requires a level of consistency in both the third and fourth requirement.

The above four steps are requirements of the Rasch Measurement Model, the statistical tool used in many large scale studies, which allows the relationship between learner ability and item difficulty to be investigated. The mathematical model converts both learner ability and item difficulty into the same linear units of measurement and therefore allows measurement and comparison of ability and difficulty on the same scale. The model presupposes that the higher a person's ability relative to the difficulty of a question, the higher the probability of a correct response on that question. It defines the difficulty of answering a question correctly, as 0.5 probability of success, when a person's location on the construct being measured is equal to the difficulty of the item

(Wright and Mok, 2004).

In keeping with the steps outlined above additional criteria for the selection of items were that the items include a range of difficulty, and that the items provide a benchmark against which to compare the sample of learners in this study. Using the TIMSS items enabled national and international comparison.

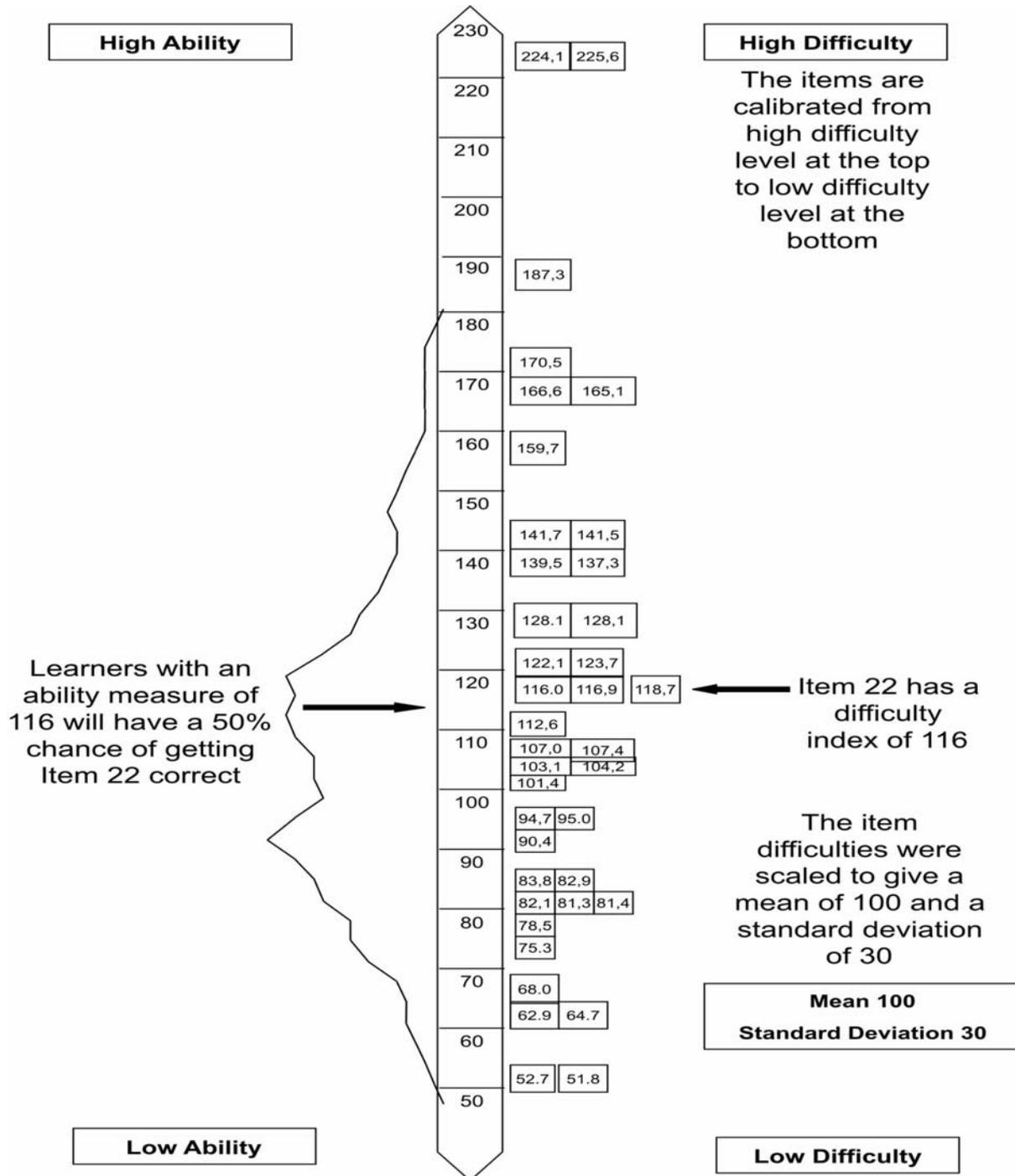


Figure 1: Item difficulty level and learner ability shown on the same scale

The initial selection of items was checked against the national sample for difficulty level. Because most of the items had a high difficulty index as determined by the national sample, making it “too difficult” in terms of item response theory, six items from the Grade 4 test were added to make a balanced test

As in the TIMSS studies matrix sampling was used in order to allow for extensive coverage of the curriculum without overburdening the individual learner (Martin, Mullis and Chrostowski, 2004). The 36 items were allocated to 4 booklets. 12 core items and 6 additional items made up each booklet. 24 items were multiple choice and 12 were constructed response format. As in the TIMSS study, probabilistic procedures were used to establish scores for individual students over the test as a whole despite the fact that individual students had not answered all the items. Three of the constructed response items required 2 responses. In this case each of the responses was allocated a difficulty index, making 39 items.

