AN EXPLORATION OF THE DESIGN AND DEVELOPMENT OF A SEMI-INTEGRATED CURRICULUM FOR A MATHEMATICAL LITERACY COURSE OFFERED IN A B.Ed. PROGRAMME AT A SOUTH AFRICAN UNIVERSITY

BY

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THESIS SUBMITTED IN FULFILLMENT OF THE DEGREE:

DOCTOR OF PHILOSOPHY

IN THE SCHOOL OF EDUCATION

COLLEGE OF HUMANITIES

EDGEWOOD CAMPUS

UNIVERSITY OF KWAZULU-NATAL, SOUTH AFRICA

MARCH 2016

DECLARATION

I declare that "An Exploration of the Design and Development of a Semi-Integrated curriculum for a Mathematical Literacy First Year Course Offered in a B.Ed Programme at a South African University" is my own work and that it has not been submitted previously for degree purposes at any higher education institution.

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ABSTRACT

An exploration of the design and development of a Semi-Integrated Curriculum conceptualized for the Mathematical Literacy module, offered as part of the Bachelor of Education course, was conducted at the University of Zululand, South Africa. The research focussed on exploring the feasibility and sustainability of integrating various curriculum elements, namely: context, content, and a set of predetermined essential skills and concepts. The research further explored the effectiveness of consolidating essential skills and concepts prior to the introduction of context-based problems. The appropriate level at which those elements should be integrated was also investigated. Another significant objective of the study was to explore the extent to which Higher Order Thinking Skills could be developed and sustained by a curricular innovation such as the Semi-Integrated Curriculum.

The mathematical-literacy-related competency levels attained at school by first-year students in the Faculty of Education and reinforced by the first-year university mathematical literacy module, were of concern to the faculty. A need for significantly improving the mathematical literacy competency levels of students across majors was therefore the principal rationale of this research. Non-science major students made up a large portion of the Faculty of Education's student population. Ensuring a satisfactory level of mathematical literacy in the student teachers across the faculty was thus imperative.

Based on a qualitative research paradigm, this research used a case-study research method that involved a single case study with multiple units of analysis. The research was guided by the overarching research question related to the design and development of a Semi-Integrated Curriculum, the answer to which was constructed by the five sub-questions that were simultaneously answered. Ten student participants were selected from the first-year mathematical literacy student cohort. These students were taken through a series of specially designed mathematical literacy teaching and learning sessions. The content matter taught was designed according to the Semi-Integrated Curriculum format. A pre-test administered prior to the contact sessions and a post-test administered after the contact sessions indicated levels of attainment and the influence the curricular intervention had had on the participants' mathematical performance. The post-test also incorporated tasks that were designed to measure the levels of attainment of Higher Order Thinking Skills. Data collected included semi-structured interviews with the participants conducted before and after the contact sessions; and an interview with the Head of Department. Sources of data collected also included informal working of participants gathered during contact sessions, curriculum materials published by the faculty, and relevant literature. Examination, test and assignment papers were also analysed to assess the level at which the current curriculum functioned and to explore the improvements needed.

Excerpts from transcripts of interviews and faculty curriculum documents were thematically analysed to determine initial categories which were later reduced to themes and concepts. The analysis focussed on deriving a broad understanding of the purpose with which the mathematical literacy course currently functioned, and possible changes in the formulation the purpose itself. The analysis also focussed on the formulation of a set of aspects that characterized the Semi-Integrated Curriculum. The influence of Higher Order Thinking Skills and their sustainability were also aspects that were scrutinised. The effect of a Semi-Integrated Curriculum on the development of mathematical-literacy-related competencies and Higher Order Thinking Skills were explored, in accordance with the conceptual framework that envisaged significant levels of attainment in such aspects of learning. Pre-test and post-test scripts were also analysed to ascertain the levels of attainment of mathematical literacy competencies, and the extent to which Higher Order Thinking Skills were fostered and sustained.

The results indicated that a focussed curricular intervention such as the Semi-Integrated Curriculum does have an effect on the general mathematical-literacy-related competencies. However, major changes in the levels of attainment could not be established. The development and sustainability of Higher Order Thinking Skills were also noticed at a relatively low level despite instances of satisfactory performances from participants that were noteworthy. However, significant changes in the approach to learning and the influence that a curricular focus on Higher Order Thinking Skills can have on learning were remarkable. Participants developed noticeable positive changes in their mathematical learning approach that placed a heavy emphasis on conceptual mastery as opposed to procedural focus; which in turn led to changes in the attainment of Higher Order Thinking Skills. The significance of this research is, therefore, that curricular interventions focussing on consolidation of Essential Skills and Concepts prior to the introduction of context-based problems, in a mathematical literacy context, underpinned by an emphasis on Higher Order Thinking Skills, do produce positive changes in mathematical literacy competencies.

The process of a Mathematical Literacy curriculum development undertaken in tertiary institutions in South Africa and across the world is to be underpinned by this finding.

ACKNOWLEDGEMENTS

The successful completion of this thesis is sincerely attributed to the scholarly supervision provided by Dr. Aneshkumar Maharaj and Prof. Deonarain Brijlall. Assistance provided by the University of Zululand is also acknowledged. The editing of this thesis was done by Mrs. Lydia Weight whose effort in that regard is also hereby acknowledged.

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CHAPTER 1: INTRODUCTION

1.1 Focus and Background

There has been a significant decline in numeracy skills among undergraduate students worldwide, which has influenced such students' retention and progression rate as well as their employability (Vicki & Naureen, 2012). The United Kingdom's Quality Assurance Agency for Higher Education, in its benchmark statements, has called upon institutions worldwide to have increased programmatic emphasis on numeracy skills. This applies to mathematically ill-prepared undergraduates who fail to meet the demands of the chosen discipline (QAA, 2011). The decline in numeracy skills of undergraduates has been attributed to a variety of reasons. These include teaching and learning practices at schools, school curriculum content, and the changing of entrance requirements at universities (Vicki & Naureen, 2012).

Research shows a similar situation prevalent in the South African higher education scenario, in which a significant number of students is poorly prepared to meet the quantitative demands of the university curricula (Frith, 2012). Frith (2012) also refers to the higher education institutions' resolution to "seek opportunities within existing curricula to strengthen basic literacies- academic, quantitative and information - both as a means of improving learning capacity and as a contribution to informed citizenship (p.2)". Existing curriculum structures are, however, emphasizing an "across-the-curriculum" approach to curriculum development in numeracy, numeracy being a competency that must be "learned and used in multiple contexts" (Hillyard, 2012). Hillyard (2012) suggests in this context that the "numeracy education community" could adopt a four-step strategy for its growth. He lists the steps as "a paradigm shift in thinking about numeracy pedagogy, a focus on campus-level faculty and student support structures and resources, development of extensive, external professional support systems and thoughtful framing of numeracy curricula within social and political contexts" (p.11). The last point put forward by Hillyard (2012), viz. "framing of numeracy curricula within social and political context which integrates activities across and within disciplines" may be stated as one of the critical issues investigated in this research. This is because numeracy is better received when students find it integrated in coursework of other academic disciplines (p.16).

Situated in the context of a multitude of varied instructional and curricular characteristics in the national and international higher education scenario, the mathematical literacy module offered at the University of Zululand (UNIZUL) deserves special mention. This is because of the unique circumstances under which the mathematical literacy module was originally conceptualized, and the myriad of institutional factors by which the module remains influenced. This study, therefore, focusses on an exploration of the design and development of a Semi-Integrated Curriculum for the mathematical literacy module offered as part of the Bachelor of Education course at the University Of Zululand. While a theoretical rationale for coining the term 'Semi-integrated curriculum' will be thoroughly dealt with in Chapter 2 of this thesis, the Semi-Integrated curriculum (SIC) may be tentatively defined here as a curricular attempt envisaged to provide synchronized emphases of contexts and concepts in learning activities. This optimized, yet differentiated, emphasis, may be considered the central defining characteristic of learning activities that constitute a Semi-Integrated Curriculum conceptualized in a mathematical literacy context. A justification for the interchangeable use of the terms 'mathematical literacy' and 'numeracy' in the preliminary sections of this thesis will also be provided, followed by explicit clarifications as to how those terms differ. While the design and development of a Semi-Integrated Curriculum is thus central to this thesis, influence that a Semi-Integrated curricular structure casts on students' higher-order thinking skills will also be studied as part of this research. While the former is the primary research focus, the latter involves an integrated curricular intervention leading to explorations in higher-order thinking skills.

1.2 Purpose of Study

In 2014, the University Of Zululand introduced Mathematical Literacy as an undergraduate module. This was a major shift in policy, in the sense that two semester modules, each of 'content' of mathematical literacy in the first and second years, were discontinued from the year 2014. Two semester modules of mathematical literacy (method) offered in the third year were also discontinued in the same year. The newly introduced mathematical literacy was designed to be taught in two semester modules which students take successively in the same year. The modules are offered in the first year of the four-year Bachelor of Education (BEd) programme. Students across the faculty, except those in the Further Education and Training (FET) programme, take these modules. Approximately seven hundred students register for mathematical literacy modules. This researcher was fortunate in having witnessed the transition process through which the faculty drastically reshuffled and streamlined the BEd curriculum. This researcher was also privileged to have been given the responsibility of teaching the new mathematical literacy modules. It is to be admitted here, that curricular or programme changes are effected through a deliberative process at a higher level than that occupied by this researcher, who happens to be placed at the lowest level of the academic hierarchy. This point is to be noted because of implications with regard to the extent to which individuals in the same academic position as this researcher can influence policy decisions and curricular changes. The argument here is that this researchers' observations of curricular changes were conducted from the perspective of a third person who has not been directly involved in the decision-making process leading to the programme changes.

The curricular transition which this researcher witnessed from the vantage point of a lecturer teaching the new modules, was intellectually overwhelming. A new curriculum had to be conceptualized, designed, and implemented, in a matter of two months. Curricular objectives had to be reformulated, content matter had to be reorganized, and instructional design had to be revisited. A new cohort of first-year students had to be taken through a set of learning experiences, the structure of which was unfamiliar to the students. An assessment system had to be put in place with which the students came to terms only towards the end of the year. At that stage, the only guidance available to this researcher was from the Head of Department of Mathematics Science and Technology Education (MSTE) in the Faculty of Education. This staff member, in an interview with the researcher, elaborated on the various aspects of the newly introduced mathematical literacy module. Data from that interview was used at various stages of this thesis because of its relevance to various contexts. It is also important to note that the views expressed by the Head of Department, for all practical purposes, may be taken as the views of the institution, because of the explicit involvement of the Head of Department in the curricular decision-making process. In other words, views expressed by the Head of Department would not have been his personal views, but rather, those of the faculty. It is also important to note here, that the observations made by the Head of Department were greatly influential in the making of the draft curriculum which the researcher drafted and which was implemented.

During both formal and informal conversations with the Head of Department and with other staff members of the MSTE department at various times, the purpose of the module emerged as the single most important issue to be conceptualized. Where the curricular emphasis should lie remained a significant question which the new mathematical literacy module had to specify at the outset. Among various objectives mentioned, reinforcing and consolidating 'basic' numerical and computational ability of a broad spectrum of first-year students, evolved as the most important feature of the proposed curriculum. This objective, by its very nature of being general and broad, was problematic, and had to be resolved into its specific constituent objectives. The problem was compounded by the fact that the cohort of students for whom this curriculum would be implemented, had a very diverse mathematical background. Some had taken mathematical literacy at school, while others had taken 'pure mathematics'; yet others had taken no mathematics at all from Grade 10 onwards.

The distinction to be drawn between 'mathematical literacy' as a competency, as found in the related literature, and as a secondary school subject in South Africa, and its relationship with 'numeracy' as a subject taken at first-year university level both nationally and internationally, is noteworthy at this stage. These interrelated terms will be dealt with in detail in the 'Literature Review' section of this thesis. However, having a clear-cut conceptual understanding of all these terms posed a challenge, because of the multitude of connotations associated with these terms that this researcher came across in the related literature. The name 'Mathematical Literacy' given to the new module is thus considered tentative, for lack of an appropriate term that encompasses the relevant curricular objectives. The reader is cautioned against possible ambiguity to which such a term can lead, because of huge differences in the objectives of school mathematical literacy and mathematical literacy offered at university level. The argument here, however, is that the curricular conceptualization of the module, from the very outset, was riddled with inherent drawbacks, with the potential of rendering the implemented curriculum ineffective.

An observation made by this researcher about the tentative curriculum that was initially implemented, is pertinent. The above-mentioned curriculum was structurally modelled after the South African Mathematical Literacy school curriculum, with the underlying philosophy of 'Mathematics in authentic context' (Kema, 2013). The concept of mathematical literacy has, over the years, assumed an incredible level of association with authentic contexts with which it is presumed inseparable (p.312). Literature shows that this affiliation with context is largely justified, owing to the fundamental objective of mathematical literacy as a school subject, which is the uplifting of an otherwise mathematically sidelined population (p.313). Teaching, learning, and assessment within the school mathematical curriculum, therefore support this notion of 'content in context' to the extent that learning activities bear a pervasive pseudo-authentic appearance. It is in this context that a mathematical literacy course at a university level is to be understood. The fundamental emphasis in a university mathematical literacy course is on the development of much-needed numerical and computational ability that help the student teachers tackle numerous situations which are quantitatively demanding. In other words, numerical and computational ability on their own, collectively constitute a significant competence with which student teachers should be empowered. This researcher experienced that the currently implemented curriculum − having been modelled after conventional school mathematical literacy − because of its overarching emphasis on contexts, is ineffective. This, as this researcher found among his students, is due to a serious lack of basic numerical computational skills which are expected to be developed at junior school level. A serious lack of basic mathematical conceptual knowledge prevented most students from taking advantage of rich authentic contexts in which problems presented themselves. This researcher therefore resolved, in most instances, to resort to conventional iterative practices of mathematical skills and manipulations, after the mastery of which contextualized problems were successfully dealt with. This amalgamation of content and context has become a permanent feature in this researcher's classrooms. This is another important aspect that will be formalized in this research by way of assigning formal terminology and research-based methodology to the process of concept − context unification at an appropriate level. A convenient term used in this thesis is 'Semi-Integrated Curriculum' to indicate the process of appropriately emphasizing concept and context when learning experiences are designed. The theory of concept − context alignment or integration will be dealt with in detail in the forthcoming chapters of this thesis. The intention here was merely to allude to semi-integration as a process of keeping concept and context in a mutually complementary status, to optimize learning. This description also serves as one of the reasons for this research being undertaken.

As the lecturer responsible for drafting the curriculum and for its implementation, this researcher found it imperative that the design and development of the 'mathematical literacy' curriculum be formalized, and be subjected to a rigorous scientific research method supported by appropriate theoretical and analytical frameworks. "The first task of the scientific curriculum maker is the discovery of social deficiencies (among the recipients of the curriculum) that result from a lack of historical, literary and geographical experiences" (Bobbit, 2013). In the context of such 'social deficiencies' and the experiences leading to those deficiencies, the purposes of this research may be listed as follows:

1. To explore the introduction of a Semi-Integrated Curriculum for the mathematical literacy module offered as part of a Bachelor of Education programme at a South African university
2. To explore the influence of SIC on the development of students' Higher-Order Thinking Skills (HOTS)
3. To explore the extent to which HOTS attained at first-year level are sustained in subsequent years of study
4. To explore the appropriateness of SIC as a curricular innovation to be undertaken for a mathematical literacy first-year module

1.3 The Rationale for Exploring the Design and Development of a Semi-Integrated Curriculum for a Mathematical Literacy Module

The rationale for an exploratory study towards the design and development of a curriculum for the mathematical literacy module is formulated based on the characteristics of the current curricular practice at the institution (as experienced by the researcher and students) (Jinchang, Gurprit, & Shaoping, 2008). National and international best practices in numeracy or mathematical literacy curriculum delivery in post-matric educational settings also influenced the conceptualization of the rationale. An investigation into the extent to which the current curricular, instructional, and assessment objectives are comparable with those pursued by international institutions in the context of post-secondary numeracy/mathematical literacy courses forms the basis of this exploratory research. The need for an ‘appropriate’ curriculum produced as a result of a structured scientific research may therefore be considered the core rationale for this research enterprise. The ambiguous purposes with which mathematical literacy was introduced into schools, and the large-scale discontent expressed in the academic fraternity with regard to its (mathematical literacy's) utility, influenced the way in which the concept of a university-level mathematical literacy course is perceived. This was evident in the preliminary interviews engaged in by this researcher with the Head of Department, and in conversations with lecturers who had taught mathematical literacy courses previously at the University of Zululand. Having been associated with mathematical literacy courses previously, the Head of Department had in-depth knowledge of implications of designing a one-year course which would replace an existing three-year ‘content and method’ course. The newly introduced mathematical literacy course was therefore afforded the recognition that it should be ‘research-based’ in its design and implementation. This was the view expressed by staff members at various department and faculty-level meetings in which this researcher participated, in his capacity as a staff member of the Department of Mathematics, Science & Technology Education, which falls under the Faculty of Education.

Having introduced the course from the beginning of year 2014 to a group of around 700 students, and having structured lectures based on a ‘tentative set of content topics’, this researcher felt an overarching need for a comprehensive curricular overhaul. Every single teaching session would expose an aspect of learning that deserved to be accommodated at a curricular level. Every instance of interaction this researcher had with students would reveal a new dimension of what constitutes ‘mathematical literacy’, how it may be fostered as a competency, and how it may be confined within the ambit of a ‘curriculum’ in its conventional sense. Every mathematical concept taught revealed the underlying ‘conceptual deficits’ which students had accumulated over the years. An utter lack of basic numerical ability would render futile neatly structured contextualized problems, which were indispensable for a ‘conventional’ mathematical literacy course. A culture of over-dependence on the calculator unintentionally inculcated from primary-school level for even the simplest arithmetical operation, and the misconceived notions of mathematical learning approaches, were the observed characteristics in such classrooms. Contextual associations of problems dismally failed to entice students into mathematical explorations, through a complete lack of concept and algorithmic knowledge. A pervasive sense of disappointment prevailed in such classrooms. The need for a comprehensive curriculum that incorporated reinforcement and consolidation of basic mathematical knowledge and skills built into the framework of real life contexts, was therefore considered an alternative to the 'conventional mathematical literacy curriculum' which singularly emphasized real-world contexts (Nathan, 2012).

The technical characteristics of such a process of embedding consolidated concepts into contexts were the defining characteristics of this exploration. The technicalities and theoretical positioning of the embedding process was investigated in the context of established theories and strands of integrated curricula, and described in the literature review section of this thesis. The ideas leading to the formulation of a theoretical and curricular standpoint called 'Semi- Integrated Curriculum' is dealt with in the same section. In other words, a Semi-Integrated Curriculum, with its proposed instructional emphasis on consolidation of concepts and skills at a level deemed appropriate for a mathematical literacy course, prior to their embedding in contexts, deserves to be subjected a rigorous research-based exploration. This selective and differentiated emphasis of concepts, skills, and contexts, which underpins the Semi-Integrated Curriculum, forms the critical aspect of a theoretical rationale. However, the rationale for this research itself, may be summarized as an ever-increasing need, felt across various stakeholders, for an all-encompassing curricular solution for the newly introduced mathematical literacy module.

In conclusion, it should be noted here, that the rationale for this research evolved out of this researcher's interactions with students and faculty staff, course materials from previous and present modules of mathematical literacy or its equivalent, and curriculum and assessment documents. Above all, this researcher's experience of six years of teaching foundation-level mathematics to underprepared students in the same institution, significantly influenced the *development of a personal theory of underprepared students' mathematical learning*. The collective awareness created by experience, interaction, and intuition, substantially strengthened the thread of rationale that runs through the fabric of this research.

1.4 Research Questions

<u>Main Question</u>

1. How can a semi-integrated curriculum be designed and developed for a mathematical literacy first-year module for a Bachelor of Education programme?

To help answer this question the following sub-questions were formulated.

<u>Sub-questions</u>

2.1 What is the purpose of a Mathematical Literacy module taught as part of a BEd programme?

2.2 What are the characteristics of a Semi-Integrated Curriculum (SIC) in the context of teaching and learning of Mathematical Literacy in higher education?

2.3 What influence does a Semi-Integrated Curriculum introduced for the Mathematical Literacy module have on students' Higher Order Thinking Skills (HOTS)?

2.4 To what extent are Higher-Order Thinking Skills, attained in a Mathematical Literacy course, sustained in subsequent years of study?

2.5 Is the introduction of a Semi-Integrated Curriculum worth being undertaken for the mathematical literacy module of a Bachelor of education course? Why?

1.5 Overview of Thesis

This section presents an overview of the thesis by way of short summaries of each chapter organized as separate sections. Short summaries of all six chapters of this thesis are appended here.

<u>CHAPTER 1</u>

This chapter provides a broad outline of focus, purpose, and rationale that govern the conceptualization of this research as a whole. Having been contained within the boundaries of formal academic research, the exploration focusses on the development of an integrated curriculum theoretically juxtaposed between various levels of concept − context alignment and their selective integration. The purpose of the research is further indicated as an investigation into the prospects of introducing a Semi-Integrated Curriculum − a term coined, defined, and explained within the context of this research − for the mathematical literacy module. The reasons behind undertaking a research of this nature, in the particular manner proposed, are also explained in this chapter.

CHAPTER 2

This chapter deals with a broad review of national and international literature on numeracy courses offered at tertiary level. This chapter also helps the reader have a clearly defined understanding of the published work about numeracy courses in South African universities, supported by related international literature. This chapter also explains a framework for analysing the quantitative demands of a quantitative literacy event. The framework gives us an indication of competences and their relative emphases involved in quantitative literacy events. This is followed by explanations of substantive constructs, 'financial literacy', 'statistical literacy', 'quantitative reasoning', 'academic literacies' research' and the relationship among them.. The chapter concludes with brief descriptions of research questions which are firmly grounded in the review of literature for their (the questions') validity and appropriateness.

CHAPTER 3

This chapter focussed on the development of the conceptual framework that guided this research as a whole. The chapter also discussed various philosophical perspectives regarding integrated curricula, providing explanations of the terms 'integration' and 'semi-integration' as curricular approaches. Local operational definitions of these terms were followed by a broad theoretical explanation of different levels of quantitative literacy from a cognitive-theory perspective. The integrative technique of having concepts integrated with contexts, with a set of predetermined and context-driven 'essential skills' preceding every thematic unit in the curriculum, is explained in detail in this chapter.

CHAPTER 4

This chapter deals with the methodology adopted for this research. It further provides a rationale for the qualitative research paradigm that involves a single-case study with multiple units of analysis. While the mathematical literacy course offered at the University of Zululand was the case, the ten student participants were the units that constituted the single case. This chapter explains how this research used the principles of phenomenological exploratory single-case study with multiple units of analysis as the methodology using an interpretive analytical perspective. This chapter also deals with the kinds of data constructed such as transcripts of interviews, pre-test and post-test scripts, and curriculum documents. The techniques of thematic analysis and cross-unit synthesis used to analyse data are also dealt with. The chapter concludes with the explanations of principles of validity, such as descriptive validity, interpretive validity, and theoretical validity.

CHAPTER 5

This chapter has dealt with the analysis of data collected before, during, and after the contact sessions, which included the analysis of documents, interviews, and tests. The chapter explains how the pre-test, contact-session work scripts, and the post-test analysis, provided deep insights into the cognitive processes that students engage on a daily basis, that are profoundly influential in the making or the discarding of a curriculum. The central question of the thesis that explored the extent to which certain essential skills and concepts (ESCs) are to be taught separately; and the extent to which certain other ESCs should be integrated with contexts, guided the analytical process. Using a thematic framework for analysis, codes and categories were developed using each line of the transcripts or the portion of text in question. The associated aspect of Higher Order Thinking Skills and the extent to which such skills are fostered by the proposed curricular innovation are also dealt with in this chapter.

CHAPTER 6

This chapter deals with the cross-unit interpretive synthesis of all units of analysis followed by the answers to the research questions. Each of the five sub questions is answered in this section followed by the answer to the main research question. Questions related to the purpose of a mathematical literacy curriculum, characteristics of SIC, influence of SIC on HOTS and the sustainability of SIC are dealt with in this chapter. Answers to the sub-questions are collectively considered for answering the main research question. This chapter also gives illustrated examples of SIC based topics designed in accordance with the curricular principles stipulated in this thesis. This chapter concludes with certain recommendations by way of providing guidelines for the design and development of a Semi-Integrated Curriculum.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summarizes the literature that has been reviewed. It presents, firstly, from a curriculum perspective, an overview of mathematical literacy courses offered by South African universities for their Bachelor of Education (BEd) programmes. This is followed by a comparison between other university mathematical literacy[1] curricula, and that followed by the University of Zululand. The chapter also deals with a section on the concept of the integrated curriculum, concluding with explanations of research questions.

2.2 An Overview of Mathematical Literacy/Quantitative Literacy/Numeracy Courses in South African Universities

Quantitative skills of all students, irrespective of their chosen majors, which may or may not be mathematically intensive, is an area on which institutions of higher education should have an increased focus (Aimee, 2006). Quantitative demands on higher education students from even the disciplines of law, and the humanities, are increasingly becoming more stringent (Frith, 2012). Many South African university students are thus not adequately prepared to meet the quantitative minimum requirements university programmes implicitly put forward as prerequisites. Curriculum interventions are thus deemed imperative in mitigating the articulation gap between curricular demands and students' quantitative literacy. Frith (2012) further contends that South African literature on quantitative literacy in higher education is limited, compared with the research discourse around school mathematical literacy in South Africa. However, the introduction of mathematical literacy as a school subject in 2006 was seen as a significant step towards preparing students for higher education (Frith, 2010). Frith's work, as the author herself put it, was intended "to stimulate more research and debate" about quantitative literacy in higher education (Frith, 2012, p.41). As the single most prominent author dominating the discourse on South African higher education numeracy courses, Frith's views are worthy of special mention.

[1] The terms "numeracy", "quantitative literacy" and "mathematical literacy" are used interchangeably in literature (Aimee, 2006)

While literacy and numeracy are conceptualized as social practices, academic disciplines are considered social entities demanding particular literacy and numeracy practices from the members who constitute such entities. Frith's contention, therefore, is that the state of being quantitatively literate is dependent on the discourse around which the literacy or numeracy is practised. The prevalence of different quantitative literacy practices embedded within various academic disciplines is thus acknowledged. The definition of the term 'quantitative literacy' is therefore carefully worded by Higher Education South Africa (HESA) (2006), as: *"Quantitative literacy is the ability to manage situations or solve problems in practice, and involves responding to quantitative (mathematical and statistical) information that may be presented verbally, graphically, in tabular or symbolic form; it requires the activation of a range of enabling knowledge, behaviours and processes and it can be observed when it is expressed in the form of communication, in written, oral or visual mode"* (Frith, 2012, p. 3).

The definition is built around the central notion of 'quantitatively literate behaviour' which, according to Frith (2012), relates to and is influenced by:

- 'Contexts' in which the practice of quantitative literacy is embedded;
- 'Content' drawn from mathematical and statistical concepts and techniques; and
- 'Thinking and competencies' that are called upon.

The use of the terms 'content', 'contexts', and 'thinking' are noted at this stage for their relevance to the formulation of the 'Semi-Integrated Curriculum' as a curriculum alternative proposed in this thesis. This proposition may be seen in the context of Frith's (2012) conceptualization of the integrated curriculum as 'the most effective curriculum for quantitative literacy' (which naturally integrates into the disciplinary curriculum) (p.43). Therefore, in the ideal sense, quantitative literacy as a curricular entity is best conceived as that which seamlessly merges with various disciplinary curricula, owing to its (quantitative literacy's) contextually bound identity. In a typical quantitative literacy course set for Humanities and Law students at the University of Cape Town, as Frith argues in defence of integration, various quantitative literacy competences were integrated into contexts that "closely mimic" contexts of the disciplines. The author views the quantitative literacy curriculum design as "a further re-contextualisation of the disciplinary curriculum". However, Frith (2012) also refers to Bernestein (2000), whose notion of "literacy as a generic mode" allows us to think of quantitative literacy as a course offered separately from the disciplines in which the voice of the discipline is weak. Quantitative literacy, as a practice embedded in disciplinary contexts, on the other hand, calls for it to be strongly integrated into such contexts. The key point here is that the complexity of contexts is to be carefully determined so as ***not*** to overburden the students with totally unfamiliar contexts, leading to the students' becoming oblivious to the integrated content (p.44). Opportunities of engaging with a variety of contexts should thus be at a level that "learners can access logically" (Hanlie, Jacobus, & Gerrit, 2013).

Frith (2012) provides a typical thematic integration of content and context, giving an appropriate balance to each. This has resulted in providing three 'context-based modules' for the first half of the year-long quantitative literacy course at the University of Cape Town. The modules are: "Children's rights", "Xenophobia", and "Prison overcrowding". Content topics covered in each of the themes are then identified. It is likely that more than one topic is covered by a theme. The overarching curricular emphasis thus remains the contexts, and not the development of mathematical content knowledge as such (p.44). The second half of the course that deals with financial mathematics and descriptive statistics, is structured around categories of mathematical and statistical content, while such material remains embedded in authentic contexts. The vertical and horizontal build-up of content as envisaged in the above instance, indicates the complex definition associated with the term numeracy. The term goes beyond an ability to do basic arithmetic–it is about being comfortable with logic and reasoning, being able to use mathematics-based elements in everyday functioning with varying degrees of emphases on application and understanding (Suzanne, Esther, & Patric, 2012). The current emphasis generally for numeracy/mathematical literacy courses, however, is on application of skills (p.42). This is an important aspect investigated in this thesis.

The design and development of an appropriate curriculum for a stand-alone quantitative literacy course for a certain discipline starts with the "re-contextualisation of the disciplinary curriculum" (p.45). This is conducted by identifying suitable contexts that resemble those contexts the students encounter in other courses. The author cautions us that we must have realistic expectations about the students' familiarity with the contexts chosen, as well as with the lexical definitions of words used to describe such contexts. An unfamiliar context shrouded in lexical jargon renders the content inaccessible. A curricular intervention devised for improving students' quantitative literacy should aim at an optimal level of integration of quantitative ideas into the disciplinary discourse (p.47).

The cognitive process of interpreting quantitatively significant statements involves a complex thought process in which, to make sense, various mathematical competencies are called upon (Frith, 2009). The curricular innovation that we see in the University of Cape Town with regard to its quantitative literacy course, may thus be considered unique because of its context-based curriculum that strives to merge context and content at an optimal level (Frith, 2012).

2.3 Quantitative Literacy as Described by HESA (2006)

Quantitative literacy, by virtue of its varied operational dimensions, cannot be labelled as a set of mathematical skills to be taught and learned without referring to social contexts in which such skills may be applied. 'Practice' is a useful and generative way of conceptualizing quantitative literacy, because it (the word 'practice') assimilates "what people do and also the ideas, attitudes, ideologies and values that inform what they do" (p.28). Quantitative literacy (QL) is therefore inherently associated with a particular social practice from which it (QL) derives a particular definition for itself. A distinction between 'quantitative literacy' and 'literacy' is also noteworthy at this stage. From a tertiary-level numeracy and literacy perspective, numeracy may be placed in the wider reconstituted concept of literacy. The notions of quantitative literacy and literacy are to be considered naturally inseparable; or at least complementary to each other. A more conciliatory approach to have them combined yielded the notion that quantitative literacy involves many interrelated competencies. Reading, writing, and mathematics, bear an interrelation which resembles their interrelationship in communication, and the learning that results from communication. The term 'academic numeracy' thus indicates the numeracy demands of academic texts and tasks (p.28). In summary, quantitative literacy may be thought to be made up of:

- **Contexts** that require the activation of quantitative literacy practice;
- The mathematical and statistical **content** required when quantitative literacy is practised; and
- The underlying **reasoning and behaviour** called upon to respond to a situation requiring the activation of quantitative literacy practice.

The three points indicated above are briefly explained below.

Contexts

The fact that contexts differentiate quantitative literacy from 'conventional mathematics' underpins the varied notions of quantitative literacy in related literature. The standard practice of teaching QL in the conventional restricted mathematics classroom contradicts the very idea of contextual grounding of QL. Contrived 'real-life' contexts are not appropriate substitutes for authentic contexts. Contexts are to be understood as clearly as the concepts that underpin such contexts. The selection of contexts that keep the students motivated to explore the content carried by the contexts, is therefore pivotal in the discourse related to QL.

Content

The fundamental aspect of QL content is its mathematical and statistical dimensions. However, there will be diverging arguments about the breadth and depth of the content which suits different disciplinary contexts. Statistics and data-handling, as opposed to traditional school mathematics topics, occupy the pride of place in QL. This holds true in a QL environment in tertiary academic disciplines. In other words, a student needs a great deal more than basic arithmetic to be quantitatively literate at tertiary level.

Reasoning and behaviour

QL cannot be conceptualized purely in terms of mathematical knowledge because of its inherent association with an individual's ability to use and apply such mathematical knowledge. The 'use and application' emphasized here implies the associated quantitative thinking and reasoning. This, in turn, leads to the competencies of drawing connections, visualizing, questioning, representing, concluding, and communicating. These competencies are integral constituent parts of quantitative literacy. Apart from these competencies, QL also equips a person to express succinctly quantitative information in verbal or visual forms. When confronted by mathematical ideas embedded in contexts, students should be able to interpret information in verbal, graphical, symbolic, or tabular form, and be able to transform one format into another. When quantitative ideas are translated into verbal messages, the ability to write "coherently about quantitative ideas" is required. An appropriate expression for a specific quantitative idea, a piece of text that brings out the idea, and the preparation of a document that supports or refutes a quantitative context, are also indispensable aspects of QL. The structural requirements of a quantitative literacy course may therefore be observed in the definition provided by HESA (2006). One aspect that seems to have been overlooked here is the power of mental calculations. “One bad result of calculators in schools is the students’ over-reliance on them for even the simplest calculations” leaving students with the lowest level of mental arithmetic (Shannon & Bernard, 2011). A sound basis of mental arithmetic, practised iteratively without calculators, leads to sound quantitative reasoning skills (p.17). The following example of quantitative literacy learning activity illustrates the significance of the above-mentioned aspects (i.e. contexts, content, reasoning and behaviour) which characterize such activities.

Example of a quantitative task

The Amtrak train is running 25 minutes behind schedule as it leaves Doverdale, travelling west to Topper Creek, which is 78 km away. If the train normally travels at 50 km an hour, about how much faster would the train have to travel to make up the lost time, arriving in Topper Creek on time? (Mathematics Association of America, 2015, p. 32).

The context involved in the above task is a non-contrived authentic quantitative situation that demands certain quantitative literacy competences. The mathematical content is built around the concepts of rate, speed, and manipulation of formula that involves distance travelled, time taken, and speed. The concept of rate is inherent to the problem, in that an understanding of speed as the rate at which the train changes its position, encapsulates the physical attributes of ‘rate’ as well as its mathematical meaning. In other words, while ‘rate’ serves as the core idea of the problem, the fact that it is applied in a physical context involving ‘speed’, ‘distance’, and ‘time’, makes it context-bound. The fact that the context is further conceived around the movement of a train makes it authentic. An element of HOTS that makes it even more interesting is the fact that the student is required to calculate the speed of the train if it needs to cover the same distance in a shorter time. An explicit association with the skills of ‘analysis, evaluation or creation’ cannot be seen in this problem, even though ‘logical reasoning’ and ‘problem-solving’ which also belong to the HOTS are clearly interwoven into the conceptualization of this quantitative literacy task (Brookhart, 2010). This example further illustrates the dimensions of content, context, reasoning and behaviour, as the fundamental aspects of a quantitative literacy event.

2.4 Explanations of the Definition –Adapted from HESA (2006)

What follows now is a conceptual framework that helps us understand the definition, the meaning of phrases that constitute the definition, and an elaboration thereof. It is important that the definition is properly understood so that its influence on this research may be sufficiently weighed for its relevance. Table 1 below indicates the different phrases and the subcategories that make up each of the phrases. Table 2 indicates the constituent broad components comprising each subcategory.

Table 1 Explanations of the definition of mathematical literacy

	The phrases	**Subcategories**
The definition	"Working in real context"	Eight different contexts
	"Responding"	Four types of responses
	"Quantitative information"	Six categories of content
	"Representation of quantitative ideas"	Four types of representation
	"Activation of enabling knowledge, behaviour and processes"	Five factors on which a response to a quantitative event depends
	"Expressions of quantitatively literate behaviour"	Written, oral, or visual

Table 2 Contents of sub-categories

Eight different contexts	Tertiary education, professions, personal finance, personal health, management, workplace, citizenship, appreciation of maths as culture
Four types of response	Comprehending the situation, acting on the situation, interpretation, communicating about the situation

Six categories of content	Quantity, number and operations, shape & dimension, relationships and pattern, change and rates, data-representation and analysis, chance and uncertainty
Four types of representation	Symbols, words, tables & charts, objects, or pictures
Five factors on which response to a quantitative event depends	Quantitative knowledge and skills, quantitative reasoning, literacy skills, use of computational technology, beliefs, and attitudes

Table 1 and Table 2 together give us a panoramic view of the definition of 'quantitative literacy'; and hence what it represents as a competence in the context of South African tertiary education. The systematic exposition of phrases and their meanings has been derived from the principles, philosophy, and practice of curriculum delivery envisaged for quantitative literacy.

2.5 Elements of the definition of quantitative literacy–a detailed explanation as given by HESA (2006) and other authors

The list of key phrases that make up the definitions of quantitative literacy and their explanations is given in the following section. HESA's exposition is supplemented in the following description by other national and international authors' ideas, whose works may be considered in conceptual alignment with that of HESA. The concept of quantitative literacy cannot be confined, however, within the definitive terms of one philosophy or ideology, because of its constantly changing attributes given by different authors and institutions at different times. What is attempted below is to have some sort of organization of factors constituting each phrase of the definition. For convenience of ordering, we call them phrase 1, phrase 2, etc.

Phrase 1- Real contexts

1. ***Tertiary education context***

Quantitative literacy as a competence is inextricably linked to contexts. It has become increasingly important in less mathematically demanding disciplines such as social sciences and law. For example, statistics is important for a social science student in the same way as calculus is important for an engineering student. Moreover, quantitative literacy as a study area is an alternative to mainstream mathematics courses which are heavily focussed on algebraic abstraction and manipulation of variables (Dan, Christina, Dale, Clare, & Clark, 2012). A quantitatively literate student will thus be able to transfer problem-solving skills to real-world applications as found in an academic environment (p.113). This is because training in mathematics alone is insufficient for the complete development of applied quantitative literacy skills, in the same way as quantitative literacy cannot by itself inculcate abstract formal reasoning skills in tertiary students (Nathan, 2012). A paradigm shift apropos of the role of numeracy education across tertiary education scenarios is thus helping students make better academic decisions (Hillyard, 2012).

2. *Professions*

A general ability to deal with quantitative data is essential for all professional individuals. Lawyers, doctors, journalists, and teachers, need a certain level of quantitative skills to cope with the demands of an increasingly quantitative working atmosphere in their respective fields. Teachers, in particular, are placed at the forefront of an educational endeavour, while entrusted with the daunting task of inculcating numerate behaviour in students, thus helping a numerate generation to evolve. Higher education institutions across the world have taken upon themselves the responsibility of educating the student population with the appropriate level of quantitative aptitude. A course called 'personal and professional numeracy' taught to all first-year teacher trainees in the Faculty of Education at the University of Tasmania, Australia, is a case in point. The content was structured around proportional reasoning needed for quantitative literacy in combination with statistical literacy (Jane, 2011). The personal numeracy goals that should be the outcome of any university education were thus considered achievable with this particular curricular content (p.4). The purpose was also to make the teachers aware that they (the teacher trainees) should be modelling numerate behaviour to their students throughout their career. An interesting aspect noticed here was the author's intention of reviewing the teacher trainees who took the course, to discover the impact the numeracy course might have on their understanding of other course materials (p.12). This particular aspect is noted because a similar objective was also intended for this research conducted at the University of Zululand, with an assessment of research participants' academic performance, after they had completed the particular curricular intervention.

3. Personal finance

Quantitatively significant expressions such as 'depreciation', 'inflation', 'different interest rates', 'risk of investment', and 'bank charges', are just a few of the quantitative expressions that individuals come across; being then required to take decisions based on an understanding of such concepts. Concepts such as 'hire-purchase', 'mortgage bonds', and 'investments', are but a few of the finance-related ideas comprising the theme 'personal finance'.

4. Personal health

Effective management of personal health by an individual is directly influenced by the individual's ability to understand statistics, and probability-related aspects of health management. This includes 'tentativeness of diagnoses', probability of being given wrong medical-test results, and treatment options with various risk levels. Costs and benefits of new treatments, medical aid schemes, and dosages of medications, are also aspects of personal health management requiring the individual to have a certain level of quantitative literacy.

5. Management

Individuals are required to make use of managerial skills in numerous ways in their daily lives. This includes situations at or related to home, travel, school, business, societies, committees, and other enterprises. Such enterprises also include developing a business plan, analysing expenditure-related data, understanding trends in data, budget-related issues, and calculating time difference and currency exchange.

6. Workplace

Quantitative literacy demands of the workplace usually involve: use of work-related formulae, understanding of statistical charts, understanding of schedules, and understanding of numerically significant instructions. Such demands may also include understanding: purchasing of orders, totalling of receipts, using of spreadsheets, interpreting of control charts, making of measurements, and reading of blueprints.

7. Citizenship

A critical stance taken by individuals with regard to mathematical arguments presented in the media lead to informed citizenship: awareness that statistics may be used to support opposing arguments; and awareness that 'power of numbers and mathematical ways of thinking' influence policy decisions.

8. Appreciation of mathematics as part of human nature

This aspect involves an appreciation of the role that mathematics plays in society and economy: an awareness of the historical significance of basic mathematical concepts, and how the development of cultures is influenced by the history of mathematics.

Phrase 2 -Responding to quantitative information: what does it involve?

The response to a quantitative situation in a quantitatively informed way may be constituted by the aspects listed in the following table. Starting with comprehending the situation, a process that is dominated by 'knowing', the response involves 'acting on the situation', indicating action verbs of 'calculating', 'estimating', 'arranging', etc. Interpretation, as a process, is constituted by the sub-processes of identifying, reasoning, translating, etc. The response is complete when it is communicated appropriately–when the quantitative information is represented verbally, visually, or in tabular form. These ideas are summarized in Table 3.

Table 3 Response to quantitative information

1.Comprehending the situation	• Know the meanings of terms used to express quantitative ideas (text literacy) • Know the mathematical and statistical concepts • Know the conventions of representation of numbers, operations, and variables • Know the conventions of representation of data in diagrams, charts, tables, and graphs • Know the conventions of 2-dimensional and 3-dimensional space • Identify the relevant quantitative actions to be engaged

2.Acting on the situation	• Perform calculations using common operations • Estimate the magnitude of answers • Visualize situations, or model them using simple formulae/diagrams • Arrange quantitative objects in order • Identify where to find the exact information from representations of data • Locate the necessary information from more than one unspecified source, and use it in combination
3.Interpretation: making sense of the situation	• Ask appropriate questions and formulate conjunctures • Understand the quantitative information in the context in which the information is embedded • Identify absence of relevant information • Reason logically • Translate from one to another type, representations of the same data • Recognize the presence of patterns in data • Identify relationships revealed by data
4.Communicating about the situation	• Represent quantitative information verbally, visually, in tabular form, or using symbols • Identify ambiguities or omissions in representations • Describe comparisons between data values and trends • Explain reasoning

The various steps involved in this framework of the individual's response is indicative of the complexity of quantitatively literate behaviour expected of individuals in a numerate society.

Phrase 3 - Quantitative information (fundamental mathematical and statistical ideas–what does it comprise?

The definition of quantitative literacy is underpinned by ideas adopted from PISA (Programme for International Student Assessment) and ALL (Adult Literacy and Life-skills) (2003). The broad content categories may be considered constituted by the following elementary mathematical concepts.

Table 4 Quantitative information - content categories

1. Quantity, number, and operations	Classification, ordering and quantification (using numbers) is fundamental to the process of making sense of and organizing the world. Whole numbers are used for counting, measuring, and estimating; fractions are needed to express greater precision, ratios for

	making relative comparisons, and positive and negative numbers for expressing direction. Numbers are also fundamental to the processes of ordering and labelling (e.g. telephone numbers and postal codes), and calculating. A very important part of quantitative literacy is the possession of a good "sense" of magnitude, the ability to judge the required level of accuracy in a given context, and to assess the consequences of any inaccuracies.
2. Shape, dimension, and space	The study of shapes is connected with the ability to know, explore, and move with understanding in the real space in which we live. This ability requires understanding the spatial properties of objects and their positions relative to one another, as well as how they appear to us. We need to understand the relationships between shapes and images (for example, the representation of three dimensions in a two-dimensional image). The idea of dimension and space involves the visualization, description, and measurement of objects in one, two, or three dimensions (projections, lengths, perimeters, surfaces, location). It requires the ability to estimate, and to make direct and indirect measurements of direction, angle, and distance.
3. Relationships, pattern, permutation	The capacity to identify patterns and relationships is fundamental to quantitative thinking. Relationships between quantities may be represented through the use of tables, charts, graphs, symbols, and text. The ability to generalize, and to describe relationships between variables, is essential for understanding even simple social or economic phenomena; and is fundamental to many everyday quantitative activities. Patterns or relationships that involve the dimension of time require particular attention, as they are so fundamental to our experience of the world (seasons, tides, days, phases of the moon, and so on).
4. Change and rates	The concept and measurement of time intervals is fundamental to understanding changes that occur over time. Change is inherent in all natural phenomena; and we are surrounded by evidence of temporary and permanent relationships among phenomena. Individuals grow, populations vary, prices fluctuate, travelling objects speed up and slow

	down. The measurement of rates of change (and changes in rate of change) helps provide a description of the world as time passes.
4. Data representation and analysis	The idea of "data" includes ideas such as variability, sampling, and error, and statistical topics such as data-collection and analysis, data displays and graphs. People are often required to interpret (or produce) analyses and representations of data, such as frequency tables, charts (such as pie and bar charts), and descriptive statistics (such as averages).
5. Chance and uncertainty	The idea of "chance" is expressed mathematically in terms of probability. Competence in this area involves the ability to attach a number to the likelihood (or risk) of an uncertain event. Being able to understand statements about, and to reason with, probabilities, is necessary, for example, in understanding weather forecasts, financial and social phenomena, legal arguments, and health risks.

An overview of the conceptual elements reveals that an extensive range of mathematical aspects is converging under each of the six groupings. The horizontal dimension of the content's coverage is noticeably large, whereas sufficient depth has been seen in the first three categories. On the whole, the breadth and depth of content seem to have been appropriately selected to meet the numeracy requirements for "graduate readiness" in the South African higher-education sector (Vivienne, et al., 2013).

Phrase 4 - Representation of quantitative ideas

When an individual confronts a quantitative-literacy-related problem situation, and tries to solve it, related ideas may be presented in symbols or words. While symbols are used to represent numbers, variables, and formulae, words are used in verbal or written texts. Tables and charts are used for tables of data, bar, pie, line, and other charts or graphs. Icons or pictures are also used to represent objects to be counted, visual displays, scale models, diagrams, or maps.

Phrase 5 - Activation of enabling knowledge, behaviour, and processes

An individual's response to a quantitative literacy event will depend on factors such as quantitative knowledge and skills, quantitative reasoning ability, literacy skills and beliefs, and attitudes of the individual. These factors are briefly explained below (adapted from HESA, 2006).

1. *Quantitative knowledge and skills (mathematical and statistical)*

Quantitative tasks based on real-life contexts in general may be successfully handled by people with basic knowledge in mathematics and statistics, supported by basic calculation skills and knowledge of procedures. This category includes knowledge and skills related to whole numbers, fractions, decimal representation of fractions, measurements, differences, directions, ratios, percentages, rates, geometry, use of the Cartesian plane, algebra, descriptive statistics, and probability (p.29).

2. *Quantitative reasoning*

Reasoning quantitatively involves the capacity for logical and systematic thinking. It includes intuitive, inductive, deductive, and probabilistic reasoning. For example, "reasoning involves the ability to observe patterns and regularities and make conjectures, as well as the realisation that incomplete evidence or inherent uncertainty could lead to tentative inferences which may later be found to be erroneous as further evidence unfolds" (p.53). It also involves "making logical deductions based on specific assumptions and rules, identifying and using evidence required to support a claim, as well as identifying claims that are supported/not supported by given evidence" (p.54). The ability to generate counter-examples to disprove a claim is also included.

3. *Literacy skills*

Engaging with quantitatively demanding contexts also needs certain levels of reading comprehension and other literacy. The text that describes a quantitative event obviously needs the reader to have a deeper analytical-thinking-based reading as opposed to a "what is needed?" to understand a piece of literary text written without any quantitative associations. Specific literacy is required for understanding descriptions written using mathematical and statistical terminology that refer to mathematical and statistical relationships. Terms such as "greater than, smaller than, percentage, half of, more than double" as well as terms used for more complex mathematical and statistical information, such as "significant difference", "weighted average", "function of", “change of rate”, “random sample”, “probability”, and “correlation”, are highly quantitatively significant. Understanding quantitative text is also associated with a degree of visual literacy which leads to the ability to interpret and create diagrams, maps, charts, graphs, and other visual representations.

4. Use of computational technology

Computers play a significant role in “science, social science, professional and everyday life, and in the workplace” (p.54). The ever-present need for individuals to be able to understand various computer systems and the information they process in quantitatively rich environments, is yet another reason for quantitative literacy to be seen in association with computational technology. At its most fundamental level, this knowledge includes the role and use of calculators; and in the context of tertiary education, includes the effective use of spreadsheets (Frith, Jaftha & Prince, 2005).

5. Beliefs and attitudes

Affective factors play a particularly significant role in people’s ability to engage productively with quantitative events. “The way in which people respond to a quantitative situation and how they choose to act depends on how familiar they feel with such situations and how confident they are in their own strategies” (p.55). General dispositions towards mathematical matters, as well as a person’s self-perception and the degree of a sense of “at-oneness” with numbers, considerably impact a person’s willingness and ability to perform mathematics tasks.” (ALL, 2002). In fact, the National Curriculum Statement for the subject Mathematical Literacy (DoE, 2003) specifies the development of confidence as part of its definition of the subject area.

Phrase 6 - Expressions of quantitatively literate behaviour

College students’ quantitative-knowledge-related behaviour has often been questionable, paving the way for the recognition of an ability gap, which in turn has given rise to the field known as quantitative literacy (Benjamin & Semra, 2010). For students taking non-mathematics/physics majors, quantitative literacy skills are more important than advanced level mathematical skills. This has led to many universities' adopting free-standing quantitative literacy curricula; or opting for quantitative skills to be embedded in courses with other content (p.35). Related to these curricula are types of assessment designed to measure proficiency in quantitative literacy skills.

Design of such assessments is based on the fact that quantitative literacy may be expressed when a person responds to a quantitative event by producing a written, oral, and/or visual (including concrete objects) text. The notion of "text" is used broadly, and includes many kinds of output, including concrete objects (Archer, Frith & Prince, 2002). For the purpose of the research objectives considered here, tests administered at different intervals, and an assessment of students' "attitudes, confidence, interest and enjoyment of math", were used to elicit expressions of quantitative literacy (Benjamin & Semra, 2010).

The particular way in which quantitative literacy is defined by Higher Education South Africa (HESA), a rationale for the definition and the subsequent table of "Competencies Specification for a Quantitative Literacy Test" provided by HESA collectively, have significantly influenced the compilation of the curricular content for SIC in general. The pre-test/post-test administration has also been guided by HESA's competencies.

2.6 Mathematical Literacy/Numeracy Courses offered by Universities in South Africa and Abroad: a Curricular Perspective

International higher-education institutions are increasingly aware of the quantitative literacy of their students, and its role in the twenty-first century, even though such awareness is not supported by sufficient resources being channelled towards the development of appropriate curricula (Nathan, 2012). The quantitative material has to 'permeate the curriculum', not just in the sciences, but in the social sciences and humanities as well (p.32)[2]. The need for "systematic approaches to curriculum changes" that can reduce the articulation gap that exists between quantitative literacy demands of various university curricula and quantitative literacy of students is also widely acknowledged (Frith & Prince, 2009). In the context of such a curriculum innovation, these authors refer to a framework that may be used for the design of "quantitative literacy interventions" that are administered as freestanding courses, or that are designed and executed within the instructional frameworks of other courses (p.85). While different quantitative literacy practices inherently exist in different academic disciplines, identification and subsequent description of particular aspects of

[2] This author also refers to the National Numeracy Network (NNN) in the US that seeks to support efforts to promote numeracy across all disciplines – the sciences, the social sciences, the humanities and the arts. It is the intellectual home for scholarship that advances numeracy as a new "discipline" (p.35).

quantitative literacy competencies deemed essential by the curricula of each of those disciplines, are central to this framework (p.85). This framework generalizes the description of various competencies that individuals are supposed to possess, for them to successfully manage quantitative literacy events.[3] The word 'competency' in this context is the "proven ability to select, combine and properly use knowledge, skills and other acquisitions to successfully solve a problem related to work or learning situations leading to professional development in terms of effectiveness and efficiency" (Iuliana, Dragos, & Paula, 2014). Quantitative literacy may be considered a 'professional competency', because of its association with the profession of teaching as attributed in this thesis. 'Transversal competency' as opposed to 'professional competency' refers to skills and knowledge that transcend a particular field of study, and therefore is trans-disciplinary in nature (p.239). The argument here is that quantitative literacy in that sense may be called a primarily transversal competency because of its trans-disciplinary applicability, while its status as a professional competency is nonetheless equally significant.

Quantitative literacy events are inherently associated with some disciplinary practices from mathematics and statistics. However, the extent of statistical or mathematical knowledge required depends on the context in which a numeracy event occurs (p.87). Frith & Prince (2009) provide us with six categories that describe the mathematical and statistical dimensions of each quantitative literacy event. They are:

- Quantitiy, number and operations;
- Relationships, pattern, permutation;
- Change and rates;
- Shape, dimension and space;
- Data representation and analysis; and
- Change and uncertainity.

This categorization is similar to the one provided by the Curriculum and Assessment Policy Statement (CAPS) (DoE, 2012). The only difference here is that 'functional relationships' from CAPS is replaced by 'change' and 'chance' because of the increased emphasis various higher-

[3] Quantitative literacy/numeracy events are "occasions in which a numeracy activity is integral to the nature of the participant's interactions and their interpretative processes" (Street & Baker, 2006).

education curricula give to these two concepts (p.88). The framework also places an equal emphasis on Higher Order Thinking Skills (HOTS). Reflective thought elicited on the use of mathematics in solving contextual problems, and on the interpretation of 'reasonableness' of solutions of such problems, are instructional instances dominated by HOTS. HOTS, in general, and reflective thought in particular, are given sufficient weighting in this framework so as *not* to reduce its (the framework's) contents to a set of basic mathematical skills. Instead, it encompasses a variety of skills including even the ability to communicate quantitative ideas usually characterizing quantitative literacy events (p.89).

A number of universities abroad, for example in the U.S, have established quantitative literacy or its equivalent as undergraduate courses in various disciplines (Rose, Monica, & James, 2011). Several institutions have developed quantitative literacy curricular requirements based on one or more of the definitions of the construct 'quantitative literacy'. Just as the purposes differ, there are several quantitative literacy assessments designed to measure various sub-constructs comprising quantitative literacy. However, a typical assessment is to be constructed bearing in mind the quantitative demands presented by differing quantitative literacy events. In other words, assessments and quantitative demands of events, are aspects that exist in close curricular proximity.

2.6.1 Framework for analysing the quantitative demands in a quantitative literacy event–adapted from Frith & Prince (2009)

The quantitative demands of a quantitative literacy event depend on various factors. Frith (2009) has classified those factors as shown in Table 5. Whether or not a particular event is severely demanding in terms of quantitative literacy depends on the required cognitive functions, and the associated levels of complexity at which those functions are called into action during quantitative literacy events. Each function thus corresponds to a variety of its aspects at various levels of complexity.

Table 5 Framework for analysing quantitative demands

1. Knowing	Knowing the meanings of quantitative terms and phrases (*verbal* representations)

	• Knowing the conventions for the *symbolic* representation of numbers, measurements, variables, and operations • Knowing the conventions for the representation of quantitative information in tables, charts, graphs, diagrams, and objects (*visual* representations)
2. Identifying and distinguishing	Identifying connections and distinctions between different representations of quantitative concepts • Identifying the mathematics to be done and the strategies to do it • Identifying both relevant and irrelevant information in representations
3. Deriving meaning	Understanding a verbal description of a quantitative concept/ situation/process • Deriving meaning from representations of data in context • Deriving meaning from graphical representations of relationships • Deriving meaning from diagrammatic representations of spatial entities • Translating between different representations
4. Applying mathematical techniques	Using mathematical techniques to solve a problem or clarify understanding – for example: calculating, estimating, measuring, ordering, modelling, applying algebraic techniques, etc.
5. Higher-order thinking	Synthesizing information or ideas from more than one source • Logical reasoning • Conjecturing • Interpreting, reflecting, and evaluating
6. Expressing quantitative concepts	Representing quantitative information using appropriate representational conventions and language • Describing quantitative ideas and relationships using appropriate language

Quantitative literacy problems or quantitative literacy events are generally characterized by a lack of “mechanical mathematical techniques such as calculation or algebraic manipulation” (p.93). Quantitative demands of many curricula are hence underemphasized because of quantitative literacy's being wrongfully associated with ‘doing basic arithmetic’ and basic algebraic manipulation. This is true in the case of disciplines such as biochemistry, physiology, and even other disciplines in science and humanities in which quantitative demands go beyond skills in basic arithmetic. It is to be noted here that the introduction of an alternative curricular concept for quantitative literacy, termed the Semi-Integrated Curriculum (SIC), assumes relevance in this context. The SIC is conceptualized around a selective integration of content and context in which contextual problems are preceded by purely concept-based consolidation of skills. The SIC also recognizes, and hence reinforces, a variety of quantitative literacy skills that are otherwise deemed insignificant. However, when interventions are proposed to ease students' transition to becoming quantitatively literate, the need for tools to analyse the demands of the discipline also arises. Such tools help make the demands explicit. The framework explained in Table 5 is helpful in this regard.