INTERPRETING RESULTS

The results from the 330 learners, the total population of Grades 7, 8 and 9 at School A and School B, were coded and scored. Information was obtained on both the item and the learner. The graph (Figure 1) shows the items on the right ranging from high difficulty level at the top and low difficulty level at the bottom. The graph on the left shows the estimated ability of learners across the test, with learners with estimated low ability as measured on this test at the bottom and learners with estimated high ability at the top. The item difficulty indices were scaled to give a mean of 100 and a standard deviation of 30. Note that Item 22 has a difficulty index of 116. The learners located on the scale to have a estimated person ability of 116 have a 0.5 probability of getting Item 22 correct, a greater probability of getting the easier items correct and a lesser probability of getting the more difficult items correct.

A conceptual analysis of the items led to the categorization of items into the subtopics fractions, ratio, rate, percentage and algebra. The working definitions were as follows;

Fraction refers to a divided quantity, for example given a region or a quantity divided into equal parts, the learner is required to determine the fraction.

Ratio relates two or more quantities and projects that relationship onto a second quantity, using proportional reasoning.

Percent refers to a fraction sense, for example comparing parts to wholes, or a ratio sense, for example finds a percentage given original and new quantities

Rate is a relational quantity that relates quantities of different types and is a compound measure, for example cost per hour.

Algebra involves relational thinking, the recognition of patterns, unknowns and equations.

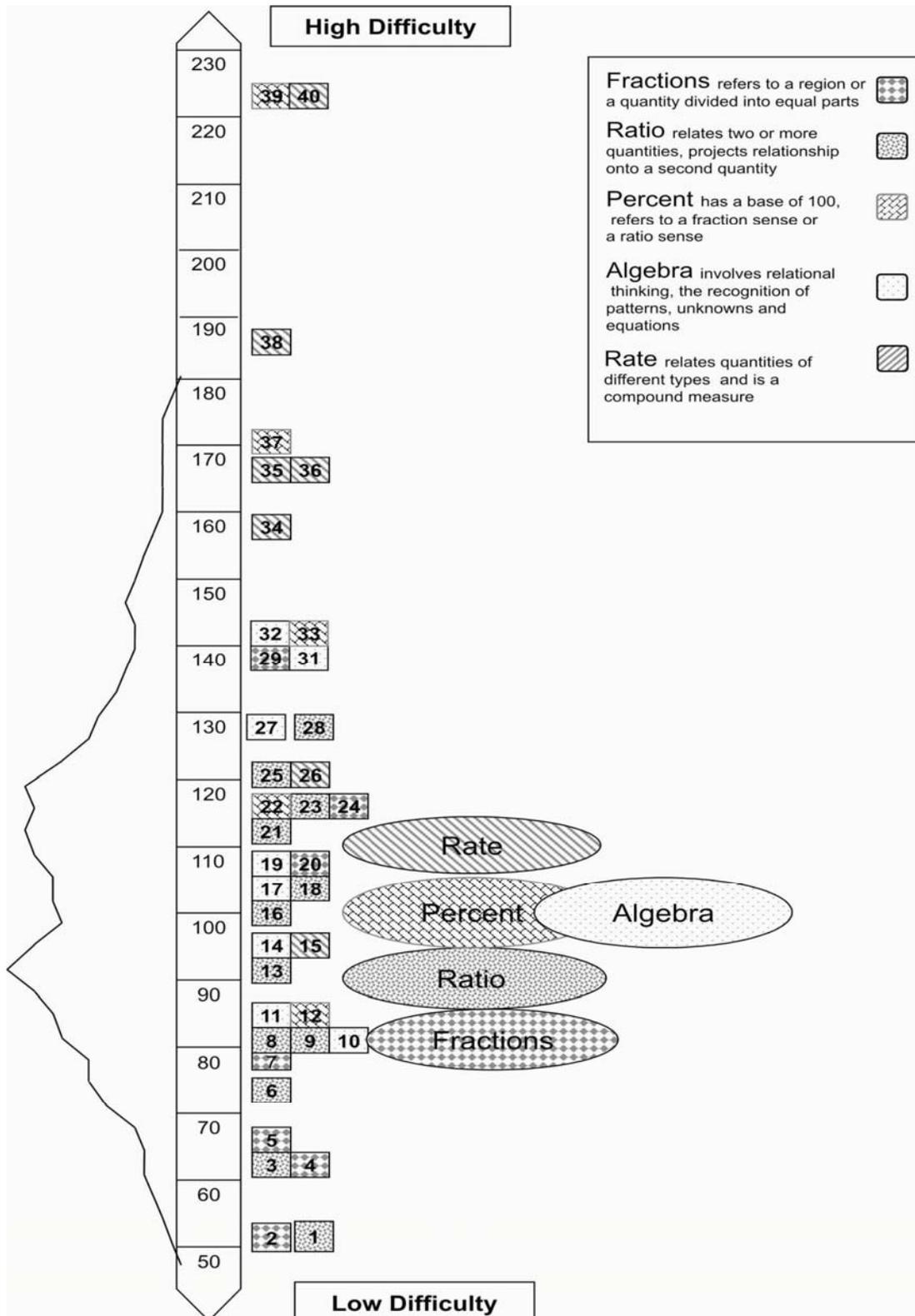


Figure 2: Item difficulty level and learner ability, showing means of subtopics

The conceptual complexities of the content categories outlined above have been described elsewhere (Long, in progress), but in general, the items selected involved