2.6.2 Other aspects of quantitative literacy events

In the process of trying to develop a framework to describe the three facets of quantitatively literate behaviour, viz., the application of mathematical concepts in context, critical reasoning, and communication, Lloyd & Frith (2013) came across some interesting aspects of students' thinking. Based on the context-driven materials, classroom interactions, and responses to assessment questions, these authors realized that critical thinking was not at all a dimension in which students' thinking manifested. This trend was further traced to the fact that many students were found not having an understanding of basic mathematical concepts and techniques (p.2). Development of critical thinking was therefore sidelined in an effort to focus on basic mathematical and statistical concepts. Those authors further argued that fundamental skills and knowledge in mathematics should be developed prior to an attempt being made to develop appropriate habits of mind, mathematical communication capabilities, and problem-solving skills.

Critical awareness that foregrounds numerate behaviour is determined by "a sound knowledge and understanding of some basic mathematical and statistical concepts" (p.2). This point is noted because mastery of such skills and concepts underpins the conceptualization of the SIC. Critical thinking, assumed to evolve as a result of certain contextual associations of concepts, is also influenced by the extent to which students are familiar with such contexts (Bansilal & Debba, 2012). While familiarity with contexts and knowledge of basic concepts and skills is crucial for the attainment of critical thinking-based numerate behaviour, the curricular emphasis need not be on ritualistic practices of "manipulating given numbers by rule rather than by reason, reducing the mathematical activity to a mere routine that students execute to get a particular result" (Lloyd & Frith, 2013, p.9). Therefore, a quantitative literacy intervention at tertiary level aimed at consolidating numerate academic behaviour in other disciplines, according to these authors, has to be structured around critical thinking ability as the most fundamental aspect (p.9). As to which pedagogies are appropriate for promoting higher order and critical thinking, and how theories of cognition connect with theories and practices of such thinking, researchers have provided us with "a theorised framework for curriculum intervention" (Tara, Marnie, & Elaine, 2012). This includes theories of cognition and nature of knowledge, theories of critical thinking and practices that promote higher order and critical thinking (p.158). Critical thinking, in other words, results from a set of cognitive skills and affective dispositions which collectively lead to the ability to "analyse and synthesise information" which eventually leads to Higher Order Thinking Skills (HOTS) (p.161). A formal exposition of all theoretical aspects of the present research will, however, be attempted quite substantially in the forthcoming chapters of this thesis.

To conclude this section, the research conducted by the authors mentioned above (Tara, Marnie, & Elaine, 2012) deserves to be mentioned here. These authors investigated the impact of a curriculum intervention structured according to theories mentioned above, using a single-site qualitative case study. The study used ethnographic and action research strategies to collect data from multiple sources such as student-group interviews, teacher interviews, classroom observations, public and private documents, course work, and test assessments (p.169). Research method, techniques, and the underlying philosophy, were hence similar to the present research conducted at the University of Zululand. The application of a theoretical model as conducted by the above-mentioned authors helped structure the curriculum intervention to consolidate HOTS. A similar theoretical model was also followed at the University of Zululand, with similar intentions.

2.6.3 Financial Literacy among Educated South Africans– Another Curricular aspect of Quantitative Literacy at Higher-Education Level

The notion of financial literacy has evolved "from an individual's ability or inability to function independently with respect to monetary and finance-related transactions" (Richard & Robert, 2012). While investigating financial literacy among university students in South Africa, these authors found that there was a substantial segment of university students that failed to demonstrate an understanding of the most basic financial concepts. Such students are likely to make uninformed finance-related decisions, leading to financial exclusion and blacklisting (p.583). Having found moderate-to-high levels of "financial illiteracy" among university students in South Africa, these authors recommend that financial literacy be included in university curricula; and that associated research be promoted to explore new ways of advancing financial literacy among higher-education students (p.589).

The term 'financial numeracy' has also been used to denote the "proficiency in processing, understanding, acquiring and using financial information and concepts based on a consumer's capacity and prior knowledge in the area" (Ronald & John, 2010). The construct 'financial numeracy' is related to the cognitive ability and financial knowledge of an individual. The concept also refers to a subjective evaluation of one's financial processing ability, just as it refers to an objective measure of the individual's intelligence (p.58). Financial numeracy is also related to 'financial-risk tolerance' which is defined as the level of uncertainty that an individual willingly accepts while making a financial decision. While these constructs (financial numeracy and financial risk-tolerance) are significant competencies for an individual, their relevance as a curricular component of numeracy courses at tertiary level is equally important, in that the essential financial decision-making ability among students is cultivated. Related to numeracy in general and financial literacy in particular is 'quantitative reasoning' ability (Annamaria & Dorothy, 2013).

There is sufficient evidence to prove the importance of practical quantitative reasoning in the tertiary curriculum; and the "economic and personal consequences" for failing to assert quantitative reasoning as a prominent competency to be fostered (p.1). These authors conclude convincingly that young people, internationally, display low levels of financial literacy. The young are the most vulnerable to being financially misled. These authors call it "irresponsibility" on the part of authorities not to require financial literacy of tertiary students. They also advocate for an "explicit, heavily emphasized practical quantitative component to be integrated with the curriculum for financial literacy" (p.2). In other words, financial literacy is now afforded the status of 'a necessary skill' to survive in today's society and hence it is imperative that it be included in university curricula around the world (p.3). However, as Annamaria & Dorothy (2013) noted, many textbooks that are written for personal finance courses do not generally give ample emphasis to the necessary mathematical understanding (p.4). This is an important point to be noted, because the Semi-Integrated Curriculum envisaged in this research has attempted to emphasize financial contexts and associated mathematical concepts at appropriate levels of complexity. Financial literacy inherently comes with an abundance of contextual settings that may be used to teach financial and quantitative reasoning skills (p.4).

2.6.4 Statistical literacy

A discussion of financial literacy cannot be concluded without reference to statistical literacy as applicable to the context of a numeracy curriculum. Statistical literacy is the "meeting point of the statistics and probability curriculum and the rest of the world, where encounters involve problems in new contexts and decision making based on the ability to apply statistical tools, contextual knowledge and critical thinking skills" (Jane, 2011). Sometimes called statistical numeracy, statistical literacy refers to fluency with the use of statistical tools, supported by a solid understanding of associated statistical concepts and contexts (Sharleen, Mike, Nathaniel, Paul, & Maxine, 2011). This invariably requires fluency in reasoning associated with 'critical thinking' that helps students solve problems posed from the data (Jane, 2011). The proficiencies inherent in statistical literacy may be linked to any general competency from any learning area. In spite of its being usually relegated to a smaller section of the mathematics curriculum, "statistics and probability builds on other parts of mathematics especially proportional reasoning and measurement, to create statistical literacy", statistical literacy is a process through which the whole curriculum remains interlinked (p.19). Jane (2011b) takes this point further, arguing that if statistical questions are not integrated with meaningful contexts from other areas of learning, 'critical statistical literacy thinking' will not be fostered (Jane, 2011). What is needed is a recognition that statistics cuts across curricula, and that it draws contexts from a variety of disciplines leading to explicit links being defined in the curriculum documents (p.203). This argument is noted for its relevance to curriculum integration as a practice envisaged within and across disciplines.

International organizations such as the American Sociological Association (ASA) and the National Science Foundation (NSF) have, over the years, called for statistical literacy to be part of a general quantitative literacy curriculum (Andrew, 2012). While improving quantitative literacy in general is essential for both the employee and the citizen of the future, the ability to be critical of statistical arguments depends fully on one's ability to interpret such arguments independently (p.57). A related argument in this context is that the statistical knowledge needed by teachers differs significantly from that needed by other professionals (Randall, 2012). An introductory statistics course for teachers, as this author argues, can simultaneously address statistical subject matter knowledge and pedagogical content knowledge (p.37). What is known as Statistical Knowledge for Teaching (SKT) is, however, different from the statistical literacy component of tertiary numeracy courses, as defined in this thesis.

A brief explanation of 'statistical numeracy' will be appropriate in this context. Statistical numeracy is one's practical understanding of probabilistic and statistical problem-solving, and is an excellent predictor of judgement and decision-making competencies (Saima, Edward, & Rocio, 2014). Tests measuring statistical numeracy, or numeracy in general, assess both mathematical knowledge and meta-cognitive processes involved in "effective thinking"; and hence are able to predict a wide range of numerate behaviour (p.26). Apart from the essential mathematical competence, numeracy tests also measure "heuristic-based deliberation[4] and meta-cognition, affective numerical intuition and meaningful intuitive understanding" (p.29). If numeracy, statistical numeracy, or mathematical literacy, are considered in their limited meaning as skills in this context, and if a skills-based pedagogy is used to foster them, then such skills facilitate the development of Higher Order Thinking Skills (Cassandra & Sara, 2008).

Looking further at statistical literacy, or the lack of it, undergraduate students taking research-methods courses often demonstrate a lack of broad statistical literacy skills (Barb & Marianne, 2009). These authors conducted a study of 110 university social science undergraduate students,

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[4] Educational psychologists argue that intellectual processes leading to decision-making involve intuitive and deliberate judgements (Arie & Gred, 2011). "Intuitive judgments have been assumed to be associative, quick, unconscious, effortless, heuristic, and error-prone. Deliberative judgments have been assumed to be rule based, slow, conscious, effortful, analytic, and rational "(p.97).

and found that there were significant statistics-related conceptual deficits among undergraduate students. They also found that those who took statistics courses prior to the research-method courses fared better than those who had not taken prior statistics courses (p.84). This further endorses the view that teaching and learning of relevant statistical concepts is essential for solving context-based statistics problems that are introduced later in the course. This, once again, leads us to the initial premise of a semi-integrated curriculum conceptualized in this thesis, one that balances the use of concepts and contexts at an optimal level.

2.6.5 Quantitative reasoning – yet another dimension of numeracy

Quantitative reasoning, sometimes used interchangeably with numeracy or quantitative literacy, is a "habit of mind, competency and comfort in working with numerical data" (Corrine, 2012). While mathematical modelling, data analysis, and construction of quantitative arguments are important even in non-mathematical and non-scientific disciplines, the curriculum and instruction for quantitative literacy courses should ideally become inter-disciplinary in nature (p.2). In a quantitative-reasoning curriculum implemented in Bowdoin College in the United States, the primary focus is on a set of basic skills such as fractions, percentages, proportion, decimals and rates (Eric, 2014). This foundation of concepts paves the way for higher-order quantitative reasoning via modelling, underpinned by a statistical literacy-based exploration and study of data (p.5). The preliminary reinforcement of basic concepts prior to the context-based higher-order learning activities is in line with the concept of semi-integration articulated in this thesis. The Semi-Integrated Curriculum also emphasizes the teaching of basic concepts and skills before contexts that are vehicles of such concepts and skills are introduced. In another study in the United States conducted to explore the advantage of using non-mathematical disciplinary contexts that can enhance 'data literacy' of students, a set of cross-disciplinary curricular materials was designed and tested (Philip, et al., 2012). An important point that these researchers raised is that the students need not rely on their direct personal experiences to link the context to the process of 'mathematizing' (p.182). This approach helps the students gain a "global perspective" on the use of mathematics in solving authentic problems (p.182). This observation is in direct contrast with the notion of 'familiar contexts' being prescribed over 'unfamiliar contexts' in mathematical literacy tasks administered in the school mathematical literacy curriculum in South Africa (Bansilal & Debba, 2012).

A six-year curriculum-development project undertaken to understand quantitative literacy of undergraduate students at the University of Arkansas deserves special mention here. Named "Quantitative Reasoning in the Contemporary World (QRCW)", the course caters for students in education- and business-related majors, in addition to students from the College of Arts and Science (Shannon & Bernard, 2010). These authors admit that the most challenging aspect of the development of the course was related to defining the scope of the mathematical content, and finding appropriate materials that would sufficiently cover the proposed content. It was also challenging for them to design the content at the correct level of difficulty (p.3). The six-year period after which these authors concluded the course development and research was supposed to yield valuable information with regard to how students develop quantitative reasoning skills; and how to offer the correct curriculum content materials and assessment tasks. The sustainability issues thus answered will have an impact on how such courses are conducted in universities around the world (p.4). It is in this context that the call for research-based enquiry into the level of alignment of quantitative reasoning-course requirements, and cross-curricular or integrated approaches to the curriculum, is to be seen relevant (Louis, Amber, Alexander, & Shimon, 2013). These authors also note that it is in the faculties of education and arts and humanities that the students have consistently shown the lowest quantitative reasoning skills (p.17).

Apart from the curricular and cross-curricular/inter-disciplinary research mentioned above, instructional innovations have also been tried and tested in international higher-education institutions. An interesting instructional framework called "Preparation for Future Learning (PFL)" for data literacy, used by Philip et al. (2012) in the school education context in the USA, is noteworthy here. In this framework, students investigate a set of problems involving the "target concept". Complete solutions are not attempted at this stage; instead they simply understand the structure of the concept and the key dimensions of the context. Students are then introduced to a standard generalized solution to the problem. Students apply this solution to a variety of contexts leading to more "abstraction and reflection" (p.187). These authors used the PFL method in such a way that the social studies module provided the preparation for the mathematics module. Students learnt 'proportional reasoning' in mathematics, after which they applied the concept in science materials. Students consolidate their learning of the concept in the English language module by 'communicating' solutions using 'data literacy skills' (p.187).

Data literacy is "inherently cross-disciplinary" and hence the opportunities for its integration with other disciplines are numerous. Preparation of students takes place in one curricular context, while the learning activity occurs in another at which transfer of learning takes place effectively (p.202). The introduction of contexts first and concepts later, followed by the concept's application in another context, constitutes an interesting aspect of curriculum integration which is similar to the Semi-Integrated Curriculum, although there are major differences in structure and practice between the two. The fact that context precedes concept, and that PFL is fundamentally iterative in nature, are the major differences.

Various aspects of literacies mentioned in the above paragraph may be linked to what is called 'academic literacies research'. Academic consolidation of various literacies as competencies has been a distinct characteristic of academic development programmes in South African universities. This is in line with the trend in international higher-education institutions to have personal and professional numeracy standards and courses clearly set up, for not only teacher trainees, but also for all university graduates (Jane, 2011).

2.6.6 Academic literacy research - a related concept

The employability of higher-education graduates is the responsibility of all universities (Iuliana, Dragos, & Paula, 2014). The academic attributes of the construct 'employability', according to those authors, should be integrated into the curriculum design. In other words, an academic curriculum is the instrument used in the educational process into which employability as an objective is to be integrated (p.245). In this context, it is imperative that the universities redesign the curriculum in line with "the expectations of the knowledge economy" (p.245). "A growing mismatch between students' needs and experiences and the academic institution and its curricula" has resulted in what is called academic literacies' research (Moragh & Vera, 2014). This field of research has questioned the prevailing assumptions with regard to 'student deficit', and argues for making higher education institutions more accessible to a wider student community (p.172). Primarily concerned with learning and pedagogy, academic literacies' research that takes place within the context of academic development programmes in South African universities may also be useful in curriculum development at tertiary level (p.173). Those authors also found that inappropriate use of quantitative terms and phrases in grammatically correct yet conceptually incorrect ways, revealed the lack of understanding of discipline-specific meanings of such mathematical terms and phrases. The use of the phrase “increasing at an increasing rate”, for example, is at the same time “lexically dense and conceptually complex with stronger semantic density and weaker semantic gravity” (p.177). Enhancing students’ familiarity with these commonly used mathematical expressions, supported by a proper understanding of an expression’s mathematical meaning, is central to the academic literacy of a student in any scientific discipline.

The point here is that a certain level of familiarity with such mathematical terms and expressions is also vital for students in the social sciences because of the likelihood that use of such expressions in everyday discourses is not confined to scientific disciplines, but cuts across disciplines. An effective embedding of academic literacies in the mathematical literacy/numeracy curriculum for teacher education is therefore relevant. The design of such a curriculum is also developed to accommodate the “prior discourses” the students come with, and the barriers that prior learning creates for further learning (p.179). It is through ethnographic and dialogic methods which characterize the practice of academic literacies' research in general, similar to those adopted for this research, that an insight into student deficits may be generated. In so doing, as is done at the University of Cape Town, curricular alterations to consolidate basic academic, quantitative, and information literacies, are undertaken to “improve the learning capacity and contribute to informed citizenship” (Frith, 2012). Central to these efforts are various quantitative literacy courses offered at the University of Cape Town (UCT) for students from Law and Humanities, or those taking the medical (MBChB) programme, Psychology, or Sociology (p.2). A summary of the quantitative literacy curriculum offered for MBChB (Bachelor of Medicine, Bachelor of Surgery) (first semester) at University of Cape Town is illustrated in Table 6, adapted from Frith (2012)[5].

Table 6 Summary of the MBChB Quantitative Literacy curriculum offered at UCT

Mathematical and statistical content	**Contexts used**	**Examples of thinking/behaviour required**

[5] The curriculum content shown here is only for the first semester. A similar breakdown of content for the second semester is also given by Frith (2012) as applied to the University of Cape Town.

Ratios, direct proportion, percentages	Birth rate	Appreciate the distinction between relative proportions and absolute quantities
Percentage change	Birth rates, cost of medicine	Appreciate the distinction between relative change and absolute change
Indirect proportion	Solutions (dilution)	Understand inverse relationships
Significant figures and precision in measurement	BMI Various measurements	Develop a feel for the connection between variability and error in measurements
Logarithm and logarithmic scales	Hearing, pH	Think in terms of orders and magnitude
Exponential change	Population growth	Understand the idea of changes in rates of change Transfer ideas to unfamiliar contexts
Representing frequency distributions Frequency tables, percentage frequencies, histograms, cumulative curves	Body weights and heights, BMI	Analyse a data-set to choose appropriate intervals for grouping of data Reason with inequalities Translate between different representations
Descriptive statistics Percentiles, statistical measures	Body weights and heights, BMI Risk- taking behaviour	Make conceptual links between different representations of same concepts. Generalize ideas from specific cases
Graphs and functions, growth charts, rate of change, graphs showing rate of change	Growth charts: body weights and heights, BMI Enzymes and reaction rates, oxygen saturation curves, growth of a culture	Make connections between data distributions and changes over time. Interpret shapes of graphs in terms of differences in rates of change.

		Make connections between quantities and rates of change of quantities

Organization of content categories, various integrated contexts, and associated "thinking/behaviour required", are noteworthy in this curriculum. The last column indicates higher-order thinking and behaviour that the curricular intervention seeks to inculcate. Incorporation of Higher Order Thinking Skills (HOTS) done in this way is noted for its relevance, in the context of the present research undertaken at the University of Zululand, with significant similarities in purpose.

A very important aspect of this curriculum followed at UCT is the level of content–context integration envisaged. It is always the best practice to integrate quantitative literacy learning experiences with appropriate discipline-specific contexts which the students encounter in the mainstream courses. However, owing to various operational difficulties with regard to having a constant instructional alliance, the course was taught by 'Numeracy Centre' staff, in which the instruction and assessment took place in a 'partially integrated' format. (p.13). The term 'partial integration', in this instance, means that contexts chosen were partially contrived, as opposed to contexts adopted completely from other courses. The partial integration thus afforded students the option either of choosing or ignoring a particular quantitative literacy (QL) material, based on its relevance. This would not have been possible had the curriculum been fully integrated. Despite the term "partial integration" being used by Frith (2012) to refer to types of contexts chosen for delivery of content, yet another dimension of content-context integration is revealed, which, to some extent, resembles the concept of the "semi-integrated curriculum" articulated in this thesis. Another point to be noted here, is that students' motivation to exploit the richness of a context-based curriculum is influenced by such contexts' presumed relevance (p.16). This leads us to the point of the ideal situation in which QL is integrated progressively in subsequent years into the disciplinary curriculum, when the need for QL is felt increasingly relevant. However, this is not always possible: stand-alone QL courses are predominantly given preference where contexts chosen mostly remain contrived, yet authentic (p.16). Students, in such instances, should be able to use the rules of those contexts, to understand the language of the contexts, and to engage in reasoning about the contexts, so that they can successfully work with context-based problems (Bansilal & Debba, 2012).

2.7 An Integrated Curriculum for a Mathematical Literacy Course: Purpose, Practice, and Possibilities

This section focusses on the purpose of an integrated curriculum for a mathematical literacy course. Formulation of the purpose in clear terms is attempted here with a view to establishing a clear link between it (the purpose) and the purpose of this research itself, which is to see the effect of a particular mode of curricular integration on students' mathematical-literacy-related competencies. This section also focusses on various integrative practices prevalent in the tertiary-education sector, and the possibilities thereof. The purpose, practice, and possibilities of curriculum integration, therefore, collectively help to position among related concepts the type of integration explored in this thesis.

2.7.1 Purpose

The purpose of an integrated curriculum for a mathematical literacy course was fundamentally conceptualized around a particular curricular need. The mathematical literacy course offered at the University of Zululand is taken by first-year education students with majors from the social sciences, arts, and languages. Hence, the need was felt across departments and disciplines for an appropriate curriculum meeting the quantitative demands of the various disciplines from which students taking mathematical literacy are drawn. Numeracy practices are fundamentally cross-disciplinary or multidisciplinary in nature (Hesham, 2013). The plurality of disciplinary backgrounds leads to the conceptualization of an integrated curriculum that "bridges and links different disciplines, emphasizes all academic subjects and integrates objectives from multiple curricular and instructional areas" (Merrit, 2014). Curriculum integration encompasses a method of teaching, as well as a philosophy rooted in 'experimentalism', a philosophy that "focusses on things that work and in which the world of experience is central" (p.1).

The purpose, therefore, of an integrated curriculum is to generate a unified curriculum that incorporates the key elements of an integrative education, in which the focus is on the themes, the issues, or the phenomena, as opposed to having divergent disciplines and distinct, isolated subjects (p.1). The thematic approach, as conceptualized for the mathematical literacy module, was used to integrate curricular content into themes that form interdisciplinary and multidisciplinary units of study (p.2). In support of this thematic approach, Regina (2014) argued, based on cognitive science research and knowledge of how the brain works, that the practice of teaching skills and knowledge prior to introducing contexts is simply not effective. This practice produces passive students who do not use high-level cognitive processing and thinking ideally suited for college courses (p.52). What Regina (2014) calls "remedial pedagogy" is, according to him, outdated, and is to be replaced with context-integrated learning environments. However, this argument is taken only for its general instructional appeal. It cannot therefore be considered contradictory to the initial premise made in this thesis, that a certain level of independent consolidation of mathematical skills devoid of any contexts, is essential for creating a cognitive receptiveness for contextualized problems introduced later.

2.7.2 Practice

Transforming a content-separated curriculum into an interdisciplinary or integrated curriculum is a daunting task. Curriculum integration that is "authentic, rigorous and sustained" is a practically difficult exercise to translate from theory into practice (Merrit, 2014). Instances of the practice of using an integrated curriculum for mathematical literacy or a related course are, as found in the literature, inherently diverse. At one end of the 'diversity spectrum' we have quantitative reasoning[6] with its own curricular elements and objectives, which are in certain ways different from the 'traditional' mathematical literacy curriculum. It is interesting to see the various elements of a typical quantitative reasoning course curriculum as listed by Patric & David (2013), which are: Confidence with Mathematics; Cultural appreciation; Interpreting data; Logical thinking; Making decisions; Mathematics in context; Number sense; Practical skills; Prerequisite knowledge; and Symbol sense.

These authors further indicate 'six typical goals' of a quantitative reasoning course aligned with the ten elements listed above. These goals are:

[6] "Quantitative reasoning involves mathematical thinking, uses mathematical analysis, is often taught by mathematicians. It is a habit of mind; a way of thinking. Whereas mathematics deals with abstractions (symbols) and generalisation, quantitative reasoning involves data and context" (Patric & David, 2013).

- Work with graphs (create and interpret);
- Statistics (interpret);
- Create mathematical model (linear and non-linear);
- Work with data;
- Use technology (graphing calculators, spreadsheets, statistics programmes); and
- Explain the results and meaning of math/numbers.

It is interesting to note that at the University of North Dakota (USA), where these authors conducted the research, only three elements and three associated goals were chosen as the most important aspects of the curriculum. In the literature, quantitative reasoning as a competency seems to have been equated to or used in place of 'quantitative literacy' or 'numeracy' (p.340). These authors further argue that quantitative literacy is not the same as mathematics or statistics, being more of a habit of mind or an approach to problems "that employs and enhances both statistics and mathematics" (p.340).

At the other end of the spectrum we have quantitative literacy as an expected learning outcome in tertiary education (Bernard & David, 2014). These authors refer to the Department of Higher Education (University of Arkansas, USA) where quantitative literacy has been included as a course as part of the State Minimum Core of collegiate courses. "It is included as an alternative to college algebra for students not majoring in science, engineering, or mathematics" (p.9). The purpose is to "develop habits of mind to analyse the quantitative content of everyday occurrences" (p.10). In this context, Bengtsson (2014) notes that an algebra-dominated tertiary mathematics curriculum does not "convey usable and transferable mathematical skills to the majority of students, most of whom go on to careers that do not use much (or any) explicit mathematics" (p.40). He further argues that such students would be better served by a different version of mathematics curriculum similar to that of quantitative literacy, in which a move to towards "teaching the process of mathematical thinking" is, however, paramount (Bengtsson, 2014). This is in line with the argument that "it is not calculus but numeracy that is key to understanding our data-drenched society" (Alicia, 2010). If our students are to develop into thoughtful citizens capable of taking informed and reasoned decisions, then numeracy has to remain an integral aspect of any curriculum, including the social sciences (p.106).

Professionals who have gone through such curricular experiences draw upon interdisciplinary knowledge to create mathematical procedures which help them make predictions, generate solutions, and produce explanations (Judith & Lynn, 2007). This takes us to the point at which curriculum integration has been used at university level to help the students understand the relationship between subject areas, which in turn makes the study meaningful. However, faculty members are sometimes either unprepared or uncomfortable with teaching in an integrated curricular environment (Ruth, 2014). This should not, in any case, be a deterrent to the practice of integrated curricula, because "strategic clustering of appropriately matched courses" that resembles a certain version of integration, will eventually be the norm in university courses in general (Ming, James, & Veronica, 2010). "Explorations in mathematics" offered at the University of Central Florida (USA) is an example of such clustering in integrative practices. With the underlying philosophy of advancement of 'quantitative fluency' among students in non-science majors, the instructional method involved integrated themes of real-life issues (Costas, Barry, & Dan, 2012). "Explorations in mathematics", because of its integrative curriculum, is hence noteworthy in the context of this research.

2.7.3 Possibilities

An integrated curriculum is meta-curricular in nature because of its association with learning skills that help students think and learn independently (Merrit, 2014). While students generally use deductive reasoning (from general to the particular) and inductive reasoning (from the particular to the general), an ability to synthesize both (deductive and inductive reasoning), results in optimized learning (p.6). When observed from the perspective of a student-centred instructional approach, curriculum integration uses active learning techniques, varied learning styles, multiple intelligences, and "multisensory attributes" (p.6). Students' creativity is enhanced; independent and inquiry-based learning is encouraged. Basic skills, process skills, research skills, and problem-solving skills, are emphasized. The possibilities of an integrated curriculum are extensive, in the sense that such integration strengthens social development of the individual and nurtures the affective dimensions of the curricular objectives. Personal and social values and moral responsibility are consolidated in an integrative learning atmosphere. As students engage in discussions and debates as part of the integrative learning process, "development of lifelong learning skills” also takes place (p.6). Such skills have often been called “twenty-first century skills”; and a call for such ‘skills for employability’ to be incorporated into college curricula is seen in literature (Ghazi, 2010). Curricular interventions at college level should, however, be designed and developed based on such skills of employability, as well as the constructs that were used to place the students in academic programmes (Kabelo, 2013).

A quantitative literacy course offered in a lab-based format takes the curricular innovation to a higher level of scope and possibility. For research conducted in one of the community colleges in the United States, redesigned sections of a quantitative literacy course were taught to a group of 25 students. While the content remained the same, the redesigning only changed the delivery and pedagogy (Nicole, 2013). A lab-based format offered an opportunity of working on meaningful applications, making use of real data, as opposed to contrived situations the students normally come across in textbooks. Nicole (2013) further found that changeover to a lab-based format in pedagogy radically transformed the quantitative literacy course; with a major positive shift in attitude towards quantitative literacy as a course of study (p.212). This finding has implications for the present research, in that it endorses curricular changes aimed at ‘contexts-driven learning environments’. Curricular materials used for such learning environments are also diverse, even having media articles serving as “prompts for investigations” (Shannon & Bernard, 2011). Curricular and instructional innovations mentioned above are, however, characterized by an emphasis on non-mathematical topics and non-mathematical content drawn from quantitative social issues such as “fuel efficiency”, “national debt”, “credit-card payments”, etc. (p.16). These issues, by their very nature of being diverse, represent a cross-disciplinary education with the underlying core-competencies of interpretation, representation, calculation, analysis and synthesis, assumptions, and communication (p.18). The notion of ‘connectionist pedagogic practices’ also offers possibilities of connecting teaching to students’ prior understanding. Connectionist pedagogy also links teaching and learning across mathematics topics, as well as between mathematics and other disciplines (Maria, et al., 2012). The practice-related similarity of connectionist pedagogy and an integrative curriculum is hence conspicuously prominent.

2.8 Research Questions and their Explanations

This section is devoted to brief explanations of research questions and descriptions of how the research questions were answered.

Main Question

1. How can a semi-integrated curriculum be designed and developed for a mathematical literacy first-year module for a Bachelor Of Education programme?