comparative relationships. The categories are not mutually exclusive, for example rate is a type of ratio, and the percent category involves both the fraction concept and the ratio concept (Parker and Leinhardt 1998). The items that have been categorized as *algebra*, involve relational thinking but in addition require recognition of a pattern, or working with an unknown in an equation. These items can sometimes be solved using counting procedures, hence making the solving of them not necessarily reliant on complex cognitive structures. As said previously the multiplicative conceptual field is complex and includes concepts, cognitive processes and problem situations. The difficulty of the item is dependent on all three parameters.

Nevertheless analysis of the above groupings elicits interesting results, from a conceptual and a psychometric perspective. Figure 2 above shows the items categorized into these subtopics. The means of performance on these subtopics shows the relative difficulty. For example rate problems are more difficult on the whole than ratio problems, given the number levels and the contextual problems in this test. What is also of significance is that the relative difficulty remains the same across the two schools, and the three grades (see table) with *fraction* and *ratio* problems easier than *percent* and *rate*. The relative difficulty decreases from Grades 7 to 9 showing progressive development in the understanding of the concept. *Fraction* is the notable exception, as the difficulty index has remained the same across the three grades.

Table 3: Analysis of subtopics within MCF by grade and school showing means of difficulty index

	Grade 7	Grade 8	Grade 9		School A	School B
Fraction	83	80	82	Fraction	92	74
Ratio	101	91	81	Ratio	100	80
Percent	109	100	90	Percent	108	90
Algebra	112	97	92	Algebra	107	89
Rate	121	115	112	Rate	125	101

The cognitive domain categories defined by TIMSS, and discussed earlier in the paper, increase in complexity, though this is influenced by the number range, the kind of number, for example rational numbers are more complex than whole numbers, and the context of the problem. Again what is of interest is that the relative difficulty of these cognitive domains remains the same across the two schools and the three classes (see Table 4).

Table 4: Analysis of cognitive domains within MCF by grade and school showing means of difficulty index

	Grade 7	Grade 8	Grade 9		School A	School B
Knowing	85	75	73	Knowing	87	66
Applying	117	109	100	Applying	117	96
Reasoning	120	112	106	Reasoning	118	102

The above results show a level of consistency, which implies that the broad construct being investigated is coherent and that the assessment is consistent. While the overall results by school and grade are interesting, what is of greater importance in this study is the analysis of responses to selected items. For discussion and analysis I have chosen four items from relatively low difficulty to high difficulty (see Figure 2). All four items were selected from the TIMSS content domain *Number* and subtopic *ratio, proportion and percent*.

Item Analysis

Item 2 (Figure 5) was empirically verified as having a *low difficulty level*

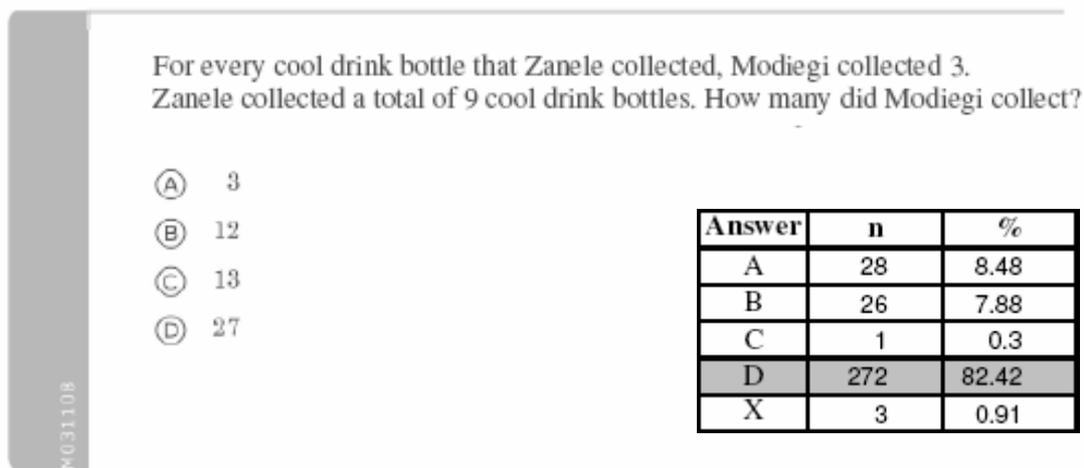


Figure 5: Item 2 - Solves a word problem showing simple proportional reasoning

for the population being tested. This was to be expected as it was selected from the TIMSS Grade 4 mathematics items. The cognitive domain was *knowing facts, procedures and concepts*. As can be seen from the table above 82 % of the sample answered this item correctly (D). The selection of A by eight percent indicates a possible language difficulty. The selection of (B) can be explained by the use of additive reasoning instead of multiplicative reasoning. The learner may have reasoned that Modiegi collected three more bottles rather than three *times* more bottles.