This is the overarching question that this research has attempted to answer. The answer to this question has been structured in such a way that it encompasses the general aspects of curriculum theory and practice, considered against the backdrop of integrative practices in mathematical literacy courses at tertiary level. The answer therefore is situated at multiple levels of conceptualization, theorization, and execution of this research as a whole. However, key aspects are summarized in the answer, incorporating necessary details, to give an overall picture of the research and the conclusions.

To help answer this question the following sub-questions were formulated:

Sub-questions

1a) What is the purpose of a Mathematical Literacy module taught as part of a BEd programme?
The purpose of a mathematical literacy module was extensively explored using document analysis. The purposes of mathematical literacy/numeracy courses taught at tertiary institutions in South Africa and abroad, with special focus on BEd programmes, were investigated. University publications and faculty handbooks were consulted for data-collection, and were supported by conversations with faculty members. Various purposes for which mathematical literacy courses are taught at various institutions, revealed the immense diversity of contexts within which mathematical literacy courses were situated. Institutional aims of mathematical literacy as a first-year module for BEd courses were contrasted with specific curricular aims and instructional aims that underpin mathematical literacy courses in general. The purpose of mathematical literacy, as seen from the perspective of research participants, has also been considered here.

1b) What are the characteristics of a Semi-Integrated Curriculum (SIC) in the context of teaching and learning of mathematical literacy in higher education?

The concept of curriculum integration, the way it is conceptualized at tertiary level for mathematical literacy/numeracy courses, is the most significant aspect of this research. Various types of curriculum integration are explored, with special focus on concept-context integration appropriate for a mathematical literacy module. From the definition of the term 'Semi-Integrated Curriculum' to the special way in which it is used for the design of a curriculum for the mathematical literacy course, the exploration spans various philosophical interpretations of curriculum integration, accompanied by the various dimensions of practice seen from the literature. The answer to this question, therefore, is primarily constructed from document analysis. A set of arguments is presented, supported by the literature on various aspects of mathematical literacy from which the Semi-Integrated Curriculum, as a novel, curricular idea, has evolved. A detailed survey of literature helps the formulation of arguments here, while experience gained from research sites was incorporated into the final conceptualization of the SIC, leading to the design of a Semi-Integrated Curriculum.

1c) What influence does a Semi-Integrated Curriculum introduced for the mathematical literacy module have on students' Higher Order Thinking Skills (HOTS) ?
The concept of Higher Order Thinking Skills is one of the most significant aspects of the SIC. "Knowing what constitutes cognition" helps the incorporation of cognitive processes into the design of curricula, enabling the associated Higher Order Thinking Skills to be fostered (Tara, Marnie, & Elaine, 2012). The effects of SIC on HOTS are explored in detail in this context. Using an appropriate analytical framework, students' work, collected as written answers to pre-test and post-test administered at predetermined intervals, is qualitatively analysed. Assessment of Higher Order Thinking Skills as a set of measurable constructs, with the support of associated theory, is well-formulated in related literature. HOTS were measured using appropriate instruments. The question is, therefore, answered with the help of data collected, as well as by concepts drawn from literature. This was supported by data from student interviews conducted at various times during the Semi-Integrated Curriculum intervention.

1d) To what extent are Higher Order Thinking Skills, attained in a mathematical literacy course, sustained in subsequent years of study?

This question is framed around the issue of sustainability of skills attained as a result of the curriculum intervention. HOTS, in its ideal sense, have multidisciplinary relevance. Aspects of HOTS once attained are made use of in later years of study. The extent to which research participants, having gone through the intervention process, maintained HOTS in their subsequent years, has been explored in this study. Semi-structured interviews with participants who have moved on to the second year in various majors, were analysed. Examination and test scores they obtained were also analysed and scrutinized to answer this question. The question was thus answered based on data collected pre-test and post-test, and from interviews conducted in the subsequent years of the participants' studies.

1.e Is the introduction of a Semi-Integrated Curriculum worth being undertaken for the mathematical literacy module of a Bachelor of Education course? If so, give reasons?

This question looks at the feasibility of a Semi-Integrated Curriculum as a sustainable curricular option for the mathematical literacy module. The answer to this question is significantly influenced by the way in which the previous research questions are answered. In other words, the extent to which HOTS are sustained in subsequent years of study determines whether or not a curricular restructuring aimed at introducing a SIC in a mathematical literacy module is a worthwhile exercise. The extent to which a SIC has influenced the development of HOTS is central to this question. However, the overall effect produced by the exposure of students to a SIC on the teaching and learning practices of lecturers and students, will also be under the spotlight. Therefore, the data used to answer this question have been drawn from a variety of qualitative and quantitative sources, and not just from the pre-test and post-test marks. The conclusions reached with regard to the appropriateness of introducing a SIC, are therefore to be based on almost all aspects of this research, with supporting arguments drawn from answers to all the previous research questions.

In Chapter Three the researcher deals with detailed formulations of ideas and explanations of concepts underpinning this research. Such explanations and suggested interrelations among concepts culminate in a conceptual framework that has guided this research as a whole.

CHAPTER 3
TOWARDS A CONCEPTUAL FRAMEWORK FOR AN INTEGRATED MATHEMATICAL LITERACY COURSE

3.1 Introduction

This chapter aims to present perspectives, concepts, and theories related to numeracy levels at which university students function academically. It also introduces the concept of curriculum integration as an alternative curricular process, with explanations of the terms 'integrated/integrative curriculum' and 'Semi-Integrated Curriculum'. General principles that underpin curriculum integration, and prominent theories that characterize the discourse on integration are broadly dealt with in this chapter. The chapter culminates in the exposition of a conceptual framework that guided this research as a whole.

3.2 Numeracy Levels of Education and Non-Science Major Students – Some Theoretical Perspectives from International Literature

"Many students begin their university studies without the necessary background and skills essential for success" (Keith & Gerard, 2013, p. 182). Some of the factors identified as reasons for this state of numeracy in Australia were related to less rigorous mathematics courses taken at high-school level, teachers manipulating material coverage to maximize results, and, most importantly, over-dependence on calculators, owing to lack of mental mathematics skills. Lack of ability to reason and analyse without the use of technology were also contributing factors (p.182). Research on institutional interventions to promote numeracy at tertiary level in the United States of America (USA) also indicated similar factors; showing a variety of remedial programmes, some of which had quantitative reasoning courses integrated into a variety of courses across the curriculum (Louis, Amber, Alexander, & Shimon, 2013). Some other universities in the USA had free-standing courses aimed at improving quantitative reasoning skills of university students (p.9). An important finding of the research was that an institutional emphasis on quantitative reasoning had a positive correlation with the use of quantitative reasoning skills of students from non-STEM (Science, Technology, Engineering, and Mathematics) disciplines (p.16). Those researchers also found that it was in the faculties of education and humanities that quantitative reasoning activities of students were recorded as having the lowest frequency of occurrence (p.17). However, "persistent intentional instruction" in these faculties had a significant influence on quantitative literacy levels of students (Nathan, 2013). Such intentional instructions are broadly based on the traditionally accepted notion that mathematical literacy curriculum is inherently the meeting point of real life contexts and certain mathematical concepts that underpin such contexts (p.18). This notion can be diagrammatically represented as in Figure 1. The curriculum followed currently at the University Of Zululand for mathematical literacy course can be considered conceptually similar to that shown in Figure 1.

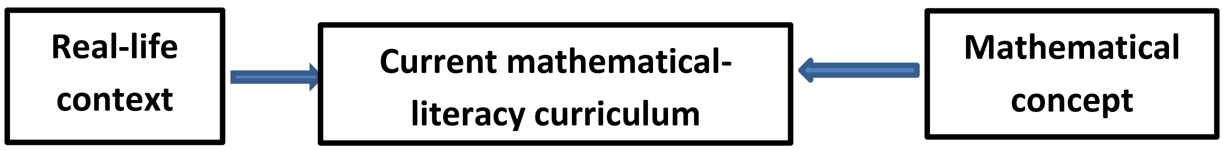

Figure 1 Conceptualisation of the mathematical literacy curriculum

Despite the importance of numeracy in personal lives, the nomological network of numeracy is the least understood by researchers (Margaret & Shuang, 2010). Assessment of numeracy as "an individual difference" allows us to focus on the understanding and use of numerical information in practice (p.257). Margaret and Shuang (2010) investigated the question of whether the numeracy construct is simply a manifestation of General Mental Ability (GMA). Would this indicate the futility of studying numeracy as a 'unique psychological construct' if there is such a relationship between the two? (p.258). Numeracy can be, according to the result of their study, correlated with rationality, while GMA cannot. While GMA was related to conscientiousness and agreeableness, numeracy could not be correlated to any of these constructs. Thus the researchers concluded that numeracy and general intelligence are "related to but distinct from one another" (p.263). In other words, numeracy cannot be replaced by General Mental Ability. That study, conducted using a college sample from a Midwestern university in the USA, was the first of its kind, producing interesting findings. The significance of the findings is that neither high nor low levels of numeracy among university students can be explained by the construct 'General Mental Ability'. However, varying levels of numeracy do have an influence on students' competencies, even though reasons for the occurrence of such an influence are disputed (Luke & Michele, 2013). While numeracy is not fully dependent on GMA, it (numeracy) constitutes an essential ingredient in thinking that leads to informed decision-making processes. There are subtle differences between numeracy and GMA, when compared with each other in this way. The underlying cognitive mechanisms that explain varying levels of numeracy among individuals is therefore worth mentioning here.

3.2.1 Cognitive mechanisms associated with numeracy

Numeracy, being a complex skill in its own right, involves the interaction of many cognitive and affective mechanisms (Edward, Mirta, Eric, Saima, & Rocio, 2012). From a psychophysical perspective, representation of *internal mental magnitudes*[7] can differ among individuals. In other words, individual differences in numeracy may be due to "differences in one's intuitive number sense and the affective meaning issued by this sense" (p.38). Moving away from this psychophysical viewpoint, and drawing ideas from psycholinguistics, *fuzzy trace theory* explains differences in numeracy levels on the basis of cognitive representations and memory. According to this theory, cognition involves encoding of verbatim information or literal facts and gist information or interpretations into two separable forms of memory. Also, people tend to have a *fuzzy-processing preference* which leads to responses that are usually based on their gist representations. In other words, their choices are based on "the fuzziest or the least precise representations of numeric information" (p.38). Fuzzy trace theory also explains judgement and decision-making based on numeracy-related cognitive processes. Interestingly, there is currently no validated instrument that may be used effectively to predict how individuals differ in their choice of gist and verbatim numerical representations (p.39).

Yet another perspective on understanding numeracy involves "computational approaches in the information processing tradition" (p.39). The central idea here is the creation of cognitive simulations from computational models. This approach depends heavily on studies that trace cognitive processes, studies on reaction times, and information search. The question of how cognition occurs over time is almost conclusively answered by cognitive simulations created by computational models. These models also give evidence of strategies and intellectual mechanisms. The most important advantage of this method is that it does not make inferences about cognitive processes based on averaged responses. Different respondents use different strategies in various instances, and hence a particular strategy cannot be identified as 'the strategy' which is singularly

[7] "It is likely that magnitudes (computable numbers) are used to represent the foundational abstractions of space, time, number, rate, and probability. The growing evidence for the arithmetic processing of the magnitudes in these different domains, together with the efficacy of representations founded on arithmetic, suggests that there must be neural mechanisms that implement the arithmetic operations" (Gallistel, 2012).

emphasized (p.39). Cognitive process-tracing studies have also indicated that numeracy and other abilities similar to the use of working memory predicted normative risky decisions of the individual. In other words, numeracy and 'superior risky decision making' were conclusively proved to have a positive correlation (p.39). In the same way, general cognitive ability also leads to increased efficiency in encoding task-relevant information. This efficient and elaborative encoding results in information from the working memory being stored in long-term memory. Additional resources and functionality thus become available for increased information-processing capacity.

Experimental data have also shown that *varying encoding and search* leads to changes in numerical-processing performance (p.39). Cognitive abilities such as numeracy, however, on their own, do not contribute to improved [8]*decision algorithms* (Mata, Schooler, & Rieskamp, 2007). Cognitive abilities, however, are good predictors of [9]*adaptive allocation* of limited cognitive resources. Cognitive abilities such as numeracy thus seem to indicate reflective, careful, and elaborative encoding, even while decisions are based on heuristics (Edward, Mirta, Eric, Saima, & Rocio, 2012). These authors further note that the question of how and when differences in numeracy levels will predict differences in encoding and search, needs further investigation. The above-mentioned researchers hypothesize, however, that numeracy and higher levels of general abilities are related to differences in meta-cognition (p.39).

Apart from the various intellectual mechanisms indicated above, knowledge and skills associated with mathematical operations and rules play key roles in the development of numeracy (p.40). Skills in techniques and procedures are domain-specific, and their transferability is governed by the extent to which a given task employs such techniques and procedures. Proficiency in those skills and techniques is therefore paramount to the attainment of numeracy. Individual attainment

[8] A decision problem is a question in some formal system with a yes-or-no answer, depending on the values of some input parameters. A formal system is broadly defined as any well-defined system of abstract thought based on the model of mathematics.

[9] An *adaptive allocation* problem is one in which the enquirer has the choice of determining the method of sampling during the course of the experiment, making use of the results already observed. This is in contrast with *fixed allocation* in which sampling is conducted strictly before the experiment. However, in this context, the two terms mean both ways in which cognitive resources are made use of.

levels and their differences in numeracy may be accounted for by various permutations and combinations of 'intuitive number sense', 'gist versus verbatim representations', 'reflective and elaborative coding', and 'skilled understanding of mathematical operations' (p.40). There are, however, certain factors that may negatively affect these theoretical propositions. Anxiety, for example, can affect the level of motivation to conduct elaborative encoding of numerical information, which in turn deters the development of skills. Another factor overlooked by this theory is that individuals who experience higher levels of affective meaning from numbers are inspired for further encoding, reflection, and learning. Greater levels of elaborative coding and knowledge may thus lead to more "contextualised gist based representations and reasoning" (p.40).

One critical point mentioned in these theoretical propositions is the overarching significance of skills and mastery of mathematical operations, rules, procedures, and basic concepts that underpin numeracy in general. The concept of the Semi-Integrated Curriculum (SIC) proposed in this thesis is in line with this particular, above-mentioned point. Differences in 'deliberate practice' yield differences in knowledge and procedural skills, which in turn lead to differing levels of numeracy (p.40). SIC proposes to consolidate such procedural skills associated with basic mathematical concepts in separate units of the learning material, broadly classified in this thesis as *Essential Basic Skills* (EBS). *Mathematics in contexts* as the underlying philosophy of numeracy courses, does not take precedence in the SIC-based instruction. On the other hand, consolidation of EBS precedes the introduction of problems embedded in contexts. Consolidation of EBS is integrated with and linked to the instructional practice in SIC. Apart from skills and concepts that are classified as EBS, any mathematical concept or skill (in which a certain context is embedded) deemed unfamiliar by the students, will be dealt with separately. In other words, SIC envisages the reinforcement of skills and basic concepts prior to, and not simultaneously with, the introduction of context-enriched problems. SIC ***does*** envisage, however, the identification and mastery of EBS to be strictly guided by the particular EBS with which various context-based problems present themselves.

The purpose of the above elucidation was to highlight the theoretical significance of 'Essential Basic Skills' in the context of effectiveness of a numeracy curriculum, giving concomitant reasons. However, a detailed exposition of concepts related to SIC will be dealt with in the following chapters of this thesis.

3.3 Integrated Curriculum as a Curricular Alternative to Mathematical Literacy

This section introduces the concept of curriculum integration as a background for the Semi-Integrated Curriculum, which is the central idea of this thesis. The intention here is to give the reader an overall picture of the meaning of curriculum integration, as conceptualized in this thesis, and then to start a discussion on the Semi-Integrated Curriculum. Both 'curriculum integration' and 'Semi-Integrated Curriculum' are conceptualized and explicated purely within the ambit of this thesis, and hence carry context-bound meanings which may or may not be different from the meanings with which they are conventionally associated.

3.3.1 Integrated curriculum

Integrated curriculum, in its semantic sense, may be considered a collective term meaning forms of curricula which have learning activities that cut across disciplinary boundaries, and which are designed with the intention of helping students recognize or create their own meaning (Tony, 2007). The same author uses the term *integrative curriculum* to refer to a student-centred model of curriculum integration, and *multidisciplinary curriculum* to refer to a subject-centred model of curriculum integration (p.53). Tony (2007) also argues that "both contemporary and historical examples of curriculum integration can be categorised into either student-centred or subject-centred traditions of curriculum integration" (p.53). However, the terminology of curriculum integration is inherently complex, with an array of terms such as: interdisciplinary curriculum, multidisciplinary curriculum, fused curricula, trans-disciplinary curriculum, cross-disciplinary curriculum and integrative curriculum (p.55). Despite this multitude of terms, one overarching dimension of the integrated curriculum is that it establishes a connection among content areas, fostering real-world understanding, with subject matter and practice becoming interactive (Cathy, Bindiya, Herbert, Nithya, Charles, & Austin, 2012). One of the major errors in terminology, according to Tony (2007), is that subject-centred curricula are sometimes called 'interdisciplinary curricula' or 'curriculum integration', while an accurate term representing subject-centred curricula would be 'multidisciplinary curricula' (p.55). Another serious contention among researchers in this context is that curriculum integration is wrongly classified as a "continuum of models". A theoretically correct argument here, according to Tony (2007), is that the 'existence of continua' should not be associated with a range of discrete models of multidisciplinary integration, but with a range of examples of the same multidisciplinary model (p.55).

The two dominant models of curriculum integration, as indicated earlier, are the student-centred integrative model and the subject-centred multidisciplinary model. A student-centred model may be defined as " a curriculum design theory that is concerned with enhancing the possibilities for personal and social integration through the organisation of curriculum around significant problems and issues, collaboratively identified by educators and young people, without regard for subject area lines" (p.55). The multidisciplinary model, on the other hand, may be defined as "the juxtaposition of several disciplines focused on one problem with no direct attempt to integrate" (p.56).

John Dewey[10] (1859-1952), the American philosopher and educationist, is credited with the initial conceptualization of the 'integrated curriculum' even though he never used the term 'integrated

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[10] The 20th century pedagogical debates were dominated by two schools of thought, viz. progressivism (or child-centredness) put forward by Francis Parker, and the social-efficiency model, put forward by behaviourists such as Edward Thorndike (Loana, 2014). The social-efficiency model considered schools as places producing useful individuals capable of serving societal needs. Franklin Bobbitt, in support of this school of thought, published his work, "The Curriculum: A Summary of the Development concerning the Theory of Curriculum" (1918). Bobbit believed that students should be taught practical tasks that prepared them for future careers; and that the curriculum should be designed to teach the students how to perform specific tasks. This theory resulted in an emphasis on vocational programmes giving importance to specific skills and specific jobs. W.W. Charters expanded on this theory, publishing "Curriculum construction" in 1923. His argument was that observing adults engaging in daily tasks will help in deriving educational objectives. After formulating objectives this way, one has to create sequenced activities to realize the objectives. The most important tasks are sequenced, which can then realistically be taught in schools. Ralph Tyler consolidated these ideas in his book "Basic Principles of Curriculum and Instruction", published in 1949. Standardization, efficiency, and accountability, emphasized by modern education systems, are his original ideas (p.2).

Opposing these ideas of social efficiency was 'progressivism', put forward by Francis Parker, John Dewey, and William Kilpatric. Francis Parker thought of schools as 'communities of scholars' and a 'collaboration of teachers across grade levels'. Parker described schools as "a model home, complete community and embryonic democracy". This led John Dewey to his conceptualization of school as a democracy, which is his most important contribution to the curriculum theory. He strongly believed that students should be allowed to contribute to curriculum development. Dewey's concept of a democratic curriculum paved the way for Kilpatrick's project-based curriculum development. The project method considers the curriculum as collaborative communal activities inspired by the environment and society. Progressivism was, in general, relegated to secondary prominence by scientific discoveries and technological advancements of the 20th century. However, these two schools of thought initiated the discussion around two other present-day curriculum approaches, which are 'critical theory' and 'technology based instruction'. Critical theory is based on the ideology of Karl Marx, but added to by Michael Foucault and Jurgen Habermas (p.3). This approach curriculum', using *organic education* instead, to mean what we now call an 'integrated curriculum'. Dewey strongly believed in bringing individual traits of students in harmony with the aims and values of their communities. He thus considered the students and the community they lived in, rather than the subject areas, as the focus of education (p.57). This has led to the view that student-centred approaches can pave the way for integrative curriculum designs in which traditional subject areas are relegated to less prominence, whereas the organizing theme dominates the design. The choice of subject matter is purely based on its (the subject matter's) relevance to the theme. In this context, the concept of *meaningful mathematical connections* as applied to numeracy curricula, is relevant for its resemblance to integrated curricula. *Meaningful mathematical connections* include connections within mathematics itself, with other subjects, and with realities in the outside world (Kemal, 2013).

The late 19th century Herbartian[11] idea of 'correlation' may be said to be the theoretical basis for the multidisciplinary model of curriculum integration (Tony, 2007). During the 20th century this *correlation* came to be interpreted as a method of identifying intersecting areas of subjects which were subsequently eliminated, resulting in *fused curricula*. The multidisciplinary curriculum is the result of such a fusion, in which subject areas are organized according to a theme identified in two or more subjects. One critical point here is that in multidisciplinary subject-centred designs, the organizing theme is only of secondary importance, whereas the subject areas remain the principal focus. The process and practice of correlation is, however, sometimes seen as artificial and contrived, when teachers desperately try to "weave a little arithmetic into the history lesson" (p.58). The crucial point here is that contextually significant themes which the students are capable of taking on must not be substituted with trivialized organizing themes that fail to entice the students.

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proposes to change the society by empowering individuals to overcome the social, institutional, and political inhibitions that curtail their freedom.

[11] A group of American educational reformers, called Herbartians (named after the German philosopher Johan Friedrich Herbart), questioned the basis of a single-subject curriculum. The reformers began to explore the idea of separate subjects being correlated with one another. Herbartians failed fully to theorize this notion of correlation. Philosophers of later years, however, took this notion further, using it to describe "the efficient distribution of subject matter within multidisciplinary curriculum designs" (p.57).

3.3.2 The integrative-model design

Inspired by John Dewey’s work, Beane (1990) set up a design for the integrative model that he pioneered. His unique way of developing subject matter involved answering questions such as “What questions do you have about yourself?”, and “What questions do you have about the world?”. Students, with the help of teachers, explore these questions within the limits of a theme or an organizing centre which the students generate. This resulted in possibilities for personal and social integration (p.58). On implementation of the integrative model in the classroom, the process of integration becomes a task that each student must accomplish. This idea of integration at a personal level conceptualized by Dewey as *reconstruction of experience* was the most significant characteristic of his (Dewey’s) curriculum design. Bean’s integrative model also allows teachers and students to plan the curriculum according to individual and social concerns, leading to a curriculum that is personally meaningful and substantially valuable to society. Dewey’s position was that a curriculum that helps establish an active relationship between the students and the common world becomes naturally integrated (p.59).

Bean’s model of integration is philosophically anchored to certain democratic values, in that the power is shared between teacher and students. This often leads to a collaborative planning and implementation of the curriculum. The collaborative teacher-student planning thus forms the basis for the *negotiated curriculum* (p.60). The concept of a *negotiated curriculum*, with a certain degree of agency attached to the recipients of the curriculum, happens to be one of the key ideas that lead to integrated curricula. Bean’s contribution, therefore, to the theory of integration, greatly influences the way we look at the recipient’s role in the making of the curriculum for whom such curricula are designed. Thus, the curricular move from a “content and supply driven to demand driven approach” is inherent in the integrative model design (Sarojni & Brian, 2011). This also places the integrative model design in line with the curriculum philosophy of progressivism emphasizing personal experiences of students, their interests, and their needs (Shashidhar, 2011).

3.3.3 The multidisciplinary model design[12]

The basic principle that governs the multidisciplinary model design is that it uses the Herbartian idea of correlation to the extent that overlaps between discrete subject areas are removed by the purposeful arrangement or integration of the subject matter. At the planning stage of multidisciplinary units, "an elaborate matrix is made use of in which subject areas are cross-referenced using a curriculum mapping process so as to make sure that subject matter in each subject is covered efficiently" (p.62) One important characteristic here is that this model (multidisciplinary model) clearly controls the content matter of the curriculum. The teacher teams select the content using clearly defined criteria and parameters. This design also seems to justify a particular pedagogical organisation and sequencing whereby parcels of knowledge are delivered which are pre-packaged by teachers or text-book writers (p.62).

The multidisciplinary model oversimplifies the concept of integration to the level of a mechanical process conducted by teachers. Students are completely out of the decision-making level of the process of integration. Jacobs (1989), as the originator of this concept, failed to contribute anything significant to the theory of curriculum integration. Jacobs simply extrapolated the concepts of *scope and sequence* to the planning of multidisciplinary units. However, subject-centred proponents took note of the multidisciplinary model of integration because of increased control over content for the teachers and administrators (p.63).

The integrative and multidisciplinary designs: A contrast

The integrative and multidisciplinary designs hold ethically opposite positions. While the former, with its heavy student-centred focus, respects the dignity of each individual, the latter, with its

[12] Models of integrated curricula may also be classified as: a) Multidisciplinary – focussing on the relationships of different subjects to each other and to a common theme; b) Interdisciplinary – organization of curriculum around common learning across disciplines; c) Trans-disciplinary – teachers organize the curriculum around student questions and concerns, allowing them to develop real-world skills, as they apply interdisciplinary and disciplinary skills in real-life contexts (Denise, 2013)

subject-centred focus, is unresponsive to student differences. The inclusive nature associated with the integrative model accommodates socio-economic, cultural, ethnic, and local differences among students. The integrative model also underscores the integration and understanding of knowledge at personal and social levels, because of the collective participation of students and teachers in the making of the curriculum. The integrative model ideologically detaches the teacher from the management of the content "where the learner takes control of what to be learned, how it should be learned and what evidence is needed to demonstrate that learning has occurred" (Sarojni & Brian, 2011). These authors therefore call for an identity transition for academics from that of traditional teachers to professionals embracing the principles of andragogy[13] (p.164).

The multidisciplinary model, on the other hand, fails to cater for individual differences, makes no provision for gifted and talented students, nor for students from ethnic minorities, nor those from lower socio-economic conditions. However, the integrative model met with stiff resistance in the United States because it tried to oppose the "transmission of knowledge and values of the dominant political group" (p.64). The American literature on curriculum integration is also biased against the integrated model. From a teacher's perspective, a switch-over to an integrative curriculum involves a paradigm shift along with a changing professional identity (p.64). However, implementation of the multidisciplinary model, and not the integrative model, was met with a general acceptance in the United States. The American experience should serve as an interesting case in question for those who wish to experiment with the concept of an integrative curriculum.

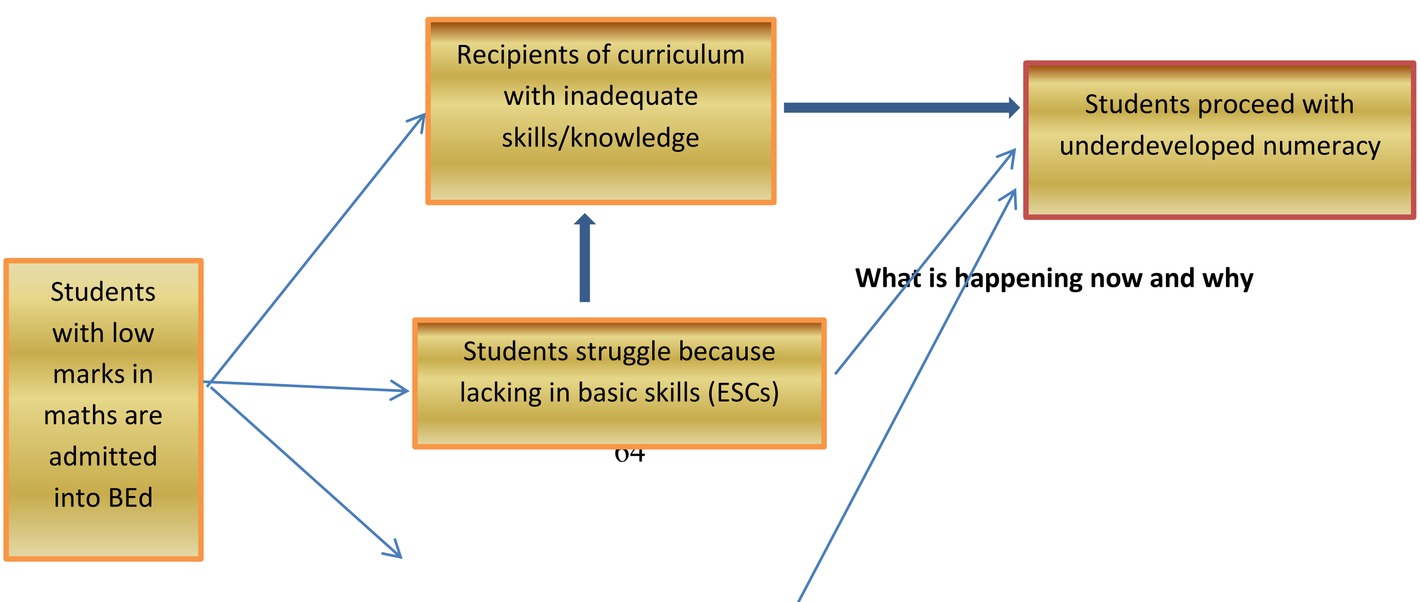
3.3.4 The student-centred integrative curriculum as a structural framework for a mathematical-literacy curriculum

The proposed curricular changes for mathematical literacy are conceptualized using the student-centred integrative curriculum as a structural framework. Of the two integration models introduced above, the student-centred integrative curriculum is chosen because of its varied progressive characteristics emphasized by current discourse on curriculum design and development. The dominance of organizing themes, underpinned by meaningful mathematical connections over

[13] Andragogy is the method and practice of teaching adult learners

separated content topics, remains the critical aspect of the integrative curriculum. This stands in stark contrast to the multidisciplinary format of integration, in which the materials from more than one discipline are seamlessly integrated (Muhammad, 2012).

The curriculum is proposed to be structured around overarching themes carefully selected from academic, non-academic, professional, and real-life contexts. As a dynamic curriculum that incorporates features of a negotiated selection of themes, the curricular structure remains open to additions and changes agreed upon from time to time by the students and the lecturers. Thus, a "cross fertilisation of ideas and approaches", as Anne (2012) called it, adopted from a variety of curricular theories, underpins the concept of the Semi-Integrated Curriculum, as formulated in this thesis. The rationale for this conceptualisation in the context of this research can be summarised diagrammatically as in Figure2



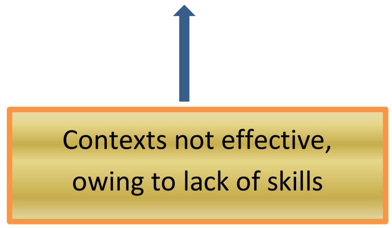


Figure 2 Current state of the curriculum at University of Zululand

3.4 Terms Explained Further: Integrated/Integrative Curriculum and Semi-Integrated Curriculum

The implications of *contexts* in mathematical literacy must foreground the discussion on integrative techniques. The point here is that learning programmes are designed using real-life contexts. At the same time, development and mastery of essential skills and knowledge must be a precursor to the introduction of context-based problems while the use of such skills in contexts, in return, reinforces understanding of the skills (Quality Council for Trades & Occupations, 2011). In other words, the mastery of essential skills expedites the solving of context-based problems, while such problems help consolidate those essential skills, producing a bidirectional relationship between essential skills and context-based problems. The techniques of integration associated with SIC make substantial use of this point.

The integrative model design is taken here as having a set of principles guiding the conceptualization of the Semi-Integrated Curriculum (SIC). SIC therefore remains a variant of the integrated curriculum, in that the former incorporates most of the underlying principles that govern the latter. The notion of themes determining other aspects of the curriculum is common to both, while SIC emphasizes certain prerequisites foregrounding the introduction of thematically integrated units of content. The major deviation from the conventional integrative model design is that SIC envisages the treatment of essential skills as a vital step towards mastery of content subsequently introduced in the themes. The three points of interest here are the 'themes', 'associated contexts', and the 'essential skills and concepts'. The expression 'essential skills and concepts' here, represents the set of concepts and skills that the theme as whole, and the context in particular, has as the network of threads that hold the understanding of the theme together. Thus, while the curriculum remains thematically integrated, Essential Skills and Concepts (ESCs) remain the backbone of the body of the collection of themes constituting the curriculum. ESCs and themes are the two entities, therefore, from which SIC, as a selective combination of the two, evolves. Fransisca & Amparo (2013), in this context, remarked on two curricular interventions they undertook in Spain. The first was aimed at reinforcement of mathematical skills, while the second was aimed at using such skills in solving problems based elsewhere (p.894).

The rationale for coining the term Semi-Integrated Curriculum is worth mentioning here. There are two levels of integration envisaged in SIC. One is the thematic integration that runs throughout the curriculum, while the other is the context-concept integration. Context and concept remain inherently integrated within the integrative model design. The term semi-integration refers to the degree to which concepts and skills remain integrated with the contexts. As the name implies, integration of concepts and skills with contexts is taken to an optimum level only in SIC. The purpose of this selective integration is that the component of the curriculum called Essential Skills and Concepts (ESC) may be considered a stand-alone constituent. This is because consolidation of a particular set of ESCs is a prerequisite for every thematic unit of the curriculum. The set of ESCs identified for each unit will vary during the course of the implementation, because of its negotiated nature. The prefix 'semi'[14] indicates that the curriculum envisaged here cannot be considered to have all content matter fully integrated with, and hence embedded in, contexts determined by the themes. Instead, SIC has a set of ESCs introduced before every thematic unit, that may be taught without reference to any particular context. Instances of research indicating genuine requests from students themselves to have "lessons focussing directly on mathematical content alongside the context based lessons" underscore the relevance of a curricular concept such as SIC (Roger & Robin, 2012, p. 43). Mastery of ESCs is therefore given an important role in the whole curriculum by way of its stand-alone nature and negotiated choice. The term 'Semi-Integrated Curriculum', semantically, denotes a curriculum that has some of the characteristics of an integrated curriculum in which the process of integration is locally defined.

3.5 Curriculum Philosophies for Higher Education – a Few more Perspectives

[14] The prefix 'semi' is used to mean 'resembling or having some of the characteristics of'.

The recent shift in focus from traditional liberal education to utilitarian, vocational, and functional curricula in the higher-education sector is significant (Peach, 2010). Particular epistemological views of "what higher education curriculum should be in a super-complex world" have led to the emergence of new curricular frameworks (p.449). Peach (2010) talks about five philosophical approaches, viz., traditional or discipline based; performance or system based; cognitive; personal relevance/experiential; and socially critical. A short discussion on this categorization is appropriate here because of the integrative model design's theoretical link with one or more of the approaches proposed by Peach (2010). Integrated curriculum as a theoretical construct, its variants, and the Semi-Integrated Curriculum as an innovative curricular approach, may all be either explicitly or implicitly linked to one or more of Peach's categorizations.

3.5.1 Traditional or discipline-based approach

Structure of knowledge in the discipline and the methods of enquiry used in the discipline determine the choice of content, according to this approach. Theoretical and abstract knowledge is emphasized, and knowledge is supposed to exist independently. Content is not determined according to students' interests or issues in society. The purpose of the curriculum, in other words, is the transmission of a body of selected disciplinary knowledge. However, the validity of the theoretical or abstract knowledge base these approaches are emphasizing, is currently being questioned. Trans-disciplinary and generalist curriculum models are at the same time emerging globally (p.452).

3.5.2 Performance- or system-based approach

This approach has a technocratic ideology by which it predetermines the curricular ends. Examples of this approach may be found in teacher-education programmes in which the curriculum follows a competency-based model. The content here is based on professional-practice related skills and knowledge that lead to effective performance. The most striking feature is that there is no distinction between theoretical and applied knowledge; theory here simply informing practice. This approach is concerned only with means of achieving desirable outcomes. This requires having "clearly defined learning objectives specified in behavioural outcomes" (p.452). An outcomes-led approach thus designed focusses on ends rather than means. An interesting point here is that process become incidental, with outcomes based on skills or competencies. This is because skills may be assessed easily and efficiently, whereas competencies are preferred because of their instrumental nature determining success in employment. However, the nature of learning at a higher education level is fundamentally complex. It is a flawed assumption that such learning may be measured or reduced to a subtle statement of outcome (p.453). This may be taken as one of the theoretical flaws of the outcomes-based curriculum when used at a higher-education level.

3.5.3 The cognitive approach

The main aim of this approach is to help the students become deep thinkers and effective problem-solvers. Skilled performance is not the only goal here. Development of higher-level critical thinking, reasoning, analysis, and enhanced intellectual abilities, are the goals of this approach. This approach trades off breadth of content for depth, for the sake of maximum cognitive development, thereby making 'thinking' the purpose of curriculum content. Knowledge, here, is personally and socially constructed; and hence this approach essentially involves interactive small-group work. It envisages issues and conceptions being challenged, and understandings critically examined. Undoubtedly, this is problematic, because of issues of resources, infrastructure, and institutional constraints.

The cognitive approach, however, has its own critics, who argue that higher-education curricula must be focussing on more than intellectual development. The critics also say that development of the whole person should be the central tenet of higher education curricula; ethical and moral developments are important for human development, in addition to cognitive development (p.453).

3.5.4 Experiential or personal-relevance approach

A strong emphasis here is learning through experience. Curriculum content and structure are not imposed on students. The experiential approach allows them, to a certain extent, to decide whether the content chosen is personally useful and significant. An emphasis on student-centred learning leads to the learning responsibility being shifted to the students. Academics do not determine the content, allowing the students to use the opportunities for risk-taking and management of their own educational development. The teacher's role is to help the students reflect upon their needs, selecting the knowledge and skills required of them by their chosen profession. Self-reflection and evaluating one's own learning are therefore important.

3.5.5 The socially critical approach

Ideas drawn from critical theory are important here. The socially critical ideology tries to develop critical consciousness in students to make them aware of social ills and how to alleviate them. Found generally in social sciences and humanities, the content is organized around significant social themes which expose the covert values of society. Similar to cognitive approach, this approach challenges students' views and perceptions, fostering alternative perspectives. This approach takes into account the transformative potential of the curriculum to empower students and challenge inequalities.

3.5.6 Peach's categories and the concepts of integrative and semi-integrated curricula

The five curriculum philosophies mentioned above are collectively considered, to assess their relative merits and demerits, determining which of the philosophies, singularly or in combination, supports the notions of integrative and semi-integrated curricula as conceptualized in this thesis. The Semi-Integrated Curriculum does not show allegiance to traditional or performance-based approaches. SIC has much in common with cognitive and experiential approaches, both of which underscore the importance of 'thinking becoming the purpose and content of the curriculum'. Development of higher-level critical thinking, reasoning, analysis, and advanced intellectual capacities, also becomes the construct around which the curriculum is designed and implemented. The fact that SIC is thematically structured around significant themes makes it, in a very limited sense, similar to the socially critical approach. However, SIC does not envisage any socially responsive content, in that its thematic focus is on mathematically significant disciplinary or inter-disciplinary contexts. The purpose of the above overview of curricular philosophies was therefore to give the reader a panoramic view of philosophical perspectives that act in a supporting role for the narrative on the chosen curricular approach.

3.6 The Semi-Integrated Curriculum (SIC) and Higher-Order Thinking Skills (HOTS): Their Relationship from a Mathematical-Literacy Perspective.

Integrated curricula in general lead to greater intellectual curiosity and enhanced problem-solving skills among students (Denise, 2013). They also help students ask meaningful questions, locate multiple sources of knowledge, and compare and contrast knowledge, information, and perspectives (p.7). The interdisciplinary curriculum, in particular, for instance, is "one of the most epistemologically complex endeavours that humans can attempt" (Zachary, Michael, & Howard, 2008, p. 402). This complexity, as with the higher-order knowledge that it leads to, is primarily owing to deep differences in disciplinary perspectives, overcome by interdisciplinary curricula, thereby generating various kinds of knowledge. One of the most significant epistemological characteristics of integrated curricula, therefore, is the emphasis on Higher-Order Thinking Skills (HOTS). Critical-thinking skills and HOTS should be taught within [15]Concrete Operational Skills (Jeanine & Michael, 2013). This may be conducted through a separate curricular offering, or through integration into other disciplinary curricula (p.346).

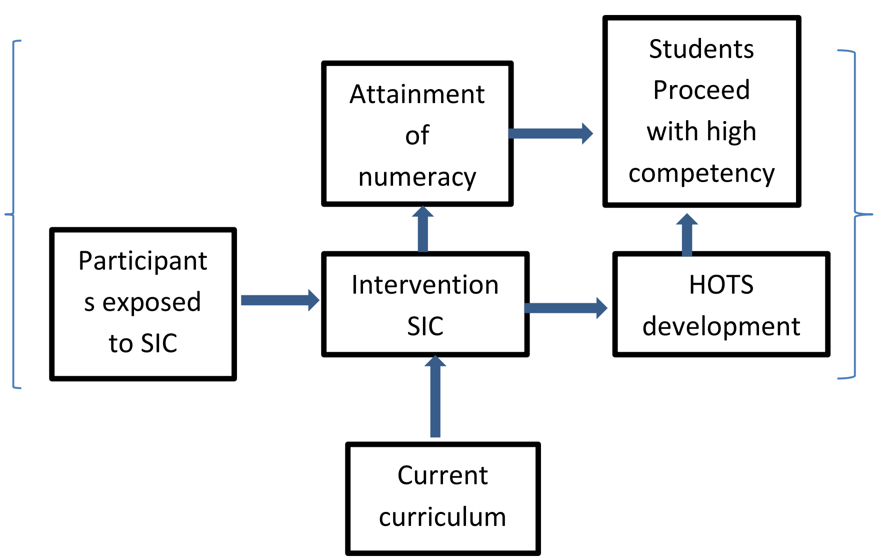
The curriculum that Eastern New Mexico University, for example, designed for quantitative literacy courses for liberal arts and social science majors, explicitly teaches critical-thinking skills (p.347). In one of the south-western universities in the US, a new mathematics course called Math 106, to suit the needs of social-science students, had critical thinking incorporated as one of the aspects of the curriculum (p.351). These curricular innovations are typical, in that they represent a recent synergy to have higher-order thinking skills and critical thinking skills integrated into curricula for non-science major students. This is because "HOTS are conceived so as to enable students to relate their learning to other elements beyond those they were taught to associate with it" (Susan, 2010, p. 6). 'Relating learning' in this context may be compared with integrated learning that takes place as a result of the integrative curriculum. Some of the HOTS that SIC envisages fostering for relational learning are: analysis, evaluation and creation, logical reasoning, judgement and critical thinking, problem-solving, creativity, and creative thinking (p.14). A rubric designed by the Association of American Colleges and Universities (AAC&U) for assessing undergraduate students' learning in quantitative literacy is noteworthy in this context. Quantitative literacy competencies identified here are 'Interpretation', 'Representation', 'Calculation', 'Analysis/Synthesis', 'Assumptions', and 'Communication' (Stuart, Caren, Shannon, & Bernard, 2011). This rubric will be further discussed in the 'Research Method' section of this thesis.

The rationale for fostering these skills as part of mathematical-literacy curricular objectives is that they (HOTS) are prevalent in all academic contexts; and that a certain level of mastery of those skills is essential for success at university (Gurudeo & Kees, 2013). The fact that mathematics is now compulsory for many non-mathematics-major degree programmes, because of an increase in quantitative-literacy demands of those majors, is also to be noted (p.220). The level of abstract thinking needed and the associated HOTS at tertiary level calls for increased focus on such skills (p.221).

3.6 Conceptual Framework

The purpose of this section was to summarize ideas dealt with in the previous sections of this chapter, leading to a comprehensive diagrammatic representation of the way in which this research has been conceptualized. Figure 3 illustrates the basic concepts and constructs involved and the relationships among them. This representation serves the purposes of: "a) a set of interrelated propositions, concepts and definitions that present a systematic point of view b) specifies relationships among concepts c) explains or make predictions about the occurrence of events based on the specified relationships" (Sitwala, 2014).

What will happen



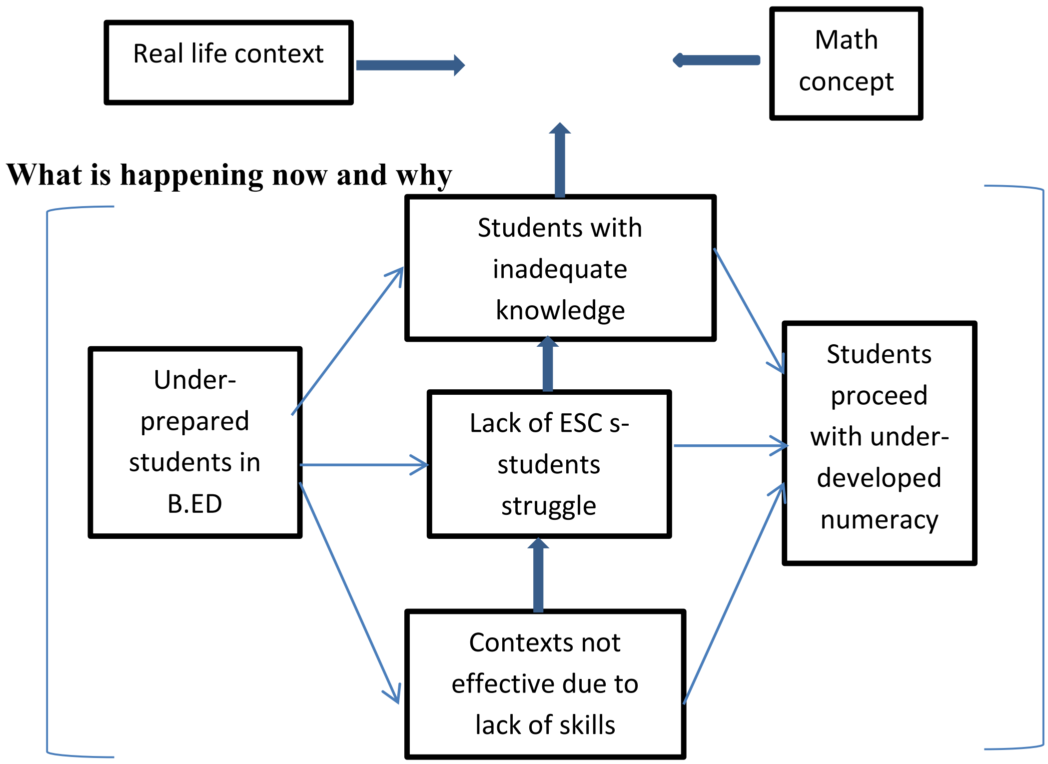


Figure 3 Conceptual framework

While the framework shown in Figure 3 indicates propositions and makes predications related to the research, an interesting point that Paul (2012) makes in this context is relevant, that "there is a lack of recognition that conceptualising research objects and analysing data involve different kinds of theory" (p.953). Paul argues further that, while it is important to have these theories aligned with one another, a clear acknowledgement that "viewing the object of your research in a particular way is different to the **ways of seeing** (emphasis inserted) involved in systematically organising and analysing data" is important (p.953). Hence, this research has separate analytical frameworks for analysing participant interviews and pre- and post-test responses. Details of those frameworks will be dealt with in the method section of this thesis.

However, considering conceptual and analytical frameworks as separate entities, is grounded on the premise that the two frameworks serve different purposes. The lower part of the framework indicates the current state of affairs, offering reasons for such a state of affairs currently existing, with predictions apropos of findings. The upper part of Fig 3 indicates the concepts and constructs associated with the proposed curricular intervention. The two parts are separated by the two salient aspects of the current curriculum, viz. ‘contexts’, and ‘concepts’, that underpin the current curricular structure.

CHAPTER 4
RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

This chapter examines the relationship between the four foundational elements of research, namely, [16] ontology, epistemology, methodology, and methods. The chapter places special

[16] Michael (2012) succinctly brings out the meanings of these terms by way of their associated questions. He relates ontology to ‘what is the form and nature of the social world?’, epistemology to ‘how can what is assumed to exist be

emphasis on the way in which this research is theoretically positioned in terms of each element constituting a frame of reference. The following sections of this chapter will therefore analyse each of these elements with a view to clarifying the methodological framework used in this research. Within the methodological framework various “philosophical and practical elements” that have influenced the choice of research methodology and hence influenced the methods adopted in this research, are dealt with (Burns, 2014, p. 32). Practical elements constitute the actual research method, while philosophical elements constitute the body of abstract principles and concepts that guided the practical elements (p.33). While the philosophical aspects are explicitly indicated with the purpose of “rendering the research open to critique and analysis”, the reference to practical aspects is aimed at describing the actual research method and analytical techniques used (Mojtaba, Hannele, & Terese, 2013, p. 398). The practical aspects, however, are contextually illustrated in the data-analysis chapter of this thesis. The purpose here is, therefore, to establish the research approach and the research methodology adopted; hence justifying and explaining the data-collection methods used in this study.

4.2 Curricular Intervention in Curriculum Design and Development: Purpose and Practice from a Methodological Perspective

The curriculum intervention carried out as part of this research focussed on the “accumulation of empirical evidence” related to the feasibility of the Semi-Integrated Curriculum for improving student’s numeracy levels and higher order thinking skills (HOTS) (Christian, Ben, Hank, Scott, Derek, & Mari, 2015). The purpose and practice of the research-based curriculum intervention determined the ontological, epistemological, and methodological positioning of the researcher and the research. This is in line with the notion that research design is fundamentally conceptualised to suit the research questions and the research purpose (Dina, 2012). The research design is thus fundamentally influenced by “certain informative relationships”, some of which are those between: a) Research problem to be tackled and purpose, aims, and research questions, and b) Philosophical assumptions, research questions, methodology, and methods (Burns, 2014, p. 34). The transparent exposition of such subtle relationships is the justification for the choice of

known’, methodology to ‘what procedure or logic should be followed’ and methods to ‘what technique of data collection should be used’.

methodologies, methods, and appropriate quality-assurance techniques within the research practice (p.36).

4.3 Research Paradigm

"Research paradigms address the philosophical dimensions of social sciences" (Dina, 2012, p. 69). Research paradigms also indicate how the researcher perceives the world by using a set of assumptions and beliefs (p.69). Current research paradigms may be broadly classified based on their philosophical dimensions of ontology and epistemology. Ontology refers to the nature of knowledge; epistemology refers to the development of that knowledge. Axiology and methodology are the other two dimensions of philosophy that influence the investigation of reality. While axiology involves ethics and values of the researcher, methodology is concerned with a "model for undertaking a research process in the context of a particular paradigm" (p.69). The ontological position adopted in this research was that of interpretivism, meaning that truth is considered socially constructed, and is subjective. Truth is subject to change, and has multiple existences. From an epistemological perspective on what constitutes acceptable knowledge, this research considered subjective meanings and social phenomena significant. This research also focussed on the "details of the situation, the reality behind these details, subjective meanings and motivating actions" (p.70). In terms of axiology (i.e. the role of values in the research in terms of the researcher's approach) the research was value-bound, the researcher being part of what was being researched; hence the research was subjective in nature (p.70). In terms of methodology, this research was purely qualitative in all respects.

The broad category to which this research belongs may be called 'action research' that focusses on "solving local problems that practitioners face" and which is "usually conducted by researchers at universities" (Burke & Larry, 2012, p. 9). Conducted in natural settings, this applied research centred on "local practice and local solutions for very specific problems" (p.11). The questions of how people relate to the world and how they generate knowledge have characteristic responses in action research. The study of knowledge thus generated, "including its nature, how it is gained, how it is warranted, and the standards that are used to judge its adequacy, is known as epistemology" (p.12). A related concept in this context is *empiricism* which is an idea that knowledge comes from experience. The philosophical doctrine of empiricism maintains that what is observed with our senses is considered true (p.13). A statement said to be empirical in nature may either be verified or disproved by observation, experiment, or experience. *Rationalism,* on the other hand, is the philosophical position that reason is the primary source of knowledge (p.13). Rationalism may be said to have two types of reasoning, viz., deductive and inductive reasoning. While deductive reasoning refers to "the process of drawing a conclusion that is necessarily true if the premises are true", inductive reasoning refers to "the process of drawing a conclusion that is probably true" (p.14). A probabilistic form of reasoning is inherent in inductive reasoning because the reasoning statements involve what is likely to occur and not what will necessarily occur. An element of risk is indispensable in probabilistic reasoning, because of the conclusions reached that go beyond the evidence in the premises. The certainty of conclusions reached as a result of inductive and probabilistic reasoning are therefore questionable (p.14).

A scientific approach to knowledge generation is also noteworthy here. This approach considers empirical data highly valid. When science is considered an approach for the generation of knowledge, it involves systematic actions carried out to answer research questions (p.14). Science invariably involves the application of scientific methods. One critical aspect of science as an approach for the generation of knowledge is that it (science) does not accept the truth behind what is merely taken for granted. Science, conversely, tries to uncover and justify descriptions and explanations of people and the associated world. The scientific method called the *exploratory method* is especially relevant here. The exploratory method involves firstly the observations, and then the systematic study of those observations. A statement of what is occurring, or a *pattern,* is then arrived at. A tentative conclusion or a generalization about the pattern, or a generalized statement about "how some aspects of the world operate" is then arrived at (p.17). The exploratory method is sometimes called the inductive method because of its emphasis on moving from the particular to the general: it starts with data and observations in discovering what is happening more generally.

The concepts of *inductive reasoning, scientific approach,* and *exploratory method* explained above, collectively lead us to the notion of what is called a *research paradigm* of a particular nature. A research paradigm is "a perspective about research held by a community of researchers that is based on a set of shared assumptions, concepts, values and practices" (p.31). Of the three dominant paradigms, namely, *quantitative, qualitative,* and *mixed,* qualitative paradigms deserve special treatment in the context of this research. Qualitative research essentially means research that depends primarily on the collection of qualitative data (non-numerical data such as words and pictures). Qualitative researchers view human behaviour as fluid, dynamic, and changing over time and place. Qualitative researchers do not attempt to generalize beyond what is applicable within the group that is studied. They do not interfere with the natural flow of behaviour. Types of people in a group, the way they think and the way they interact, are all subject to study, based on the argument that reality is socially constructed (p.36). One of the most important characteristics of qualitative research, therefore, is that it is focussed on insider perspectives of people and their cultures, the understanding of which requires "direct personal and often participatory contact" (p.36).

The ideas presented in the above section under 'Research paradigm' are summarized in Table 7 so as to provide the reader with a brief recapitulation of the salient paradigmatic standpoints this research adopted. The arguments presented in the rest of this thesis are collectively governed by the paradigmatic reference points summarized below.

Table 7 Characteristics and emphases of qualitative research

Characteristics and emphases of qualitative research	
Scientific method	Exploratory in nature, researcher generates or constructs knowledge and grounded theory from data
Ontology (nature of truth or reality)	Subjective, mental, personal, and constructed
Axiology (the role of values in research and the researcher's stance)	Value-bound and emic researcher is part of what is being researched, subjective in nature

Epistemology (theory of knowledge)	Constructivist, individual, and group justification
Methodology	Qualitative
View of human thought and behaviour	Situational, social, contextual, personal, and unpredictable
Research objectives	Qualitative or subjective description, empathetic understanding and exploration
Interest	Understanding and appreciation of particular groups and individuals, informing local policy
Focus	Examining the breadth and depth of phenomena to learn more about them
Nature of observation	Study groups and individuals in natural settings, attempt to understand insiders' views, meanings, and perspectives
Form of data collected	Qualitative data obtained from interviews, participant observation, field notes, and open-ended questions. Researcher is the primary data-collection instrument
Nature of data	Words, images, categories
Data analysis	Use descriptive data, search for patterns, themes and holistic features, and appreciate difference or variation
Results	Particularistic findings, provision of insider viewpoints
Form of final report	Informal narrative report with contextual description and direct quotations from research participants

Adapted from Burke & Larry (2012, p.34) and (Dina, 2012, p. 70).

Apart from the characteristics mentioned above, qualitative research discourse may be considered as dealing broadly with phenomena in context, interpretations of processes or meanings, use of theoretically based concepts, and the search for 'understanding' (Silverman, 2014). While the use of words dominates such discourses, the researcher's primary concern is with *meanings* and the "induction of hypotheses from data" as generally found in case studies (p.5). These aspects are, however, dealt with in detail in the following sections of this chapter.

4.4 Research Design

The research design as shown in Figure 5 was conceptualized within the ideas of a qualitative research paradigm. The diagrammatic representation in Figure 5 indicates the assumptions, approaches and methods that are drawn from the ontological, epistemological, and methodological perspectives adopted by this research. According to Michael (2012), ontological positions may be assumed to exist along a continuum from realism to constructivism. At the end of the continuum, falling under constructivist ontology, this research adopted interpretivism as its theoretical perspective. According to interpretivism, direct development of knowledge is not possible. “It is the accounts and observations of the world that provide indirect indications of the phenomena”, in turn leading to the development of knowledge as a process of interpretation (p.16). Emanating from a constructivist epistemological perspective, this research also took the view that knowledge is socially constructed. A critical idea of constructivism that guided this research is that reality is neither one-sided nor objective: multiple realities are constructed by individuals (Michael, 2012).

Basic assumptions that underpin interpretivist paradigms may be further elaborated for the clarity of theoretical positions this researcher adopted. Interpretivism, being an anti-positivist theory, gives emphasis to interpretations of the social world which are culturally derived and historically situated. Interpretivism maintains the view that the natural reality and the laws of science are different from social reality. Natural reality and social reality require different kinds of method. This leads to the interpretivist argument that, while natural sciences try to deduce laws based on consistencies in the data (nomothetic), social sciences deal with actions of the individual (ideographic). This ideographic-nomothetic distinction drawn in the context of interpretivism is noteworthy. This is because interpretivism as a qualitative research paradigm has a clearly defined ideographic identity (David, 2014).

The ontological position the interpretivist takes may be called *internal-idealist* or *relativist*, applying to one who considers realities as constructed locally and specifically. To the interpretivist they (realities) are holistic and dynamic (David, 2014). This ontological position takes the view that realities are mind-dependent. This means that “the knower and the process of knowing cannot be separated from what is known” (Michael, 2012, p. 18). From an epistemological point of view, both the investigator and the object of investigation are interactively linked. This means that research findings are actually created as the research proceeds. Therefore it may be argued that, in interpretivism, ontology and epistemology merge seamlessly, even though they are conventionally considered distinct (p.18). When it comes to methodology, interpretivists consider methodology "ideographic (something that uses a symbol to describe it without a word or sound), dialectical (relating to the logical discussion of ideas and opinions) and hermeneutical (a method or principle of interpretation)" (p.18). By virtue of the socially constructed reality, individual constructions are encouraged and refined through "interaction between and among investigators and respondents" (p.18). Conventional techniques of interpretations are used and are compared and contrasted through "dialectical interchange". These hermeneutical techniques do not eliminate conflicting interpretations, but strive for a "more sophisticated and informed consensus construction" (p.18). Another important assumption in interpretivist paradigm is that formulations that are made become more informed and sophisticated over time, while individuals become more aware of the "content and meaning of the competing constructions" (p.18).