The graph (Figure 6) shows the probability of a learner getting this item correct on the vertical axis. The horizontal axis shows learner ability as measured by the test on a scale from -2 (estimated low ability on the test as a whole) to +2 (estimated high ability on the test as a whole). So for example learners with high ‘ratio attainment’, will be shown to the right of the graph, while learners with low ‘ratio attainment’ will show to the left of the horizontal axis. On this item it can be seen that learners at the upper end, between 1 and 2 learner ability measures had a 90% probability of getting this item correct. Even those at the low end of ratio attainment were more likely to choose the correct answer (D), than any of the distracters. There was a reasonable chance (20-30%) of the learners with ‘low attainment’ selecting the distracters (A) and (B).

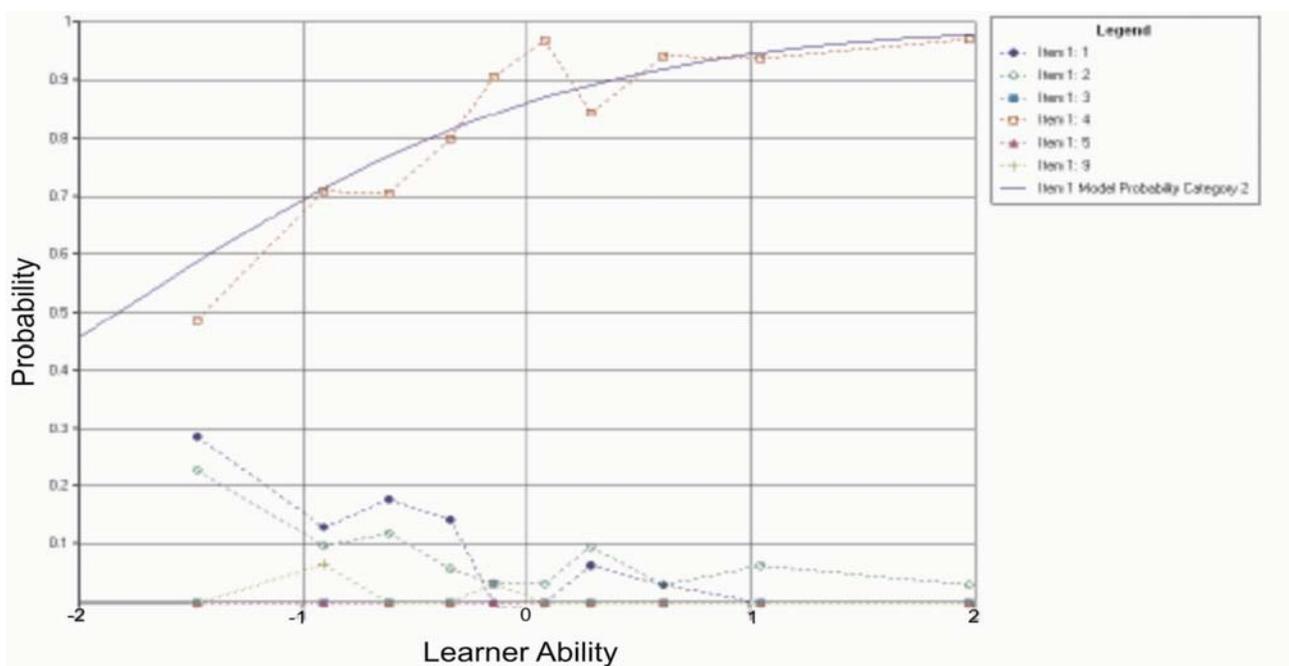


Figure 6: Characteristic curve by category for Item 2

Item 12 (Figure 7) was empirically verified as being of *moderate difficult*. The cognitive domain in which this item was categorized was *knowing facts, procedures and concepts*, the same as Item 2. 62% of the sample from the study got this item correct. The most common errors were (B), 15%, and (C), 14%. In the case of (B) it appears that the learners had not understood the concept of percent and selected the response where the % sign was added. The choice of (D) was in fact “more right” than either (B) or (C), as it takes account of the equivalence of $3/25$ and $12/100$.

Looking at the graph below we see that at the top end of the learner ability scale there is an 80% probability of getting the item correct. At the lower end there is a less than 50% probability of getting this correct. The tendency is for students at the lower end of the learner ability scale to select (B) and (C).

At a play, $\frac{3}{25}$ of the people in the audience were children.

What percent of the audience was this?

(A) 12%
 (B) 3%
 (C) 0.3%
 (D) 0.12%

Answer	n	%
A	206	62.42
B	48	14.55
C	47	14.24
D	19	5.76
X	10	3.03

Figure 7: Item 12: Identifies a percent equivalent to a given fraction when the denominator is a factor of 100.