4.4.1 Phenomenological aspects of this research

[17]Interpretivist paradigms may also be considered to conceptually overlap with phenomenology in general, when phenomenology is considered in its methodological meaning. A particular type of phenomenology known as *hermeneutic phenomenology or interpretive phenomenology* has inherent interpretivist characteristics (Art & Brian, 2014). Hermeneutic phenomenology is used as a research methodology to give voice to the "lived experiences" of the participants, leading to such voices being reduced to *themes* (p.1292). This is achieved by reading texts and transcripts with a view to "isolating the themes" which (the themes) are then treated as "written interpretations of the lived experience" (p.1292). Subsequently, phenomenological themes are isolated, after which the meaning of the lived experience is interpreted by rewriting the themes. Certain aspects of interpretive phenomenology, similar to 'isolation of themes', have thus been made use of in the analysis of textual data in this thesis (p.1292). However, Art & Brian (2014), interestingly, noted that in hermeneutic phenomenology the researcher uses "empathy or relevant prior experiences" as aids to data analysis and interpretation of meanings. This feature is referred to by these authors as 'reflexivity'; and is common to all interpretivist methodologies (p.1297). Reflexivity of the researcher has also had a profound influence on the analysis of textual data in this research. Phenomenology most often becomes an exploration of current cultural understandings through personal experience (David, 2014). Instead of using a theoretical model that forces an external

[17] Examples of interpretivist approach are: symbolic interactionism, phenomenology, realism, hermeneutics, and naturalistic inquiry (David, 2014)

logic on a phenomenon, phenomenology seeks an internal logic of the subject in which the units of analysis are often individuals (p.24). David (2014) further indicates that phenomenology makes use almost exclusively of the interview as a data-collection technique, while phenomenological research usually involves 5-15 participants (p.25). Another important feature is that relatively unstructured methods of data collection are employed in phenomenology. As a result of the unstructured character the research ultimately discovers factors that it originally did not plan to discover. Usually involving case studies, phenomenological research concentrates on thick descriptions of people's experiences, as a result of which the purpose of interviews is "not to look for answers but to allow data to emerge" (p.30). These characteristics were taken into account while selecting the participants for this research.

Figure 5 shows an overall research design ado pted for this research from the period of its conceptualization to that of formulation of conclusions, with three other significant phases in between. The idea of having the research structured in terms of different phases was taken from Sharon (2008). The organization of this research into different phases was, however, to suit particular needs, and hence differed significantly from that used by Sharon (2008). Phase 1 was made up of the researcher's constant interaction with the mathematical literacy students over a period of two years. The mathematical literacy curricular, instructional, and assessment experience which this researcher accumulated over the years contributed substantially towards the constructing of a personal philosophy for the researcher. In other words, Phase 1 of the research involved interactions with students at various levels that led to the realization that an alternative curricular approach was essential. The researcher's classroom experience thus constituted the most important factor that permeated the researcher's vision of an ambitious curricular transformation, philosophically grounded on a personal theory of such transformations. This vision manifested as a need for curriculum change in Phase 2, which triggered further thought processes entailing curricular needs. Identification and formulation of an appropriate curriculum model as an alternative to the current model constituted Phase 3 of the research. Phase 3 was thus yet another significant developmental stage in the research. Phase 3, once again, was conceptually rooted in the researcher's personal experience. However, it was immensely influenced by the multitude of curricular formulations that the literature provided. While a theoretical justification for the curriculum model chosen for the intervention may be traced to the current literature, the personal experience of the researcher also played a major part.

Phase 4 involved the curricular intervention designed and implemented with the suggested curricular alternative. Phase 4 comprised ten contact sessions with ten voluntary participants drawn from the current mathematical-literacy first-year course. Participants were introduced to and taken through a predetermined course sequence designed using principles of the Semi-Integrated Curriculum. The instructional intervention involved a pre-test and a post-test administered prior to and after the intervention. The pre-test involved certain context-based problems set up in the conventional style of mathematical-literacy course content. The post-test, on the other hand, involved context-based problems that used the same context as the pre-test; and also problems involving different contexts but employing the same underlying concepts.

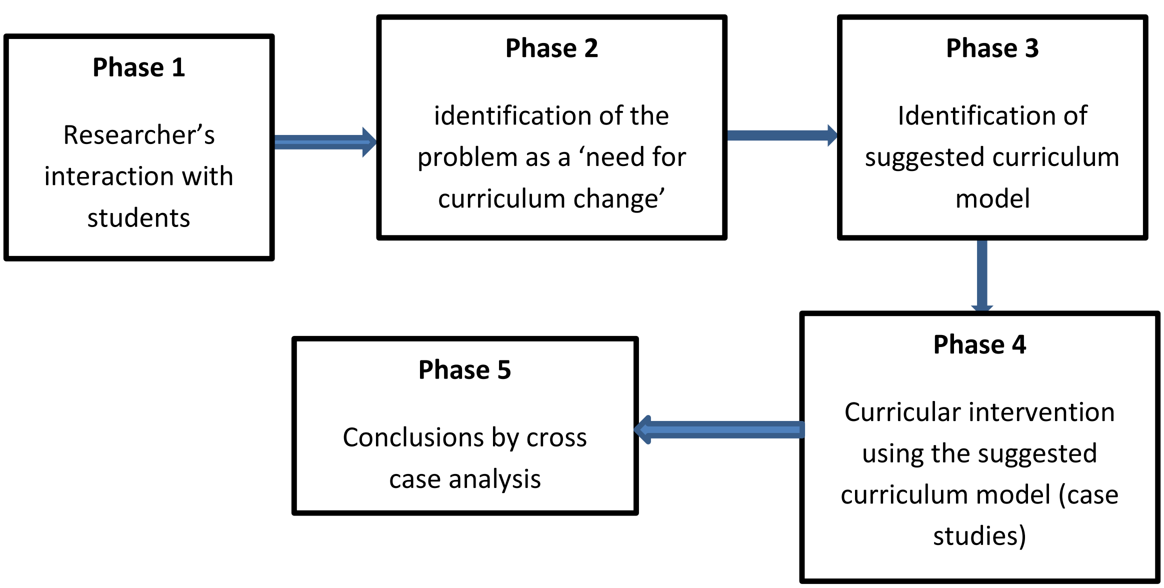
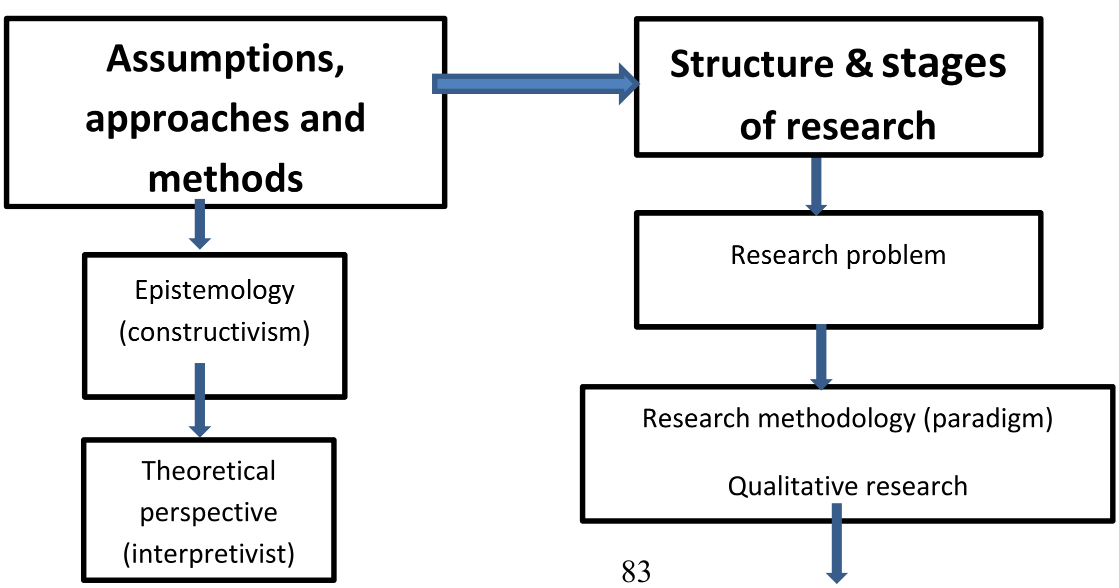


Figure 4 Different phases of the research

Figure 5 represents a comprehensive overview of the overall research design adopted for this research. The overview connects the fundamental assumptions, approaches, and methods to the associated structure and different stages of the research. This association resulted from the particular assumptions underpinning this research, also determining particular approaches and methods. Such methods, in turn, determined particular structuring or particular sequencing of different stages of this research (Dina, 2012).



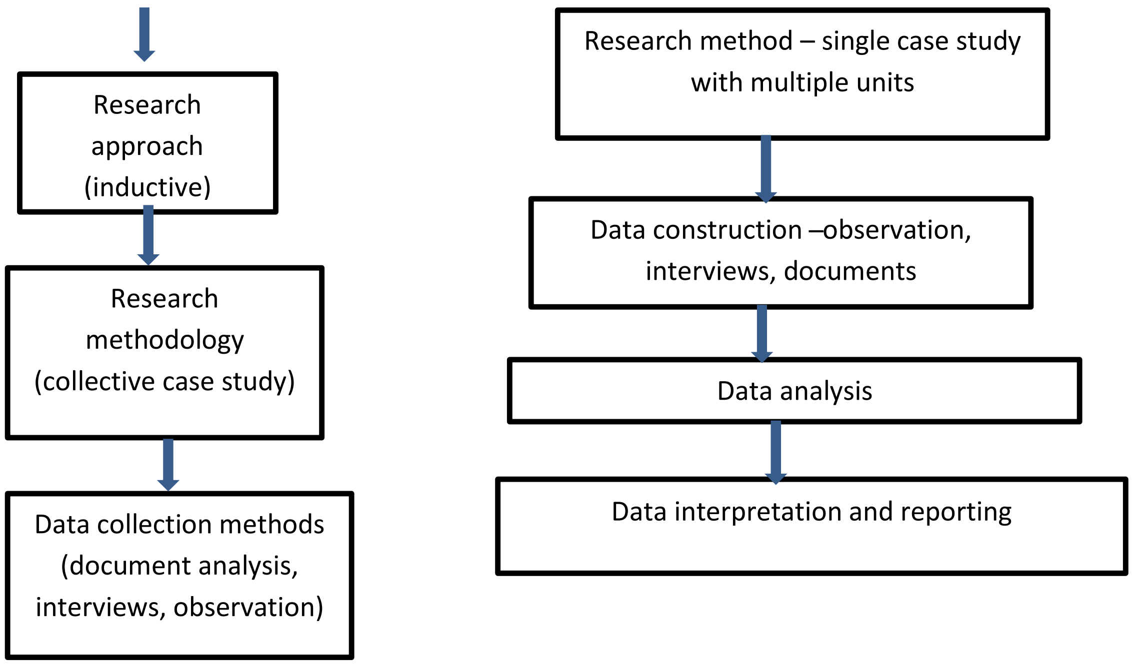


Figure 5 Overall research design adopted in this research

4.5 Research Methodology

"A methodology refers to a model to conduct a research within the context of a particular paradigm" (Dina, 2012, p. 72). Research methodology, in other words, is the science that deals with the principles of methods. Within the higher education system, however, there is no consensus on what the best practice is with regard to adopting the correct methodological models (Ryan, Ethan, Elizabeth, & Daniel, 2015). There is consensus, however, that several aspects of methodology should be appropriately emphasized in research. Those aspects are: careful documentation of the researched field, identifying of principles and rules of conduct, and constructing the research instrument and certification criteria for the results (Catalina & Anca, 2015). While these methodological aspects are vital for the practice of research, methodology itself is governed by the theoretical perspectives adopted by the researcher, and also, by implication, the researcher's epistemological viewpoints (David, 2014). These perspectives were thus instrumental in the categorization of this research as a phenomenological case study.

4.5.1 Phenomenological multiple (exploratory) case-study research method

"A case study approach is an in-depth examination of a particular case or several cases" (Marilyn, 2013, p. 90). As a method, case study involves a deep investigation of an authentic phenomenon occurring in a natural context (Dina, 2012). Case studies are usually associated with research that involves questions taking the form of *why* or *how.* One important aspect of case study is that no control is exercised over the behavioural events involving participants. A case may be limited to a characteristic, trait, or behaviour. A particular programme or a classroom could also become a case. The most important point here is that "what is studied is critical to the design, analysis and interpretation" (p.92). Marilyn (2013) also notes that information from case studies leads to rich and detailed insight into the cases in question. Generalization of findings, however, is not expected or viable in case studies (p.94). Case-study research may therefore be defined as "research that provides a detailed account and analysis of one or more cases" (Burke & Larry, 2012, p. 395).

A case is sometimes described as a bounded system; meaning that cases are to be seen as holistic entities constituted by different parts that operate in particular environments. A case may be described as a bounded system, implying that the boundaries of the system, namely, *what the case is* and *what the case is not* are extremely important in the context of a case-study research (p.395). Burke & Larry (2012) also point out that it is important to understand how the components of a system work together to understand that system. Even an individual as a system is considered to have many components. Examples are those in the realm of the cognitive, emotional, and physiological, together with the components of the context in which the case occurs. All these examples are thoroughly studied to explain the functioning of the case (p.396). Within this notion of case being a system, the fundamental problem defining what the case is, becomes significant (Yin, 2009). In this research, the case was the mathematical literacy module offered at University of Zululand. The ten participant students chosen from the first-year cohort within the Faculty of Education, University of Zululand, constituted the units of analysis. The individual student participant was therefore the primary unit of analysis (p.29).

Another important point Yin (2009) brings out is the five different components of a typical case-study research design, namely, a study question, its propositions (if any), units of analysis, the logic for linking data to propositions, and the criteria for interpreting the findings (p.27). While the case-study method is appropriate for *how* and *why* questions, and hence appropriate in the context of this research, the second component of *propositions* bears special mention. Propositions generally direct the attention of the researcher to something that should be examined within the scope of the study. However, the *how* and *why* questions capture what the researcher is actually interested in answering. This leads the researcher to case study as the appropriate method. What is interesting is that *how* and *why* questions do not point to what the researcher should study (p.28). The associated propositions, on the other hand, reflect important theoretical issues and tell the researcher where to look for evidence.

However, some case studies may not have, and rightly so, any proposition at all (p.28). These are studies in which the topic is the subject of “exploration”. Despite clearly defined theoretical propositions, exploratory case studies are generally driven by explicitly stated purposes. A purpose-driven as opposed to theory-driven case study thus becomes an exploratory case study. However, case-study methodology adopted in this research has, while maintaining its exploratory nature, incorporated a propositional element in its design to guide the exploration and subsequent data analysis. The theoretical proposition, as subsumed by the conceptual framework of this research, that a selective integration of concepts, skills, and contexts in the mathematical-literacy curriculum enhances mathematical literacy competencies among students, is the propositional element underpinning this research (Gregory, 2014). This research is therefore phenomenological, because it “made enquiries into how things seem to individuals” and hence the categorization of this research as *phenomenological exploratory case study* is thus justified (Snelgrove, 2014, p. 21)
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Having discussed the basic tenets of case studies, it is appropriate now to turn to the specific characteristics of phenomenological case studies under the category of which this research falls. The phenomenologist’s view that individual perspectives of lived experience evolve over time as people interact with their environment and social contexts, is a critical aspect of phenomenological thought (Roberts, 2009). In other words, while lived experiences of participants are the methodological focus of phenomenology, case study focusses on “developing an in-depth description and analysis of a case or multiple cases” (Creswell, 2013, p. 104). Creswell (2013) provides us with an excellent comparison of the two approaches, stating that phenomenology aims at studying several individuals who have shared the experience, whereas case study aims at studying an event, a programme, an activity, or more than one individual (p.105). Phenomenological case study, therefore, combines certain characteristics of both phenomenology and case study. While understanding the essence of experience is emphasized, detailed descriptions of multiple cases leading to cross-case analysis are also given sufficient weighting. Phenomenological case study, therefore, makes use of interviews, documents, observations, and artefacts as data-collection forms (p.105). In terms of data-analysis strategies, analysis focusses on significant statements, meaning units, textual and structural descriptions, and a description of the essence. The phenomenological case study also analyses for "themes of case or cross-case themes" using thick description of the cases. In the written report of the research, the essence of the experience of the participants is described through the analysis of the cases (p.105).

4.5.2 Sampling method used

This section aims to clarify the researcher's position with regard to the number and type of units of analysis chosen for the case study, a process which is formally known as sampling. Three different methods of sampling (i.e. the act, process, or technique of selecting an appropriate sample) known as random sampling, purposive sampling, and theoretical sampling, are generally used in qualitative research. Of these three methods, theoretical sampling was chosen for this research (Silverman, 2014). The logic of random sampling is not appropriate for qualitative research owing to its inherent validity problems (p.59). Purposive sampling, on the other hand, allows one to choose a case "because it illustrates some feature or process in which we are interested" (p.60). However, David (2014) warns that purposive sampling should be based on serious thinking about "the parameters of the population we are interested in" and those samples should be chosen accordingly (p.61). The third sampling type is the theoretical sampling which is synonymous with purposive sampling. The only difference between the two is that theoretical sampling is theoretically defined in all its aspects while the "purpose behind the purposive sampling is not theoretically defined" (p.62). However, in qualitative studies, selection of cases is always to be guided by appropriate theory, probably the theory that the researcher wishes to test.

Theory, in case studies, is also related to the study's generalizability. The point that Yin (2009) makes in this context is extremely important. Yin (2009) states that case studies are generalizable to theoretical propositions and not to populations or universes. In conducting a case study, the goal will be to expand and generalize theories, the practice of which is called analytic generalization (Yin, 2009). This point is noted for the type of case selections made in this research. The theoretical proposition, made in this thesis to the effect that SIC is capable of promoting general numeracy and HOTS, is what the cases selected in this study attempted to generalize. Therefore, the selection of cases was also governed by the same theoretical proposition in this research.

4.5.3 Analytical methods used

"Analysis of case study evidence is one of the least developed and most difficult aspects of doing case studies" (Yin, 2009, p. 127). Yin (2009) further notes that success in analysis depends heavily on an investigator's own style of rigorous empirical thinking, supported by a meticulous presentation of evidence, with significant weighting given to alternative interpretations.

Analysis of data in this research has been characterized by what is called *interim analysis,* defined as a "recursive process of collecting data, analysing data, collecting additional data, analysing those data and so on throughout the research process" (Burke & Larry, 2012, p. 517). Interim analysis is thus continued until what the researcher is studying is fully understood. A useful practice in a prolonged data-collection period is *memoing* which is the process of collecting notes "about anything" that are related to thoughts on emerging concepts, themes, or patterns appearing in the data. This researcher practised *memoing* extensively to record insights developed from reflecting on data periodically collected. *Memoing* was used specifically to record reflective thoughts after every contact session during the SIC intervention period. Reflective thoughts recorded in memos thus helped the researcher vividly reconstruct events unfolded during contact sessions so as to meticulously explore the lived experiences of the participants. *Memoing* was therefore the most fundamental yet consistently used data-collection technique associated with the interim analysis carried out in this research.

The following sections of this chapter are aimed at documenting the analytical methods used in this research in the context of the methodological standpoints taken by this researcher.

4.5.4 Qualitative data analysis- initial considerations

Qualitative research, by virtue of its use of inductive strategies, purposefully examines the 'whole' in its natural setting to gain perceptions of those interviewed and observed (Marilyn, 2013). Characterized by a lack of universal rules and standardization, qualitative-data analysis leaves much to the discretion of the researcher. This is because of its (qualitative data analysis) being "the most complex and mysterious of all of the phases of a qualitative project" (p.245). It is common practice among researchers to use more than one analysis protocol within the same research project. Marilyn (2013), however, remarked that the best way of analysing qualitative data, despite diverse approaches, "remains conflicting, or more likely, somewhat vague" (p.246). Yin (2009) had also stated that "analysis of case study evidence is one of the least developed and most difficult aspects of doing case studies" (p.127). Burke & Larry (2012) also noted in this context that many qualitative researchers had realized the need for an increased emphasis on systematic qualitative-data analysis procedures in related discourses (p.516). However, one important point Marilyn (2013) emphasizes is that the researcher has to clearly document how the analysis was carried out, despite such procedures' correctness not being assessed against any set of standards through lack of such standards (p.262).

Data analysis is conceptualized in different ways within qualitative research (Marilyn, 2013). "Identifying themes" is one way; and is the approach chosen in this research. According to this tradition, the large amount of data collected is subjected to a process of *sorting* and *sifting*. While there are no correct ways or clear rules for starting and executing this part of the analysis, one way is to start at some point to practice coding, looking for themes which might make sense of the data (p.249). However, some critics have questioned the validity of this approach. This approach, operating from a reductionist perspective, has questionable ability, according to the critics, to capture much of what a person thinks and feels, portraying it in five or six themes (p.249). In spite of this criticism levelled against thematic analysis in general, Marilyn (2013) contends that for those who follow the phenomenological tradition, and for those who are interested in the lived experiences of the individuals, as in this research, thematic analysis will be appropriate for data analysis. Marilyn (2013) further pointed out that, for pursuing the case-study method, a thematic approach may be used in such a way that building themes within cases and then comparing cases are useful techniques. Cross-case comparisons are also possible in multiple-case studies (p.257).

Having presented certain general commonly accepted perspectives that underpinned the qualitative research methods adopted in this research, the remaining part of this section proceeds to discuss the actual coding procedure followed in this research. The coding, which formed an important part of the analytical procedure, involved the following constituent steps described here. Data collected from interview transcripts, pre- and post-test scripts, and curriculum documents, were all analysed using this analytical procedure. Detailed illustrations of the process of analysis as a whole are, however, appended to Chapters 5 and 6 of this thesis.

4.5.4.1 Kinds of data constructed in this research

There were three main kinds of data constructed for this research. These were transcripts of interviews, pre-test and post-test scripts, and curriculum documents. Interviews with participants conducted before the contact sessions were described as pre-SIC interviews. Those conducted after the contact sessions were labelled post-SIC interviews. The transcripts of both yielded a significant amount of data which were analysed using the technique of thematic analysis. Written responses to mathematical-literacy tasks presented during the pre- and post-tests were also qualitatively analysed for underlying themes. Relevant curriculum documents published at departmental, faculty, and institutional levels, were yet another source of data which were also analysed thematically in this way. Informal notes made by the researcher during and after contact sessions, and during numerous informal contacts with the participants, were also analysed for themes, while the researcher's own reflections recorded throughout the research period significantly supplemented such data.

The following section deals further with the subtleties of the thematic analysis carried out in this research.

4.5.4.2 Segmenting and coding of interview, curriculum, and test data, for developing category systems

Segmenting essentially involved dividing textual data into meaningful analytical units (p.520). When the textual data as presented by the interview transcript, for instance, was studied, a particular segment of text that had a specific meaning which could be considered 'a meaningful unit of text' was identified. Such a meaningful unit could be a word, a single sentence, several sentences, or a paragraph. The segmented unit must have a meaning that the researcher can document. Segmenting subsequently led to what is called *coding*. Coding is the "process of marking segments of data with symbols, descriptive words or category names" (p.520). A meaningful segment of a text in a transcript was assigned a code or category name to identify that particular segment. In other words, segmenting and coding were sequential processes, in that, while segmenting involved locating meaningful segments of data, coding involved marking or labelling the segments with codes of categories (p.521). As new codes emerged during coding, such codes were included in the master list of codes containing the full names of the codes and associated descriptions or definitions. One important point here is that codes on the master list were repeatedly used when similar segments of texts were seen across cases in this case study.

Certain normal practices in coding are noteworthy here. Category names were usually words that described the content of the segmented data. Initially, names that were more abstract than the literal text were chosen, so that the name was applied to similar instances of the phenomenon elsewhere. The type of coding conducted here was inductive in nature, in that the codes were generated as a result of the direct examination of the data. This meant that the researcher did not use any *a priori* codes which are usually developed before examining the data (p.522).

4.5.4.3 Enumeration

Enumeration was the next important step that followed coding in the analysis of textual data in this research. This was particularly significant in the case of document analysis. However, enumeration was not used in the analysis of written responses to test questions. Enumeration, as practised in this research, refers to the determination of how frequently words or coded categories appear in the data. Frequency of word or code could indicate the importance of words or ideas in the context of cases. Prominent themes in the data could also be determined in this way. One important aspect of enumeration is that it does not always indicate prominence of a particular theme. There is the possibility that a particular participant might use a particular word frequently, whereas across cases the same word might have been used only with reasonable frequency. Enumeration was, therefore, practised cautiously, to avoid undue emphasis on themes that were of mediocre prominence.

4.5.4.4 Hierarchical category systems

Following enumeration, analysis of textual data involved the identification of hierarchical category systems. “Categories are the building blocks of qualitative data analysis” (Burke & Larry, 2012, p. 528). Categories constituted by themes identified after enumeration helped this researcher make sense of the data by the identification and study of categories that appeared in the data. Categories were therefore considered to form a classification system characterizing a particular set of data. Such categories eventually became the classification system, and thus represented broader dimensions of the data set. Categories were later organized into different levels: a set of subcategories would fall under a particular category, which in turn belonged to a higher category. Higher levels of categories were more general than those at lower levels.

4.5.4.5 Inter-category relationships

Burke & Larry (2012) give us a summary of different kinds of inter-category relationships, the formulation of which is originally credited to James Spardley (1979). Spardley’s table as indicated in Table 8 was used in this research as guidance on the categorization of data. As Burke & Larry (2012) aptly noted, the list was not considered exhaustive. Additional kinds of relationship were later identified during the data-analysis stage of this research.

Table 8 Spardley's Universal Semantic Relationships adapted from Burke & Larry (2012)

Title	**Form of relationship**
1. Strict inclusion	X is a kind of Y
2. Spatial	X is a place in Y; X is a part of Y
3. Cause-effect	X is a result of Y; X is a cause of Y

4. Rationale	X is a reason for doing Y
5. Location for action	X is a place for doing Y
6. Function	X is used for Y
7. Means-end	X is a way of doing Y
8. Sequence	X is a step (stage) in Y
9. Attribution	X is an attribute (characteristic) of Y

Identification and association of relationships among categories with any one of the above-mentioned types was helpful in the final stages of the analysis in this research. Most of the categories could be linked to at least one of the relationships. The most significant among them was the cause-effect relation which this research tried to explore. The cause-effect relationship was theoretically considered to exist between a curricular content driven by concept-context integration and mathematical-literacy competencies, and higher order thinking skills (HOTS). The codes assigned to different student responses, the themes that such codes led to, the categories that subsequently evolved, and the relationships between such categories eventually helped this researcher study the influence of a Semi-Integrated Curriculum on mathematical-literacy competencies and HOTS. The evolved categories and their significance in the broader picture of the Semi-Integrated Curriculum design and development were later explored. However, the data analysis as a process was then taken to a higher level of rigour by the creation of a typology which involved [18]mutually exclusive and exhaustive categories.

Analytical strategies and analytical techniques for case studies suggested by Yin (2009) may now be contrasted with those suggested by Burke & Larry (2012) for clarity of analytical choices made in this thesis. Of the four propositions made by Yin, two were relevant in the context of this thesis. These were *theoretical propositions* and *developing case descriptions*. The *theoretical propositions'* strategy is built around the idea that a set of theoretical propositions originally led to the case study; and that objectives and the design of the case study were based on those

[18] Mutually exclusive categories are those categories that are separate or distinct; while mutually exhaustive categories are those that classify all of the relevant cases in the data (Burke & Larry, 2012).

propositions. The same propositions reflected the research questions, review of the literature, and new propositions (p.130). The propositions shape the data-collection plan, giving directions on appropriate analytical strategies. The basic proposition made in this thesis, that a curricular strategy involving a set of essential skills and concepts, reinforced and consolidated prior to introducing contextual problems in mathematical literacy (conceptualized as a Semi-Integrated Curriculum) would lead to increased mathematical literacy competencies and HOTS, was traced in multiple cases. For each case, the purpose of the case study was to show how mathematical literacy competencies and HOTS changed as a result of the Semi-Integrated Curriculum intervention. This proposition may be considered the theoretical orientation guiding the case-study analysis in this research.

4.5.4.6 Cross-case synthesis

Cross-case synthesis, as used in this research, is generally used in the analysis of multiple cases (Yin, 2009). The technique of cross-case synthesis as employed in this research essentially treated each case on an individual basis. One way of carrying out this technique is to create word tables displaying data from individual cases based on the conceptual framework (p.156). Overall patterns in the word table led the researcher to certain conclusions. Additional word tables were created, representing other processes and outcomes of interest, which were also examined for underlying patterns.

Analysis of the whole set of word tables enabled the researcher to arrive at cross-case conclusions. Word tables created subsequently became complementary to one another, progressing from the single feature of a case by demonstrating sets of features on a case-by-case basis. The analysis now focused on similarities that various groups of cases appeared to share. Such cases were then considered instances of the same type of the general case. Such an observation helped the researcher analyse “whether arrayed case studies reflected subgroups or categories of general cases” which might lead to a typology of different cases that could be very insightful (p.160). The most important characteristic that Yin (2009) points out in this context is that cross-case synthesis is heavily dependent on the researcher’s skill in developing “strong, plausible, and fair arguments that are supported by data” (p.160). Cross-unit synthesis, as practised in this research, therefore, was one of the crucial stages, involving the strategic combination of conclusions derived from the study of ten individual units of analysis. These units formed the basis for the answers to the research questions posed in this research. Cross-unit synthesis as an analytical process will, however, be illustrated in detail in the data-analysis chapter of this thesis. The purpose here was simply to allude to it as the single most important analytical procedure forming the backbone of data analysis carried out in this research.

Underpinning the process of cross-unit synthesis, four basic principles that governed this case-study analysis were proposed by Yin (2009). These principles were extremely helpful at this stage: "attending to all the evidence, addressing all major rival interpretations, addressing the most significant aspect of the case study, and using the researcher's own prior, expert knowledge in the case study" (p.160). An exhaustive coverage of all available evidence precluded the possibility of alternative interpretations. An attempt to address all possible rival interpretations made the findings convincing. If an alternative explanation was provided by previous research for some of the findings, such findings were considered rival. The researcher then searched for evidence to address the rival interpretation. The most important aspect of the case study was, however, quite significantly addressed in the analysis so as to maintain the analytical focus on the main issue, irrespective of the possibility that the study might have produced negative findings (p.161). Lastly, the researcher's own prior knowledge and experience also significantly affected the way in which the analysis unfolded. At this juncture, as Yin (2009) noted, the researcher was expected to demonstrate a good awareness of "current thinking and discourse about the case study topic" which meaningfully influenced the conclusions of this research (p.161).

4.5.5 Data-construction methods employed in this research

The nature of data-construction methods used in this research could be clearly linked to what Creswell (2013) referred to as an emergent nature of qualitative data. This means that an increasing number of types of data are being classified as qualitative in nature. However, as Creswell (2013) noted, the types of data used in this research were: "observations (ranging from non-participant to participant), interviews (ranging from closed-ended to open ended), documents (ranging from private to public) and audio-visual materials (including photographs, compact discs and video recordings)" (p.159). How these types of data were made use of in this research is explained in the following four sections.

4.5.5.1 Literature review and document analysis

Marilyn (2013) noted the significance of literature review as a data-generation activity and advocated for it to be "interwoven into the framework of qualitative research project and be included in the written results" (p.175). Apart from its use for other aspects of this research in general, reliance on the review of literature as a secondary source of data in this research is acknowledged here (p.176). Literature has been reviewed in this research with a view to answering the main research question and sub-questions 2.1 and 2.2. This is apart from the fact that arguments have generally been formulated extensively in this research based on literature. In other words, this research has been heavily dependent on literature for all aspects, including research questions, theory, methodology, and data-collection techniques. This research thus considered literature review a secondary source of data for answering some of its research questions. Apart from the review of literature, several other sources of data have also been made use of in this research, which are: faculty documents, curriculum documents, interviews, direct observation, participant observation, post-test and pre-test scripts, written responses to questions, participants' academic records, and the researcher's reflections and daily notes on contact sessions. The role of literature review in this research in general and in the analysis of data derived from all these sources mentioned above cannot, therefore, be overemphasized. Literature review as an independent source of data, has also been made use of extensively in answering all the research questions in this research.

Documentary evidence was also extensively made use of in this study (Yin, 2009). Such documents may include letters, email correspondence, diaries, calendars, minutes of meetings, progress reports, newspaper clippings or articles that appeared in mass media (p.103). The most important role of documents in this case study was to corroborate and augment evidence from other sources. Inferences drawn from documents were, however, only to be treated as clues to be investigated further, rather than as verified findings. There is also a telling amount of criticism levelled against the 'overemphasis' given to documents in analysis of case-study findings (p.105). Yin (2009) warns the researcher against the possibility of documents being relied upon for the wrong reasons; or the researcher depending on those documents with questionable integrity being presented. The sheer quantity of documents with presumed relevance was overwhelming to this researcher; even though "focussing on the most pertinent information" reduced the quantity to a manageable level (p.105). Documents selected for such apposite information included faculty documents from various universities accessed online, curriculum documents from various institutions, course outlines and examination question papers, and memoranda collected for the period between 2012 and 2015.

4.5.5.2 Interviews

One of the important methods of data collection used in this research was interviews; interviews being considered vital sources of data in case studies (Yin, 2009, p. 106). There were two principal sets of interviews conducted with the participants, namely, the pre-SIC and post-SIC interviews (conducted before and after the research-based curriculum intervention). Pre-SIC interviews were conducted with all ten participants, based on a semi-structured interview protocol. Participants were asked a set of pre-designed questions with a view to eliciting participant perspectives. Such perspectives were based on their learning experiences, on issues that ranged from the level of appreciation of participants on the way in which mathematical literacy was taught. The changes they would like to see in the curriculum content and curriculum delivery were elicited. Participants were also asked about the extent to which they were able to transfer skills and concepts acquired in the mathematical literacy course to other disciplinary areas. Interview questions also involved issues related to the breadth and depth of content, the mode of assessment, and the extent to which such curricular characteristics contributed to the attainment of curricular and personal objectives that the participants set for themselves. One of the underlying purposes of the pre-SIC interview was to gain a clear understanding of how the participants experienced and viewed the way in which the *content driven by context* format of the current curriculum was effective in achieving the set curricular goals. Data generated by pre-SIC interviews thus produced a wealth of information which was used in answering the first three research questions.

Post-SIC interviews, on the other hand, focussed on many different issues. Also based on a pre-designed semi-structured interview format, post-SIC interviews elicited responses related to the learning experiences that the participants were taken through during the contact sessions. The fundamental objective here, and perhaps the most important one in the whole research, was to see the effectiveness of lessons designed according to the principles of the Semi-Integrated Curriculum. This refers to the SIC as conceptualized in this thesis for the enhancement of mathematical literacy competencies among the participants. Therefore the questions were intended to elicit whether Essential Skills and Concepts (ESCs), reinforced *per se* without being embedded into contexts in the preliminary contact sessions, helped build mathematical literacy proficiency essential for taking on content, contextualized in the 'conventional' format. Post-SIC interviews also focussed on a variety of aspects related to the particular way in which SIC content was delivered. Participants' comfort, ease, and confidence with which they (the participants) passed through the SIC-based learning experiences, in direct contrast with the kind of experiences that they went through in the normal lecture classes, were the striking aspects of what the post-Sic interviews tried to expose. Post-SIC interviews were also intended to gain participants' perspectives on the viability of having a full mathematical-literacy year-long course transformed into a SIC-based course. HOTS, another important aspect of student learning that this researcher tried to explore, was also an aspect on which the post-Sic interview was based. Even though a convincing proof of whether or not SIC-based learning experiences contributed to a noticeable increase in HOTS was derived from pre- and post-test responses, interview data provided significant clarity on how such increases might or might not have materialized. In brief, both pre-SIC and post-SIC interviews contributed substantially to the generation of data needed to answer two of the most relevant questions in this research.

4.5.5.3 Observation of participants during contact sessions

This researcher had thirteen contact sessions with the participants, each session being of two hours' duration. Contact sessions organized as part of the case study involving curricular interventions were "invaluable aids" for the effective understanding of the curriculum being practised (p.110). Observations of all the thirteen sessions were therefore of immense value to this research as a whole. The distinction drawn by Yin (2009) between direct observation and participant observation is important here. Direct observation refers to the observer's being independent of the phenomenon of interest, while participant observation takes place when the observer is part of the phenomenon. These two methods have both merits and demerits. Being a participant observer allows one to gain access to events or groups that are otherwise inaccessible. Having a participant observer also affords the opportunity of having an insider perspective; which is not the case with the direct observer. A participant observer also stands to gain from an ability to manipulate minor events not given to the direct observer. However, participant observation has a serious drawback, in the sense that such observation is subject to potential bias. The researcher is often tempted to be biased, assuming “positions of advocacy roles contrary to the interest of good social science practice” (p.113).

The advantages and disadvantages of direct and participant observations have all influenced the kind of observation practised in this research. This is because, while this researcher was the sole facilitator for the curriculum intervention contact sessions, he also acted as the sole observer of the events that unfolded during the sessions. A second, passive observer could have been used; however, such a feature was ruled out for fear of loss of spontaneity on the part of the participants, affecting their behaviour. The trade-off between unrestricted involvement of the participants and an opportunity of maintaining a structured observation protocol was considered. A balance was struck which allowed even weighting for both participant involvement and an adherence to the protocol.

4.5.5.4 Students’ workbooks and test scripts

Students’ workbooks and pre-test and post-test scripts were the major sources of mathematical-literacy task-based data collected from the participants. Pre-tests involved certain tasks structured in the conventional mathematical-literacy format, consisting of purely context-based problems. The context was built around the idea of ‘nutrients present in an adult salmon’ while the mathematical concepts were those of ratios and percentages. The whole task could be considered the application of the ‘Essential Concepts’ (so-called in this thesis), namely, ratios and percentages embedded in the context of ‘nutrients present in an adult salmon’ which could thematically be called ‘nutrients’. The ‘Essential Skills’ involved were those related to manipulation or conversion of ratios to corresponding percentages, or vice versa. In other words, there was a set of clearly defined Essential Skills and Concepts (ESCs) that underpinned the theme of ‘nutrients’. The pre-test, however, made no distinction between these ESCs and the contexts. Tasks were simply considered consisting of a few context-based problems similar to those found in conventional mathematical literacy school textbooks.

The post-test, on the other hand, was designed with the specific intention of checking the advancement of mathematical literacy competencies attained as a result of the participants’ exposure to SIC. The post-test therefore consisted of two parts. While the first part comprised tasks involving the same context and concepts underpinned by the same ESCs, the second part of the post-test consisted of tasks with the same concepts as the pre-test, but having a different context embedding the same concepts. The purpose of having the same concepts embedded into a different context was that participants' ability or absence thereof, to transfer skills to a different context could be explored – skills attained presumably by the exposure to SIC.

Apart from the pre-test and post-test scripts that produced a wealth of information about the complex ways of participants' mathematical thinking, the workbooks in which participants worked out tasks given during the contact sessions were also analysed for important themes that evolved. Students' informal working out thus found in their workbooks and collected over the entire intervention period revealed the intricate ways in which participants' cognitive engagements unfolded as intervention progressed. Participants' workbooks, together with the researcher's reflective remarks made and collected regularly, built up a data base that contributed to the holistic understanding of the participants' overall development in mathematical-literacy-related competencies.

4.5.5.5 Chain of evidence

To conclude the discussion on data-construction methods used in this research, the concept of *chain of evidence* as practised in this research must be mentioned (Yin, 2009). The chain of evidence refers to the use of data-based arguments for the purpose of producing a logical link between data, its interpretations, and the conclusions on which answers to research questions are based. The chain of evidence is, in other words, a series of both direct and indirect references to the raw data collected in this research. This principle helps the reader of the research report trace the "evidentiary process backward" (p.123). This case-study report in the chapters dealing with analysis as the first link in the chain of evidence, made sufficient citations from the case-study data base; meaning that citing from documents, interviews, and observations, was used to substantiate arguments in this thesis. It was also clearly shown that data collection had actually followed the case-study protocol. The protocol, in turn, indicated the link between its content and the research questions. In other words, an explicit chain of evidence indicated the researcher's movement from one part of this case-study process to another "with clear cross-referencing to methodological procedures and to the resulting evidence" (p.124).

4.5.6 Research validity

This section deals with the principles of research validity that guided this research as a whole. The ideas for this section were taken mainly from the works of Burke & Larry (2012), Marilyn (2013), and Yin (2009). Of these three authors, Marilyn (2013) has a distinct perspective, and has designed "personal criteria" by which the quality of a particular piece of research may be judged (p.294). The personal criteria have three dimensions: 'the self', 'the other', and the interaction between 'the self' and 'the other'. With regard to the self, Marilyn (2013) argues that the researcher should not try to achieve objectivity; and that the researcher should reveal himself through self-reflexivity. The term 'the other' refers to individuals who are studied, who are real people with "real needs, ambitions, fears and desires" (p.295). In other words, the self and the other influence each other, and remain influenced by each other. Both are transformed as a result of the research process. In the context of this research, 'the self' as an entity ever present in the domain of this research, was not purposely kept apart, but rather, its influence was acknowledged; due considerations being taken for its optimal influence throughout the research process. While this researcher was aware of his influence on student responses in the contact sessions and interviews, an effort was made, nevertheless, to keep such influences at an optimal level without compromising the integrity of the researcher or the validity of the research process.
Another set of criteria that this research considered to maintain research validity was the four distinct questions that Marilyn (2013) mentions in this context. The four questions are: What was studied? What was found? How was the study done? How does the writer communicate? However, many authors feel that it is impossible to have universally agreed-upon criteria to judge qualitative research along all these dimensions; arguing that external, objectified, oversimplified, and mechanical approaches to validity are to be avoided (p.303). This research, therefore, used these questions as broadly stated reference points for validity-related issues: more emphasis was placed on three other distinctly classified dimensions of research validity put forward by Burke & Larry (2012).

Burke & Larry (2012) state that trustworthiness refers to research validity in qualitative research. 'Research validity' refers to the degree to which a piece of research is deemed plausible, credible, trustworthy, and hence defensible. One potential threat to validity stems from *research bias.* Such bias manifests itself in the researcher's purposeful effort to find what the "researcher wants to find" (p.264). Researcher bias tends to result from selective observation and selective recording of data; and also from freely allowing personal views to influence data interpretation. This research used certain strategies to control bias. They were *reflexivity* and *negative case sampling*. A self-reflection by the researcher apropos of his or her biases and preconceived notions is known as reflexivity (p.265). Negative case sampling refers to selecting cases that are expected to disconfirm the researcher's expectations and generalizations. Negative case sampling leads to a meticulous treatment of data that makes it difficult to ignore important information. A broad review of the three types of validity: descriptive validity, interpretive validity, and theoretical validity, is now attempted in the following section. The following account also reveals the measures taken to maintain the validity of this research along the four distinct dimensions mentioned above.

4.5.6.1 Descriptive validity

This validity refers to "the factual accuracy of an account as reported by the researcher" (p.265). The questions of whether what is reported actually took place or whether what is reported is a reflection of what actually happened are the points to be noted in this context. Descriptive validity essentially involves accuracy in the descriptions of events, objects, behaviours, and people, inter alia. This is because description is fundamental to qualitative research. One strategy used to enhance descriptive validity is the practice of investigator triangulation. This involves making use of multiple investigators in the collection and interpretation of data. If multiple investigators corroborate in findings the research is deemed credible and defensible (p.265). However, the use of multiple investigators was not practised in this research. Apart from the fact that it was logistically arduous, there were clear indications that the participants would have been reluctant to show spontaneity because of presumed unfamiliarity with an external observer. This case-study observation, in the presence of an external observer, would have been reduced to a mere mechanical exercise. Therefore, this study had the researcher himself as the sole investigator.

4.5.6.2 Interpretive validity

Interpretation as a discourse technique was inherent in the very design of this research. Interpretation of data was therefore fundamental to the methodology adopted for this research. Interpretive validity as an aspect of research validity refers to the degree to which the researcher understands and portrays accurately the participants' viewpoints, thoughts, feelings, intentions and experiences (p.265). Interpretive validity is also an indication of the researcher's ability to see things through the eyes of the participants; and to be able to see and feel the same way as the participants. In this way, the researcher was able to produce a valid account of the participants' perspectives. *Participant feedback* was used to enhance interpretive validity in this research (p.267). The interpretations that the researcher arrived at were shared with the participants to check for miscommunication. Within the constraints of the participants' sincere responses, inaccuracies were identified in this way. *Low-inference descriptors* also helped the researcher in this context. A description that is phrased very similarly to the participants' accounts and the researcher's field notes is called a low-inference descriptor (p.267). The reader, in this way, is given the real feeling of the raw responses before such responses are refined by the researcher. When the participant's exact words are reproduced in direct quotations this is the *verbatim* description, the lowest inference descriptor. There were two instances in which the participants' responses to sets of prepared questions were recorded. Verbatim descriptions of the responses were extensively used in this research to depict such responses as truthfully as possible. The participants' voices therefore dominated the analysis, and helped the researcher to present a holistic picture of the scenario.

4.5.6.3 Theoretical validity

"Theoretical validity refers to the degree to which a theoretical explanation developed from a research study fits the data and is therefore credible and defensible" (Burke & Larry, 2012, p. 267). It also refers to the validity of "the researcher's concepts and the theorised relationships among the concepts in context with the phenomena" (Thomson, 2011, p. 79). The appropriate question here is whether the researcher was able accurately to explain the phenomena (p.79). Questions may also be raised about the extent to which the researcher was able to organize theoretical constructs that he (the researcher) created, so that they all fit together to produce coherence. The degree to which the patterns, concepts, categories, properties, and dimensions collectively lead to constructs, which in turn "tell the story of the phenomena" lends itself to theoretical validity (p.79).

A strategy used for enhancing theoretical validity in this research was *extended fieldwork* (Burke & Larry, 2012). This meant that an extended period of time of contact with the research participants at various levels was maintained. Patterns of relationships arrived at by the researcher could be confirmed to be operating at a stable level; the reasons behind those relationships being well understood. One associated idea in this regard is that the theoretical explanation might become more detailed, which calls for *theory triangulation* (p.268). Theory triangulation is the process of examining the phenomenon using various theories. Multiple theoretical perspectives helped this researcher obtain a "more cogent explanation" (p.268). Even though this research was primarily underpinned by one particular theory – that a curriculum content optimally integrating concepts, contexts, and essential skills, will enhance mathematical-literacy competencies and HOTS, alternative theories were not completely ruled out. In other words, this researcher did not force this particular theoretical perspective on the data. The phenomenon called 'the attainment of mathematical literacy competencies' as unfolded in the data, was scrutinized from various theoretical perspectives, thereby avoiding the sole dependence on one particular theoretical proposition.

As the theoretical explanations were further developed, more predictions based on the theory were made, the accuracy of which were further tested. It is here that the *pattern matching* strategy was used. This strategy involved making several predictions at once. In the event of all those predictions coming to pass, the explanation was considered "supported by evidence" (p.268). While the theoretical explanation was developed, the *negative case sampling* strategy was also used. As per this strategy, an effort was always made to find cases that did not fit into the explanatory framework. The researcher thus guarded himself against the tendency of simply finding data in support of the theory. However, a general rule in this context was that the researcher's final explanation reflected the views of a majority of the participants (p.268).

Of all the strategies described above, *extended fieldwork* deserves special mention. Apart from the fact that the researcher was the lecturer responsible for teaching mathematical literacy, he (the researcher) was in direct contact with the participants at various levels. Contact sessions were held for a period of one month, for a total of approximately twenty hours, in addition to numerous instances of informal exchanges of ideas with the participants. Therefore this researcher is confident that extended fieldwork was effectively used in this research as a strategy for building validity. However, *investigator triangulation* was not a strategy used in this research. The use of other strategies will be further explained in the context of answers to appropriate research questions dealt with in the following chapters of this thesis. These strategies will also be explained in the context of analysis of data, which is the topic of discussion for the next chapter.

4.6 Conclusion

Within a qualitative research paradigm this research used a single-case study with multiple units of analysis. While the mathematical literacy course offered at the University of Zululand was the case, the ten student participants were the units that constituted the single case. Through an interpretive analytical perspective, this research used the principles of phenomenological exploratory single-case study as the methodology. The kinds of data constructed were transcripts of interviews, pre-test and post-test scripts, and curriculum documents. The techniques of thematic analysis and cross-unit synthesis were used to analyse data from a variety of sources such as literature review, documents, interviews, participant observation, contact-session workbooks, and test scripts. Various principles of validity, such as descriptive validity, interpretive validity, and theoretical validity, were also followed during the research period.

CHAPTER 5
DATA ANALYSIS

5.1 Introduction

This chapter deals with the data analysis part of this research. Analysis of interviews and analysis of documents form the central part of this chapter. Participants' work scripts and test scripts are also analysed here, in accordance with the analytical methods described in Chapter 4. A collection of informal notes and anecdotal records compiled over the entire research period also provided invaluable sources of information. The analysis conducted here is therefore a process that involved the compilation and scrutiny of data from a variety of sources. The main sections in this chapter are devoted to various types of data and the analysis thereof. This chapter therefore provides a detailed picture of the analytical process followed in this research, with intermittent illustrations of that process, using sections of actual data collected. Conclusions reached as a result of the analysis will, however, be dealt with extensively in Chapter 6 in the form of answers to research questions.

5.2 Analysis of documents

Documents collected mainly involved curriculum documents, course outlines of two separate semester modules ESML 111 and ESML 112, study guides, examination, test, and assignment question papers, faculty handbook, and other university publications regarding rules and regulations that govern the teaching, learning, and the design of instructional material. The purpose of document analysis carried out in this section was specifically to answer the main research question 1 which explores the modalities of designing a mathematical literacy curriculum based on the principles of SIC. Document analysis also helped answer the research sub-question 2.1 which refers to the purpose of a mathematical-literacy module taught as part of a BEd programme. The envisaged purpose of a mathematical-literacy module, and the extent to which such a purpose has or has not materialized at curricular, instructional, and assessment levels, were explored in detail in this section. The question 'What is the purpose of a mathematical literacy module taught as part of a BEd programme?' is therefore answered by the analysis of curriculum, assessment, and instructional materials, revealing the extent to which the purpose of the module was realized in practice. The answer to this research question, however, inadvertently made implicit references to 'what should be the purpose' while exploring 'what is the purpose'. An exploration of the design and development of SIC as a research process was therefore conceptually supported by both. It is to this context of answering this research question that national and international literature have contributed significantly.

5.2.1 The Mathematical literacy (ESML 111) course/module outline

The course outline considered here for analysis had a letter written by the lecturer as the preface to the module outline. This was followed by the actual module outline which was designed according to a newly approved template. The letter, addressed to the students, at the very outset clearly stated that the purpose of the module was to "consolidate essential mathematical skills and understanding with a heavy emphasis on academic and non-academic contexts in which such skills are embedded". It further said that the content covered in the outline must not be considered prescriptive. This meant that students were expected to engage with contextually relevant mathematical ideas that "cut across disciplinary boundaries". The most significant curricular aspect mentioned in this letter was that the purpose of this module was envisaged as the developing of mathematical skills and understanding deemed appropriate for the non-science major students to efficiently manage mathematically rich academic and non-academic contexts. 'Consolidation of mathematical skills and understanding', therefore, may be considered the central tenet around which the purpose of this module was conceptualized at the departmental level, thereafter implemented through the curriculum. The extent to which this central tenet is followed in the actual module structure can, however, be seen in the way in which content matter was structured in the module outline.

The module outline template was divided into various sections such as ‘purpose’, ‘outcomes’, ‘content’, ‘assessment procedure’, ‘assessment criteria’ and ‘prescribed readings’. The anticipated outcomes were the ‘confident use of numbers to solve authentic problems’ and ‘the ability to model situations using functions and graphical representations’. ‘The ability to describe, represent and analyse shape and space in two and three dimensions using geometric skills’ was yet another outcome stipulated. Lastly, the module outline envisaged the ability to use computational tools such as scientific calculators to enhance the attainment of mathematical literacy competencies. Under ‘Module content’ the document provided a list of content topics under two fields, viz. ‘Number and operations in context’ and ‘Functional relationships’. While the concepts of percentage, rate, ratio, interest rate and profit margin were treated in the first section, the second section dealt with linear functions, graphs, rates of change, quadratic functions, exponential equations, and linear programming. After briefly mentioning that equal weighting would be given to continuous assessment and final examination, the document went on to state the various assessment criteria that govern the attainment of outcomes.

Four clearly stated assessment criteria brought out the academic-achievement-related expectations. The action verbs used in the four criteria were: use, demonstrate, and calculate. The first two criteria spoke to the use of numbers in contextualized problems, and the demonstration of understanding of basic functions and related problems in context. While the third criterion centred on the accurate calculation of simple and compound interest, the last of the four criteria set out to check how well the student demonstrated calculator skills.

The last section of the outline was devoted to ‘prescribed readings and additional (recommended) readings’. In addition to a prescribed study guide prepared by the lecturer, another book titled “Basic College Mathematics: An Applied Approach” (Richard, 2011) was recommended for enrichment purposes. The module outline then concluded its prescriptions with a suggestion that students be in possession of a notepad and a calculator as the ‘materials needed for the module’.

5.2.2 The Mathematical-literacy (ESML 112) course/module outline

The second semester module ESML 112 was structured in more or less the same vein as the first semester module, even though the outcomes and assessment criteria differed significantly. The module could be broadly said to consist of financial mathematics and statistics as the major topics. The outcomes were conceived around action verbs of 'read and interpret', 'identify', 'classify', 'plan', 'evaluate', 'calculate', and 'analyse'. Of the nine outcomes stipulated, the first four focussed on basic calculations of personal finances, while just one focussed on geometrical shapes. The last three outcomes centred on basic statistics.

Assessment criteria for this module were, however, limited to six, of which the first three targeted management and critical analysis of financial information leading to the use of discretion in the financial decision-making process. While one criterion concentrated on perimeter, area and volume of two- and three-dimensional figures, two others were based on interpretation of statistical graphs and charts and a basic understanding of probability. The particular way in which outcomes and assessment criteria are formulated in these two modules was noted here. Such criteria have implications with regard to their alignment and the curricular effectiveness to which such alignment leads (Brian & Marian, 2011). This alignment will be scrutinized later in this chapter.

5.2.3 Identifying codes using a coding matrix

The illustration given in Table 9 shows how the data from the course outline was coded. Significant meaning-making chunks of text from the course outline was first taken, and an appropriate description or code attributed to it. Under 'preliminary thoughts' the codes were further given a higher level of abstract attributions. These preliminary thoughts were later associated with broader categories which were called 'initial categories'.

Table 9 Identifying codes-coding matrix

Text from module outline	Description (code)	Preliminary thoughts (what this is about)	Initial categories
"An overall development of mathematical literacy as a competency is central to the purpose of this module"	Mathematical literacy as a competency and its overall development	Indication that curricular content consists of a variety of aspects of the same entity known as ML	Multiple aspects of the same competency

"It is aimed at consolidating essential mathematical skills and understanding with a heavy emphasis on academic and non-academic contexts in which such skills are embedded"	Aims at skills and understanding. Academic and non-academic contexts	Indicates curricular emphasis on skills and understanding embedded in contexts	Contexts drive content
"cover most of the significant mathematical aspects of curricular content that you are likely to come across in other modules"	Cross-disciplinary nature of curriculum	Indicates the need for identifying the cross-disciplinary needs of the curriculum	Curriculum cuts across disciplines
Module purpose: "To help all first year (non-mathematics major) students in the Faculty of Education develop mathematical literacy as a competency which in turn helps them use mathematics in all aspects of their day-to-day lives."	To make the students competent in the use of mathematics in their daily lives	Use of mathematical knowledge and skills for the betterment of personal lives	A utilitarian approach to attainment of knowledge and skills
Outcomes : "use numbers, model relevant situations, represent and analyse shape and space, use computational tools"	Module covers basics in numerical calculations and geometry, use of calculator emphasized	Coverage of a variety of algebraic and geometrical concepts, no indications of what contexts would look like	A traditional approach to curricular structure
Assessment criteria: "Student uses numbers with confidence, demonstrates	Understanding of concepts and accuracy of calculations	Criteria uses understanding and accuracy as measures of educational attainment	Curricular focus on conceptual mastery and accuracy

understanding of concepts, accurately conducts calculations, demonstrates skill in the use of calculator”			

The initial categories arrived at indicate various aspects of the curriculum that are noteworthy. In Table 10 various sets of initial categories were taken together to indicate the initial themes that evolved. In the following instance, two initial themes were arrived at which indicated the overarching purposes for which the mathematical literacy curriculum was conceptualized and implemented by the faculty.

5.2.4 Coding index

Table 10 Coding index

Initial categories	**Initial themes**
Multiple aspects of the same competency	Progressive and integrative curriculum
Contexts drive content	
Curriculum cuts across disciplines	
A utilitarian approach to attainment of knowledge and skills	A traditional curricular perspective
A traditional approach to curricular structure.	
Curricular focus on conceptual mastery and accuracy	

As coded in Table 10 the themes that evolved were ‘Progressive and integrative curriculum’ and ‘A traditional curricular perspective’ both indicating the kind of instructional intentions that drove the curriculum. Progressive and integrative characteristics refer to the aspirations of the curriculum makers who embrace progressive ideals such as student-centred instruction and an emphasis on a variety of higher-order competencies. Integrative characteristics refer to the prospects of a curriculum that is based on interdisciplinary contexts which, in the case of the mathematical literacy module, translates to contexts being drawn from a variety of disciplines, whereas the content remains purely mathematical in nature. The curriculum, as envisaged in the module outlines, in terms of its objective, was fundamentally characterized by purposes which were both progressive and traditional at the same time.