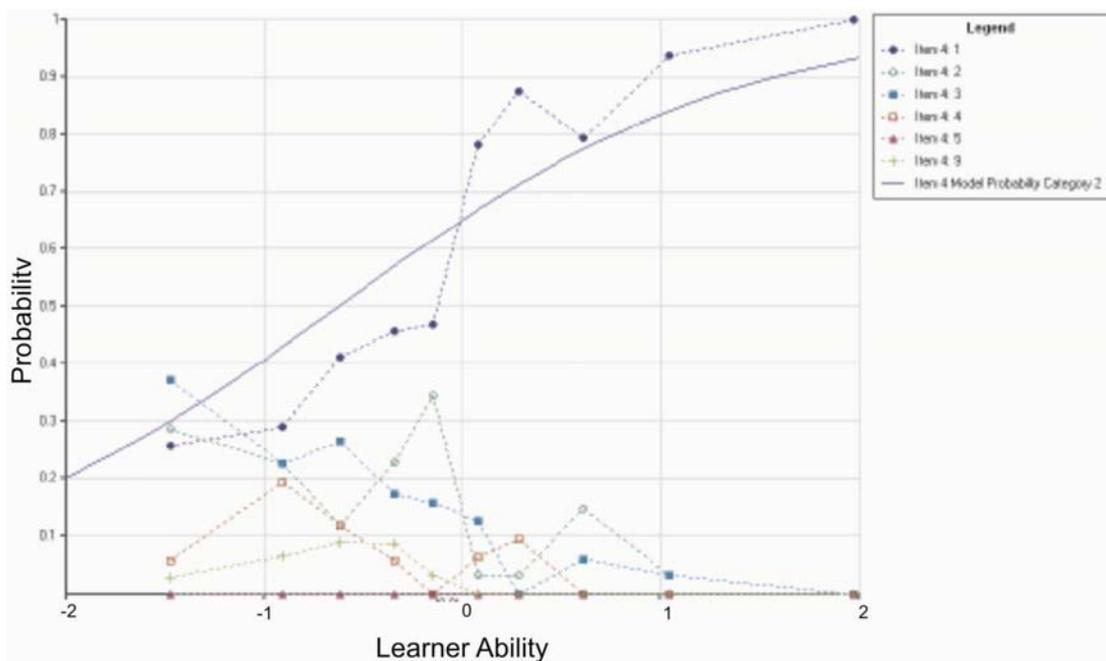


Figure 8: Characteristic curve by category for Item 12

Item 22 (Figure 9) below was of moderate to high difficulty level as measured in this test. The cognitive domain was *applying knowledge and concepts*. The understanding of percent to have a ratio meaning rather than the part-whole meaning is required here. The average correct for this sample is 37%. Of interest to mathematics teachers is that 34% selected response (D). The learner who selected answer 1000, (D), used a part-whole understanding of percentage rather than a ratio understanding. Their reasoning may have been 800 is to 1000, as 80% is to 100%. The part-whole understanding of percent is reinforced when converting between fractions and percent; the more difficult move to a ratio understanding is required for this item.

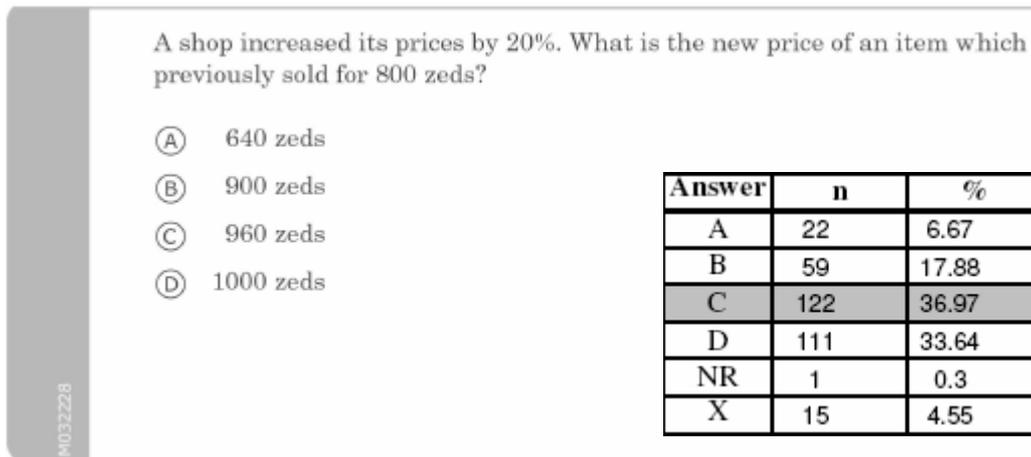


Figure 9: Item 22-Calculates new price given percentage increase

For learners with a higher measure of attainment, greater than 0.5 there is a 50-70% chance of getting this item correct. For learners with low attainment, less than 0.5, on the test as a whole the likelihood of choosing the response C and D is greater.

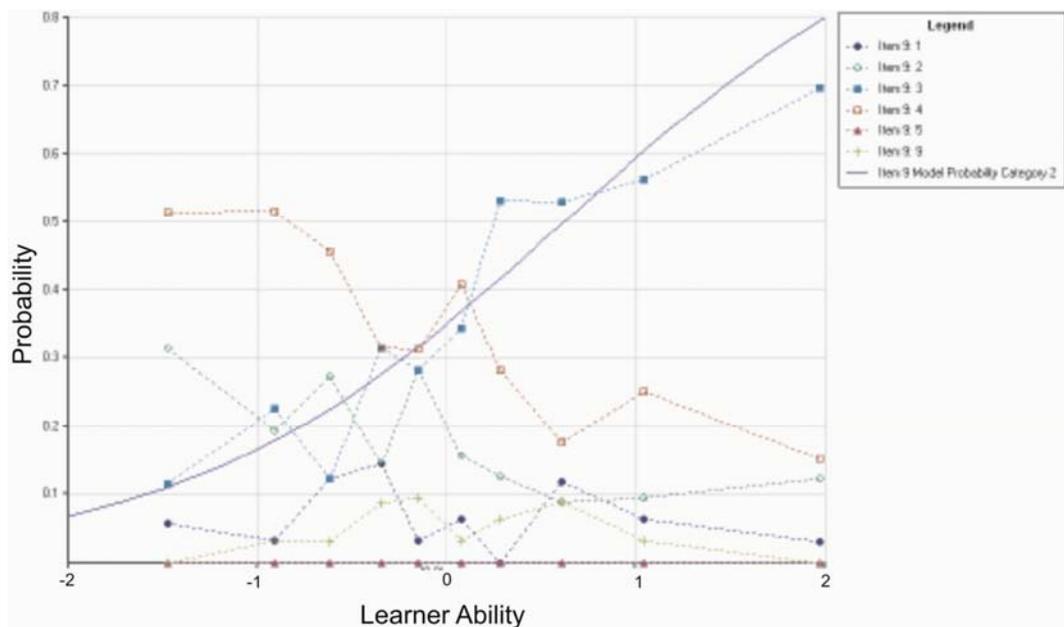


Figure 10: Characteristic curve by category of person measure for Item 22

Item 36, the final item was *very difficult*. This item was from the cognitive domain *reasoning*, which as defined by the TIMSS study (see earlier) includes more complex contexts and multi-step processing. An additional factor leading to the difficulty was that it was a constructed response item, which for South African learners have proved to be more difficult. There are two percentage related concepts, the first is “finding a percentage of” (What is 60% of 40?); the second requires finding the percent when given two quantities (Given 24/50, what is the percent?). The item proved to be very

difficult for the sample tested, with 8% getting the item partially correct. The international mean for this item was 12%, also relatively low, indicating that this type of problem is complex.

A computer club had 40 members, and 60% of the members were girls. Later, 10 boys joined the club. What percent of the members now are girls? Show the calculations that lead to your answer.

Answer: _____

Answer	n	%
1	25	7.58
2	1	0.3
NR	7	2.12
X	297	90

1. Correct scored if: 48% with calculations own
 2. Partial correct scored if: 24 girls or correct method but computational error or 48% with no calculations shown

Figure 11: Item 36- Solves a multi-step non routine problem involving percents

The graph shows the learners with high person ability having a 30% probability of getting this item correct whereas there was little understanding among learners with low ability on the overall test.

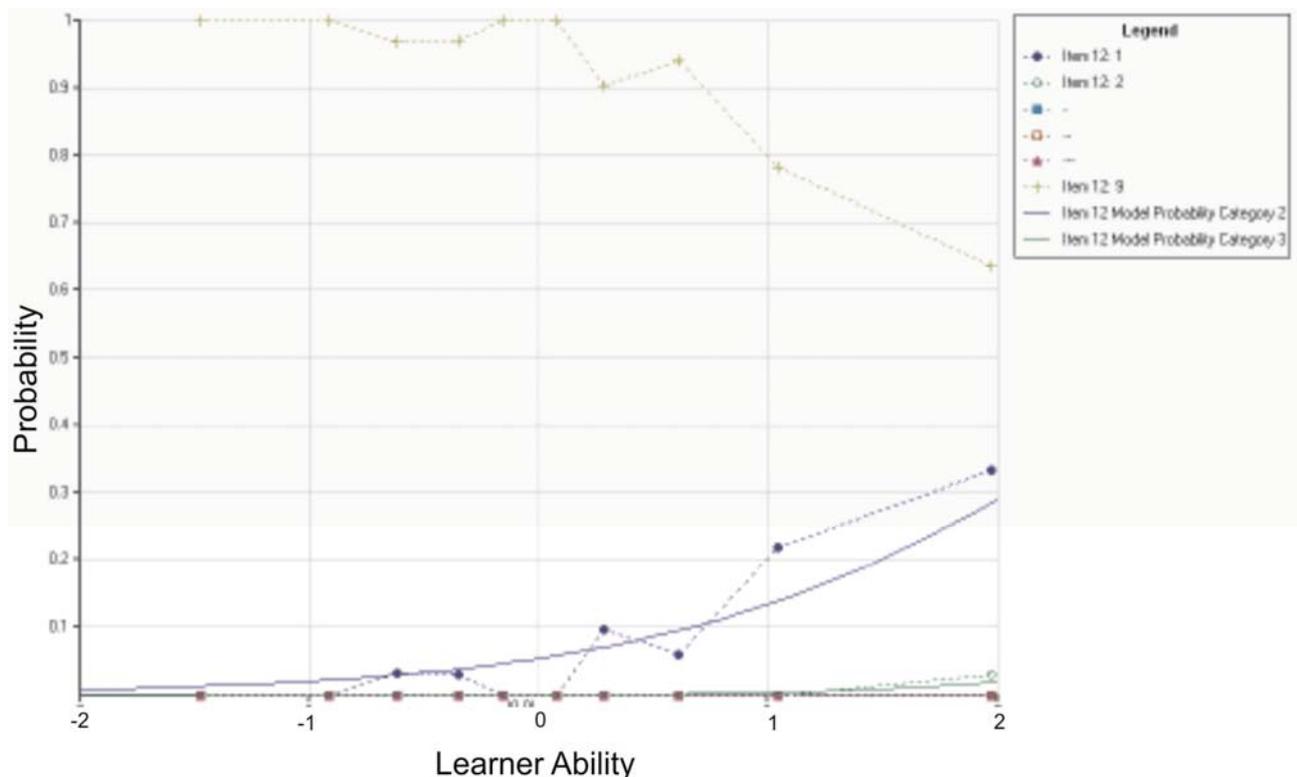


Figure 12: Characteristic curve by category of person ability for Item 22

OVERVIEW OF RESULTS

Four of the 36 items have been discussed in this paper. Preliminary analysis of all 36 items, in relation to the conceptual framework and current literature, is in process.

Many of the errors, observed in the item analysis, suggested that learners were relying on informal estimation skills, and intuitive responses (Long, in process). While these skills work with simpler concepts, the multiplicative conceptual field requires more complex cognitive skills. Another significant error was the use of additive reasoning where multiplicative reasoning was required. From research on this topic it has been noted that additive reasoning is the precursor to multiplicative reasoning (Misailidou and Williams, 2003), suggesting that this is a developmental issue, in addition to being an instructional issue. It appeared from some of the responses that incomplete reasoning (Kaput and West, 1994; Misailidou and William, 2003) was the cause of error in a number of learners. Their reasoning took them part way towards the correct answer. What was also evident was that there was little understanding of percentage problems and speed, distance and time problems. Both of these areas have been identified as highly complex (Parker and Leinhardt, 1998). And finally language and reading cannot be discounted among the causes of errors in this study as well as in the larger South African study. These preliminary findings will be further investigated through the teacher and learner interviews.

At the time of writing the results on selected items had been discussed with one of the teachers. This teacher had been responsible for the Grade 8 class, but had experience from Grade 3 to 12. Questions were put as to whether the item is at the level expected for Grade 7s, 8s and 9s, how the learner might have reasoned to find the correct answer and what errors in thinking may have led to incorrect answer. Plans were in process for interviews with the other teachers. The teacher from School A reported that it was by Grade 9, rather than Grade 8, that more than half of the learners would be able to grasp the concepts required in this test. This preliminary information together with the TIMSS data collected on curriculum indicates the need for a more thorough investigation of the curriculum requirements at Grades 7, 8 and 9, and even perhaps at Grades 4, 5 and 6.

Also at the time of writing interviews were being held with learners with high ability, medium ability and low ability as measured by the test, on selected items. The purpose of these interviews was to gain further insight into the concepts and processes used in solving the particular item. The plan was for learners to redo the selected items showing their working. An interview would then be conducted to investigate their strategies for solving these problems, thereby gaining insight into this field.

CONCLUSION

The investigation of learner attainment on a specific mathematical topic reinforces the need to address systemic issues facing education in South Africa. Two major problems are the specification of the intended curriculum, and the related implementation by the teachers. In addition the detailed analysis of specific problem areas by researchers, motivated by the

TIMSS results and supported by analysis of the specific conceptual field provides insightful information for curriculum planners and teacher educators.

The value of participating in international external evaluation studies such as TIMSS is that we are alerted to problems in the education system as a whole. The TIMSS 2003 report, and this secondary analysis using the TIMSS items, has brought attention to the South African curriculum. In comparison with the TIMSS curriculum framework, which includes generally agreed upon goals of mathematics, our curriculum is underspecified and in implementation is lagging a year behind when it comes to problems related to the multiplicative conceptual field. These topics are dealt with in Grade 5 in the Chinese curriculum and a great deal of time is devoted to mastery of these concepts at this phase (Cai & Sun, 2002). By contrast the South African curriculum is underspecified, with the same topic repeated in a number of grades, with little elaboration of content.

In the case of ratio and proportional reasoning and related topics within MCF, the TIMSS curriculum framework shows levels of detail, which are not apparent in the South African curriculum. The expectation is either that the textbook writers will fill in the gaps or that teachers themselves will be able to elaborate the curriculum statements for use in the classroom.

A focused investigation of items designed to test ratio and proportional reasoning and related concepts in MCF highlight some of the errors. The errors are not new, in fact the literature points to the same significant errors that are apparent among South African learners' responses. This points to the complexity in the multiplicative conceptual field and alerts us to the necessity of giving this section of the curriculum more time, and perhaps engaging the learners on these topics in earlier grades. We might learn from the University of Chicago Schools Mathematics Project (UCSMP) where learners to expected to master concepts over three years of instruction. This means implementing a program of concepts within this mathematical field that progress with increasing complexity starting at Grade 6, so that by Grade 8 the procedures and concepts are in place.

The debate about whether South Africa should have participated in TIMSS 2007 will resurface when the decision to participate in TIMSS 2011 has to be made. To get the most benefit out of participation in the TIMSS studies more people at different levels of the education system, but especially the mathematics and science teachers at the cutting edge could be involved. They could, for example, engage with the research design, compare the TIMSS mathematical frameworks with our own curriculum documents with a view to enriching our curriculum, or justifying the differences between them. The released items could also be used as part of class tests, for both formative and diagnostic purposes.

Finally, well-designed and researched international studies such as TIMSS are evaluative in nature, informing the educational system as a whole, but they also have an important function in providing information and resources for improving teaching and learning.

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APPENDIX A: ITEM DESCRIPTIONS

No	Content domain	Cognitive domain	Item description:Example Type
1	Number : Fractions and decimals	Knowing facts, procedures and concepts	Recognises one-half of a set of objects
2	Number : Ratio, proportion, percent	Applying knowledge and concepts	Solves a word problem involving simple proportional reasoning
3	Number: Fractions and decimals	Knowing facts, procedures and concepts	Recognises a figure that illustrates a simple ratio
4	Number:Fractions and decimals	Applying knowledge and concepts	Word problem: adding $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{4}$
5	Number: Fractions and decimals	Knowing facts, procedures and concepts	Recognises a familiar fraction represented by a figure with shaded parts
6	Number: Fractions and decimals	Applying knowledge and concepts	Selects a fraction representing the comparison of part to whole, given two parts in a word problem setting
7	Number: Fractions and decimals	Reasoning	Selects the statement that describes the effect of adding the same to both terms of a ratio
8	Algebra: Equations and formulas	Knowing facts, procedures and concepts	Using properties of a balance, reasons to find an unknown weight (mass)
9	Algebra:Equation s and formulas	Knowing facts, procedures and concepts	Solves equation for missing number in a proportion
10	Data: Uncertainty and probability	Reasoning	Given the set of possible outcomes as fractions of all outcomes, recognizes probability is associated with size of fraction
11	Data: Data interpretation	Reasoning	Solves a comparison problem by associating elements of a bar graph with the terms, most often, fewer, more
12	Number: Ratio, proportion, percent	Knowing facts, procedures and concepts	Identifies a percent equivalent to a given fraction with denominator a factor of 100
13	Number: Ratio, proportion, percent	Applying knowledge and concepts	Solves a word problem by finding the missing term in a proportion
14	Algebra: Patterns	Reasoning	Finds a specified term in a sequence given the first three terms pictorially
15	Data: Data interpretation	Reasoning	Interprets data from a table, draws and justifies conclusions

16	Number: Ratio, proportion, percent	Applying knowledge and concepts	Identifies proportional share of an amount divided into three unequal parts
17	Algebra: Patterns	Reasoning	Identifies numbers common to two different arithmetic sequences
18	Data: Uncertainty and probability	Applying knowledge and concepts	Given possible number of outcomes and probability of successful outcomes, solves for the number of successful outcomes
19	Algebra: Patterns	Applying knowledge and concepts	Given a sequence of diagrams growing in two dimensions and a partially completed table, finds the next two terms in a table.
20	Number: Fractions and decimals	Applying knowledge and concepts	Solves a multi step problem involving multiplication of whole numbers by fractions
21	Number: Ratio, proportion, percent	Knowing facts, procedures and concepts	Determines the simplified ratio of shaded to unshaded parts of a shape
22	Number: Ratio, proportion, percent	Applying knowledge and concepts	Calculates the new price of an item given the percent increase in price
23	Geometry: Congruence and similarity	Knowing facts, procedures and concepts	Identifies a triangle similar to a specific triangle given the lengths of all sides
24	Number: Fractions and decimals	Knowing facts, procedures and concepts	Finds $\frac{4}{5}$ of a region divided into 10 equal parts
25	Data: Uncertainty and probability	Reasoning	Uses size of a group with a given characteristic in a sample to estimate size of a group with that characteristic in a population
26	Data: Data interpretation	Reasoning	Interprets data from a table, draws and justifies conclusions.
27	Algebra: Patterns	Reasoning	Generalising from the first several terms of a sequence growing in two dimensions, explains a way to find a specified term,
28	Number: Ratio, proportion, percent	Applying knowledge and concepts	Solves a word problem with decimals involving a proportion 2.4: 30 as X : 100
29	Number: Fractions and decimals	Knowing facts, procedures and concepts	Solves a one step word problem involving division of a whole number by a unit fraction
30	Algebra: Patterns	Reasoning	Generalising from the first several terms of a sequence growing in two dimensions, explains a way to find a specified term,
31	Algebra: Patterns	Applying knowledge and concepts	Knowing the first three terms of a sequence growing in two dimension finds the seventh term

32	Number: Ratio, proportion, percent	Knowing facts, procedures and concepts	Finds the percent change given the original and the new quantities
33	Measurement: Tools, techniques and formulas	Applying knowledge and concepts	Solves a word problem to find average speed given distance and time.
34	Data: Data interpretation	Applying knowledge and concepts	Interprets the data from a table to make calculations to solve a problem.
35	Measurement: Tools, techniques and formulas	Reasoning	Solves a multi step problem involving time distance and average speed
36	Number: Ratio, proportion, percent	Reasoning	Solves a multi step non-routine problem involving percents
37	Data: Data interpretation	Applying knowledge and concepts	Interprets the data from a table to make calculations to solve a problem
38	Number: Ratio, proportion, percent	Reasoning	Solves a multi step non-routine problem involving percents
39	Data: Data interpretation	Applying knowledge and concepts	Interprets the data from a table to make calculations to solve a problem