5.2.5 The Faculty handbook

The faculty handbook is the official information booklet published every year by the Faculty of Education, University of Zululand. It contains detailed information about the faculty and its functions. It also contains information about the courses it offers, and the syllabi. The faculty handbook, as a whole, and its descriptions of modules in particular, may be considered in line with the official and thus institutionally approved interpretations of the way in which the modules are to be presented in terms of these aspects. Each module in each department is described in terms of four of its aspects, namely, purpose, content, instruction, and assessment. The description given in the handbook significantly differs from that given in the course outlines of these modules. Each of these aspects of ESML 111 and ESML 112 as given in the faculty book is analysed in Table11.

Table 11 Analysis of course outline as seen in the handbook

Text from Faculty handbook	Description (code)	Preliminary thoughts (what this is about)	Initial categories
ESML 111			
Purpose : To use situations or contexts to reveal the underlying mathematics while simultaneously using the mathematics to make sense of situations or contexts, and in so doing develop in students the habits or attributes of a mathematically literate person	Bidirectional relationship between contexts and underlying mathematics, each helping to make sense of the other.	Mathematical literacy is about both contexts and concepts, the curriculum emphasizing both equally.	Context and concept are of equal importance
Content: working with patterns; working with equations	Content limited to patterns and equations	Very limited curriculum content	Curriculum not properly conceptualized
Instruction: instructional method includes lectures,	Variety of instructional methods		

group discussions, independent learning and research/study projects **Assessmen**t: continuous formative assessment through participation in class, assignments and presentations, summative assessment through to examination in June.	'Participation in class' as an assessment method, final examination considered 'summative'	Learning takes place in different ways Formative assessment emphasized, wrong meaning attributed to 'summative assessment' to mean just one exam	Multiple instructional methods Progressive, yet inherent misconceptions about assessment
<u>ESML 112</u> Purpose & assessment is the same as **ESML111** **Content:** Ratio and proportion, speed, time and distance, polygons, perimeter and area of triangles, area of circles, prisms	A mix of algebra and geometry completely different from ESML111, not in any order	Content not aligned with ESML 111	Inappropriate choice of content

A comparison of the course objectives and characteristics as indicated by the course outline and by the handbook offered interesting aspects that emerge in contrast. A serious mismatch of content across semesters and the inclusion of content of peripheral breadth and depth, raised weighty questions about the legitimacy of objectives the curriculum strived to achieve. Therefore the purposes of the curriculum as indicated in the course outline and handbook are not formulated to mean the same thing and are therefore structurally incompatible.

5.2.6 Study guides

The way in which the study guide for ESML 111 was structured in terms of its content, in comparison with what was published in the faculty handbook about the envisaged curriculum content of the module, made interesting exploration. The study guide opens with a section on 'Basic ideas in mathematics'. This section involved a detailed treatment of fractions and decimals with extensive applications in numerical examples devoid of any contexts. A significant aspect of this study guide was the intermittent sections called 'applying the concepts', followed by exercises involving numerical problems. However, 'applying concepts' generally involved contrived word problems that mimicked authentic situations. These were problems such as "If a recipe calls for $2\frac{1}{2}$ cups of sugar, how much sugar is needed to make $\frac{1}{3}$ of the recipe?" This was followed by a section on decimal fractions and the conversion between decimal numbers and fractions. Numerical problems based on 'rounding off to the nearest tenth, hundredth, and thousandth' constituted one of the latter sections of the study guide. The very last section focussed on ratio, proportion and percentage with numerical as well as pseudo-authentic contrived word problems involving those concepts. Once again the study guide stopped short of presenting problems in real-life contexts.

The second semester module ESML 112, on the other hand, centred primarily on basic financial mathematics and fundamentals of statistics. The section opens with the concept of simple interest calculations followed by compound interest calculations built into partially contrived word problems. Word problems in this section generally were designed around contexts with limited authenticity. An example would be: "An office building is purchased for R 1 500 000 with a down payment of 25% of the purchase price. Calculate the mortgage." This is followed by a section of real-estate expenses that involved word problems intended to be solved by the manipulation of the compound interest formula which had been dealt with in the previous section. What followed was a section on 'car expenses' which dealt with the calculations of 'purchase price' and 'down payment'. The difficulty level of this section was, however, of the lowest, because of a deliberate omission of complex compound-interest-related calculations. The scope of student engagement was therefore limited to the calculation of a certain percentage of an amount, as in: "A car is purchased at R 38 000 and the lender requires a down payment of 15% of the purchase price.

Calculate the amount financed". The study guide then presented 'wages' as a section to deal with calculations of commissions, wages and salaries. The fundamental mathematical concept and skill involved, however, were still those of percentage. All these finance-related ideas had the fundamental mathematical concept 'percentage' built into them (the concepts) both at a conceptual level and at an application level. The last topic in the study guide 'Histograms and frequency polygons' began by introducing histograms, giving brief descriptions of the terms 'class interval' and 'class frequency'. This was followed by consolidation of skills related to reading and interpreting statistical graphs in general and frequency polygons in particular, by the use of contrived statistical problems, drawing contexts from finance-related issues.

5.2.7 Tests, assignments, exam papers, memoranda, and scripts

Tests, assignments, exam papers, memoranda and scripts for the year 2014 were scrutinized to ascertain the purpose of assessments (in terms of skills, concepts, and HOTS assessed, and contexts used) and the extent to which such purposes were aligned with the purpose of the module as stipulated in the module outline and faculty handbook. The purpose of analysing those documents was also to study the manner in which the curriculum with its set purposes was received and responded to by students, as reflected in the test and assignment scripts of ten participant students. Only three types of assessment were used in this module: assignments, tests and examination. The main aim of examining these documents was, therefore, to study, as mentioned above, the overarching purpose of the mathematical-literacy module as conceptualized, taught and assessed at University of Zululand.

5.2.7.1 Analysis of tests

Tests administered for this module were studied for the extent to which test as an assessment type was aligned with the overall curricular purpose as set out in other documents. The fact that only one test was written during the semester was attributed to the logistical problem of marking close to seven hundred scripts. This was the same reason for using multiple-choice questions for the test and examination instead of the more conventional descriptive type questions used in mathematics assessments. While the credibility and validity of such an assessment method in a mathematical literacy course at a university level is worthy of exploration, it was the type of questions set in those assessments that was the focus of scrutiny in this research. More specifically, the extent to which context–concept integration underpinned the design of test items remained under the spotlight of research scrutiny. Added to this was the fact that a component of descriptive questions written in traditional test answer books has recently been added to the other component of multiple-choice questions in an attempt, according to the HOD, to strike a balance between the two types. However, while the weighting for multiple choice was fixed at 80%, the descriptive section was given 20% in the test and examination question papers.

The test was administered prior to the enforcement of the new regulation, and hence had twenty multiple-choice questions. The questions were designed mainly to test the understanding and skills related to basic operations involving fractions, area, and perimeter of basic geometric figures, and place values of digits in decimal fractions. The paper presented a mix of word and numerical problems based on these concepts and skills. However, as previously noted, the word problems were merely presenting contrived contexts with which the embedded numerical aspects failed to remain integrated. In other words, the problems fell short of being authentic. A typical context – content integration as seen in these problems was of the type: "A family decides that they can spend $\frac{3}{8}$ of their monthly income on house payments. If their monthly income is R 2120, how much can they spend on house payments?" This was merely a purposeful attempt to integrate a purely numerical problem with a trivialized context. Another example: A bus travels $55\frac{14}{22}$ k.m using $10\frac{2}{3}$ litres of diesel. What distance in km does it cover on 1 litre of diesel? This example also illustrates the kind of context-content integration that underpinned the type of tasks that appeared in the test. This aspect of integrative attempts made, characterizing the assessments, is further elaborated on under the 'answers to research questions' section of this thesis.

The fact that more than 90% of students managed to score above 80% for this test may imply that questions were set at a very low difficulty level; and that the use of calculators might have helped the students overcome/bypass an apparent lack of basic computational ability. Whether or not to restrict the use of calculators to only relatively complex problems was a contentious issue throughout the research period. As to how to implement such a proposition in a test or examination scenario was an even more complicated issue. The use of calculator, as this researcher found, was one of the most significant factors that influenced both positively and negatively the attainment of mathematical literacy competencies. In other words, there were instances in which the use of calculators helped enhance mathematical conceptual understanding, while in certain other instances such use merely obscured the basic numerical ability. The attainment of Higher Order Thinking Skills, however, was an aspect that undoubtedly was positively influenced by the use of calculators; especially in the case of participants who were otherwise fluent in basic arithmetic. The issue of calculator usage will, however, be dealt with more contextually in the next chapter of this thesis.

5.2.7.2 Analysis of the assignment

The assignment administered during the research period also had the same weighting of 25% as the test. However, the assignment as an assessment item intended to be carried out over an extended period of time had unique, purpose-related characteristics. There were two questions with numerous sub-questions attached. The first of the two questions contained the concepts of radical expressions, decimal fraction and ratio, and the skills of currency conversion, interpretation of bar graph, and interpretation of a cash-sale slip. The last sub-question had a grid of data on which names of countries from which South Africa imported crude oil in the years 2010 and 2011 were indicated against the corresponding quantities of oil imported. Sub-questions of the type "Which country showed the largest increase in the amount of crude oil exported to South Africa between 2010 and 2011?" were set using the same context.

The second question, on the other hand, had a 'spin wheel' divided into 24 equal sectors as the context. When the wheel stops after being set in motion, the arrow could point to any of the 24 sectors. The task went on to say that half of the sectors was grey, one third was white, and one eighth was black. One twenty-fourth was spotted. The sub-questions were built around the skills of calculating circumference and area of circles. The second question also had a sub-question based on the context of percentage increase in driver-reaction time while the driver of a car is simultaneously using a cellphone. Another sub-question was based on the context of "Travelling to Pretoria" in which the distance –time graph was given, from which the students were asked to read and interpret various positions of two travellers at various times. The last sub-question focussed on service fees charged by a bank on different transactions. Working within a table of different transactions and corresponding bank charges, one missing value each from the transaction list and from the service-fee list was to be calculated using two given formulae. This particular question has a unique characteristic in that, while it involves an interesting context of bank transactions, the actual solution involved was a direct substitution of values in a given formula. This reduced the mathematical level of the problem to that of mere manipulation of formulae, or an algorithmic practice that involved no HOTS whatsoever. The associated context added no authenticity other than references to a few finance-related words. In other words, this task was a perfect example of what a context-driven mathematical literacy task should ***not*** be. An overall assessment of these tasks set as an assignment is that, while a set of essential skills based on context-free tasks indicated the emphasis on such skills, the rest of context-based problems generally failed to reach a desirable standard of context – content-skill alignment.

5.2.7.3 Analysis of final semester examination

The examination paper analysed here was written in June 2015. The paper consisted of two parts. While the first part was made up of multiple-choice questions worth 80 marks, the remaining 20 marks were drawn from descriptive questions. The first part had, much the same as seen in the test, a set of purely numerical problems on complex fractions. This was followed by a few place-value and ratio-based numerical problems. While another set of questions was based on equivalent ratio and percentage, the last section dealt with calculations based on a pie chart. The section B, however, had two context-based problems. The first of the two was based on an electricity-tariff table which contained tariffs for various brackets of consumption. The context for the second problem was also based on tariffs for telephone calls which varied according to call distance.

From the perspective of curricular purpose as reflected in the final examination of a particular module, the structure of the paper analysed here was very interesting. This was because, while 80% of the weighting was on partially contrived and numerical problems of the most basic nature, only 20 per cent weighting was attributed to several context-based problems. From the point of a curriculum that heavily emphasizes context-based authentic tasks, this paper could be considered a ‘skill-dominated assessment’. The range of skills tested was limited in itself, such skills being used in authentic context not being a feature of this examination paper. A conscious effort was seen in the paper to test the skills attained with regard to certain basic mathematical operations and manipulations; however, the application of such skills in contexts was not appropriately tested. This paper, therefore, was heavily biased towards the assessment of computational skills which, within the ambit of the Semi-Integrated Curriculum, would form only one aspect of a wide range of concepts, skills, and contexts that collectively contribute to the development of mathematical-literacy-related competencies.

To illustrate this aspect further, a few examples are considered below (from Section A).

1. An athlete runs 175 km in 5 hours. What is the speed of the athlete in kilometres per hour?
2. A mixture contains 5 l of acid and 7 l of water. How many litres of water must be added to 25 l of acid to achieve a solution with the same concentration?
3. What number is 67% of 632?
4. Of what number is 10 twenty per cent?

It may be seen from the above examples that problems of this kind are contextually less significant; and that a one-step numerical calculation would yield the answer in most of these cases that contributed to 80% of the total marks. In other words 80% weighting was given for contrived word problems involving basic computational skills. The following example taken from Section B of the paper, however, presents, in general, a different picture of this assessment.

<u>Question 2 of Section B</u>

2.1 Use the table of landline phone tariffs below to calculate the average monthly phone account for a small business. The staff spend about 4.5 hrs. making local calls (to places less than 50 km away) every day during working hours (Monday to Friday, 08:00-17:00). An analogue phone line is a fixed landline).

Tariffs	Residential tariff		Business tariff	
	R 139.97/month		R 191,84/month	
Analogue phone line rental	0-50 km	>50 km	0-50 km	>50 km
Standard time (per minute)	43.4 c	65.0 c	42.0 c	57.0 c
Call more (per minute)	20,7 c	32.5 c	20.7 c	28.5 c

2.2 Would the phone account be lower if the staff worked from home (where they pay the residential tariff on their phone calls)?

2.3 Do your calculations give an accurate picture of the phone costs for the business?

This task stands out as one the most striking examples of a typical context-based mathematical literacy problem. While the finance-related concept of tariff is both mathematically and contextually significant, the mathematical skills and knowledge that are embedded are also significant. The concepts of ‘average’, ‘rate’, and ‘operations involving decimal fractions’ are skilfully integrated in this problem with the context of tariffs. While the problem on the whole does not pose any serious mathematical challenge to students, the mastery of Essential Skills and Concepts (ESCs) underpinning the successful comprehension and solution of the problem is noteworthy. Mastery of those ESCs is therefore a prerequisite to the attainment of a correct solution to the problem. The aspect of HOTS underlying the context used is equally significant. The statements of questions under 2.2 and 2.3 involve, to some extent, certain HOTS, such as judgement and critical thinking. While the question 2.2 is answered by ‘comparing’ two scenarios and subsequent solutions, 2.3 involves judgement and critical thinking, in that the accuracy of solutions need to be critically analysed to observe the implicit error margins. Students who indicate that the whole problem is based on information that is not completely accurate, and that average call durations are subject to changes, may be considered, in this context, to have achieved certain Higher Order Thinking Skills. Those students are also most likely to note that not all months are exactly made up of four weeks; and hence such an assumption leaves an element of error in the final solution. An awareness of that kind may also be considered an aspect of HOTS.

5.2.8 Summary of documents analysed

Documents analysed in this section included course outlines, study guides, test, examination, and assignment question papers, and faculty handbook. The principal research question of how a SIC may be designed and developed; and the sub-question exploring the purpose of a mathematical literacy module at tertiary level, have guided this analysis. A coding matrix was used in the analysis of course outlines and faculty handbook. Test, examination, and assignment papers were analysed, based on an intense scrutiny of individual items of tasks. However, the analysis in general was guided by the conceptual framework adopted by this research. The levels at which course materials and assessments envisaged and fostered aspects of ESCs which were either integrated with contexts, or presented separately, were the critical issues on which the analysis concentrated. In terms of purpose of the module, the degree to which module outlines, study guide, and assessments were aligned and the aspects of purpose on which all the three entities had divergent standpoints were also explored. The theoretical proposition made in this thesis that a SIC-based approach in which ESCs preceding context-based problems lead to the development of HOTS, underpinned the analysis as a whole. The conclusions reached as a result of the analysis with regard to the purpose of the module observed through this theoretical lens, will be thoroughly dealt with in the answer to the first sub-question appearing in the next chapter.

5.3 Analysis of interviews- Pre-SIC (Semi-Integrated Curriculum) interviews

This section gives analytical summaries on: pre-SIC interviews; post-SIC interviews; Head of Department of MSTE interview

5.3.1 Pre-SIC interviews

This section deals with the analytical summary of pre-SIC interviews illustrated with excerpts from the transcripts. Of the ten research participants' interview data collected, four were intensely scrutinized here. However, the purpose of reducing the analytical units to four was that data could be limited to a manageable quantity, even though the rest of the participants' responses were given equal weighting in reaching the conclusions in this research. The purpose here is, therefore, to take the reader through the analytical process leading to the build-up of a coherent set of arguments. This set of arguments is a preface to the answers to the research questions that appear in the next chapter. Reference to literature has been purposely avoided here, so as to keep the analytical process from being theoretically influenced by literature.

Each participant was asked a total of twenty-five questions in two separate interview sessions. The questions ranged from those related to personal likes and dislikes, their views on the quality and quantity of the present curriculum. Questions were also posed to explore the frequency of interesting learning instances that they had recently come across. The purpose was to explore those instances that might have prompted the participants to question the validity of having complex context-based problems while the students were lacking in basic skills and concepts underpinning such problems. The interview questions thus tried to explore the learning experiences of the participants prior to their exposure to SIC. This was with a view to studying the experiences; while the participants' outlook about such experiences helped the researcher examine the implementation of SIC from a student's perspective. The views expressed by the participants were therefore accounts of personal likes and dislikes as opposed to well-thought-out and informed pronouncements of what is effective and what is not with regard to a particular curriculum. The students' experiences, on the other hand, as revealed through these interviews and written responses, contained graphic details of certain cognitive characteristics, as found by this researcher.

The method of analysis involved taking data-rich excerpts that seemed to have a natural similarity in textual meaning from the interview transcript, assembling them in a group. This was followed by assigning a 'description (code)' to the group of excerpts. The description essentially contained words or phrases that closely described the excerpts. The next step was to assign a more concise phrasing of what the description was about under the heading 'preliminary thoughts'. The final step was to assign a broader conceptual category to the preliminary thoughts, to be listed under 'initial categories'. This analytical sequence of grouping excerpts, assigning 'description (code)' followed by 'preliminary thoughts' which finally led to 'initial category' was repeated for all the twenty-five questions for the four participants. The collection of all 'initial categories' were then grouped under one heading called 'categories'. Categories of similar suggestive meanings were then grouped together to see to which broader 'themes' such categories belonged. Various themes of similar connotation were then associated with a 'core concept'. The 'core concept' was then weighed against the conceptual framework to ascertain whether findings were in favour of or against the theoretical assumptions made in this thesis. This process may be illustrated by the example given in Table12 taken from the pre-SIC interviews, in which the pre-SIC interview question 3 has been analysed. Question 3 was: What do you like the most about the way you are taught mathematical literacy at the moment?

Table 12 Illustration of pre-SIC interview analysis

Excerpts from interview (Question 3)	**Description (code)**	**Preliminary thoughts (what this is about)**	**Initial categories**
I like it questionnaire , it questions is clear and understandable and I like the way our lecturer taught	Participant seems to 'like' certain instructional methods	Instructional methods trigger 'likes' and 'dislikes' towards module	

us because he always made an example when we start a new topic so that makes me like mathematical literacy			
The think I like the most is that the teachers or lecturers they associate the mathematical literacy with what is happening outside the community. For an example they ask questions like how many paint will be needed to paint that particular house or given one.	Maths lit is associated with what is happening outside; context-based problems	Emphasis of context in maths lit	Emphasis on context should underpin purpose; purpose to acknowledge cognitive influence of contexts
It relevant to the contents, the method and styles make it easy to understand	Relevance associated with context -based problems-easy to understand	Contexts used are pedagogically significant	
I like that mathematical literacy is simple, the way it taught it is very easy for everyone to understand as it is more concerned about the really life situation and it can be applied anywhere	Real-life contexts make maths lit easy and simple; it may be applied anywhere	Contexts influence cognition	

As noted earlier, initial categories arrived at were later put together to form groups of categories. Different 'themes' were later assigned to such category groupings. Various themes were then considered in identifying the 'core concept' to which a group of themes seemed to belong. This part of the analytical process is illustrated in the following Table 13.

Table 13 Illustration of analytical process

Categories	Themes	Core concept
Maths lit is to be a multi-purpose module	Traditional stand-alone curriculum with multiple purposes	Increased and clear content in simple multidisciplinary contexts
Students' development at multiple levels is the purpose of module.		
Curricular focus is to be multidimensional		
Traditional curriculum preferred		
Curriculum to maintain own identity		
Emphasis on context should underpin purpose; purpose to acknowledge cognitive influence of contexts	Context is fundamental	
Curricular focus on clear content, interpretation appreciated	Clear wider content preferred	
Increased content preferred		
Broader/deeper curriculum content preferred		
Integrated curriculum preferred	Concepts to be tied to multidisciplinary contexts	
Curriculum to be guided by inhibiting factors(like fluency in English);		

Multidisciplinary contexts to carry maths lit concepts		
Context-concept integration favoured		
Interdisciplinary relevance of maths lit not realized	Traditional curriculum objective with disciplinary boundaries	
Module to remain independent; integration possible only within the module		
Optimal level of concept-context integration	Concept tied to context without jargon	
Context not to be lost in jargon - a curriculum guideline		

The core concepts of the type “Increased & clear content in simple multi-disciplinary contexts” arrived at in Table 13 and those arrived at elsewhere were scrutinized repeatedly for possible alternative concepts that could be arrived at from the same set of themes or categories. Such alternative concepts are dealt with in detail in the next chapter.

Pre-SIC interviews thus analysed produced a wealth of insights into the possible answers to the main research question as well as to the first two sub-questions. The question of what the curricular purpose currently is, as experienced by the participants, was clearly indicated by the answers to these questions. The answers also pointed to the aspects of a curriculum that would meet the academic requirements of a typical tertiary mathematical literacy first-year student.

5.3.2 Post-SIC interviews

The post-SIC interviews were analysed based on individual responses to a set of twenty questions. Each set of questions was analysed separately after excerpts from the same participant were grouped together and given appropriate descriptions. This was followed by drawing preliminary thoughts apropos of the descriptions. Such thoughts were then associated with categories. The initial categories were then transferred to a coding index in which a group of categories was linked to an appropriate theme. In this way different groups of categories were thematically categorized, with each thematic group being given a particular identifying name. Different themes were then considered together to determine the core concept to which such themes belonged. Table 14 illustrates the analytical process used in the analysis of post-SIC interviews.

Table 14 Illustration of post-SIC interview

Excerpts from interview	Description (code)	Preliminary thoughts (what this is about)	Initial categories
I like that we did more challenging activities than we did in maths lit because I like to be challenged a bit	More challenging SIC; like to be challenged	Low difficulty level of normal curriculum; SIC correctly pitched	Aspects contributing to SIC's appeal
The SIC is more like pure maths and we covered a lot of things in SIC than in the normal curriculum	SIC's presumed resemblance to 'pure maths'.	SIC's increased complexity	
In SIC we are learning differently, mistakes didn't count and there was opportunity for discussion if one didn't understand a certain question	Learning differently	SIC as a different learning approach	
Yes, because in SIC we cover a lot of concepts and contexts rather than in maths lit	Covered many topics	Coverage of concepts and contexts	
The understanding from SIC was very adequate and the understanding form the normal curriculum was very easy, I understood normal curriculum easily than SIC.	SIC was not as easy as the normal curriculum; SIC understanding adequate	Higher difficulty level of SIC	
I think SIC is suitable for math slit	Endorses SIC		

The curriculum should also integrate concepts and contexts, I support certain sections of the curriculum because they also deal with new concepts	Only certain sections of the curriculum should be integrated	Full integration not appropriate	Integration to be based on discretion
It will be easier because I have learnt a lot about maths lit in SIC and got very difficult tasks that I was able to solve.	Attained competency in solving difficult problems	SIC's ability to enhance competencies	

The subsequent process of developing the core concept is illustrated in Table 15. The table indicates excerpts from transcripts of interviews. The excerpts were taken from the transcripts of the participants with pseudonyms: Herbert, Robert, Peter, and Sarah.

Table 15 Development of core-concept in post-SIC interview analysis

	Categories	**Themes**	**Core concept**
Herbert	Something more than normal curriculum needed	SIC seen as a curricular need, higher-order skills; problem-solving aspects	SIC is experienced as a need at a certain integrative level, helping to enhance HOTS; pedagogically well received
	Wider use of SIC preferred		
	SIC's higher-order features		
	Problem-solving ability enhanced		
Robert	Relative merit of SIC experienced	Impact on HOTS, sustainability of skills attained, changes in learning styles, pedagogical appeal	
	SIC pitched at a higher level		
	SIC is uniquely suited to building HOTS		
	SIC evokes academic enterprise		
	Convinced of positive influence of curricular change		
	Sustainability of HOTS		
	Significant changes in learning style		
	Multiple levels of influence of SIC		
	SIC has pedagogical appeal		

	SIC's sustainability		
Peter	Concepts and contexts together make curriculum clear	SIC related to general enhancement of maths lit as a competency	
	SIC helps deeper conceptual understanding		
	Enhanced maths lit competency		
	All aspects of maths lit developed		
Sarah	Aspects that help SIC's appeal	Integrative level is a subjective matter; SIC considered sustainable	
	Integration to be based on discretion		
	SIC's features result in its positive effect		
	Guidelines to be built into SIC's design		
	Sustainability of SIC		

The core concept formed was then considered in the light of the conceptual framework adopted in the research.

Both pre-SIC and post-SIC interviews analysed produced insights into a variety of aspects of the mathematical literacy curriculum that the faculty is currently using. The analysis also revealed the intricacies of student responses to curricular innovations and the factors that influence such responses. The core concepts thus produced, theoretical assumptions this research adopted, and the degree to which the core concepts and assumptions differ or are aligned, will be further explored later in this thesis. The analytical conclusions reached in this section will also be contrasted with the core concepts reached after analysing data from the pre- and post- test scripts, as well as contact-session work. In other words, arriving at core concepts at this stage was, to some extent, a matter of speculative, and hence tentative, practise of theorisation. Arriving at core concepts was therefore subject to rigorous scrutiny in the light of new core concepts that were to appear when further data analysis was undertaken. The final conclusions thus reached were the result of the iterative practice of moving back and forth between data and theory.

5.3.3 Interview with the Head of Department of MSTE, University of Zululand

An interview was set up with the HOD prior to the commencement of the intervention programme. The purpose was to elicit the HOD's views on certain aspects of the current curriculum and the changes that the HOD, on behalf of the faculty, would like to see effected on the current curriculum. The questions therefore ranged from those related to the fundamental objectives with which the faculty originally conceptualized and implemented the curriculum, to those related to the perceived effectiveness of the current curriculum. Questions were also asked about the breadth and depth of content, both presumed and practised, and also about the scope of a research-based curriculum that could be designed and implemented. The views expressed by the HOD, as the single source of institutional perspectives, were used in various instances in answering all research questions in this thesis. A summary of his views, for the express purpose of positioning such views correctly in the context of the general arguments provided in the rest of this thesis, is given below.

According to the HOD, the basic objective of having a mathematical literacy course was that teacher educators of all specializations should have a certain level of mathematical literacy as a competency. This was essential, according to him, because of the current scenario of curricular changes at school level, with the associated demands the teaching profession places on the potential teachers. Teachers in general, irrespective of what they were trained to teach, were expected to be competent in handling mathematically demanding situations. The university mathematical literacy curriculum was therefore supposed to cater for such needs of all students across the faculty with a view to, as noted by the HOD, alleviating the general dislike towards mathematics-related areas of study by the students in general. In terms of content to be covered, the HOD was of the view that the content could be structured along the lines of the school mathematical literacy curriculum, but given added breadth and depth.

The HOD further noted that a curriculum that caters for the general mathematical needs of students, specifically those who are not majoring in science and mathematics-related areas, would go a long way to enhancing the quality of the teachers produced by the institution. The HOD summarized his views on what the ideal mathematical literacy curriculum for a university should be in these words "a complete competency package" indicating the diverse skills, concepts, and competencies that such a curriculum should encompass. From a curriculum design and development point of view, these views were supremely instrumental in the conceptualization of the type of curriculum proposed in this thesis. The emphasis on concepts, skills and contexts to suit the varied needs of the teacher-educator from the non-science and mathematics background, a curricular conceptualization as articulated by the HOD, was in alignment with what was proposed in this thesis.

The above analytical summary does not cover all aspects of the interview. There were many other aspects, relevant in the context of various research questions of this research, which were extensively made use of in the answers to research questions section of this thesis.

5.4 Analysis of Class-work Scripts and Test scripts: Pre-test

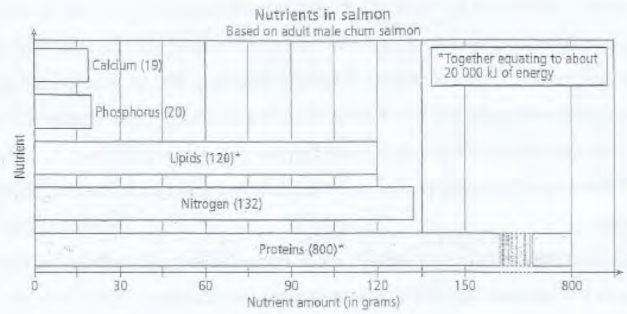
The designed pre-test administered to participants comprised eleven questions, based on two broad topics of ‘ratios’ and ‘interest’. While ‘ratios’ involved the authentic context of ‘nutrients present in adult salmon’ the section on ‘interest’ basically had contrived word problems aimed at testing the students’ conceptual understanding of ‘simple interest’. The word problems were underpinned by an array of skills which involved conversions between ratios and percentages, and direct and indirect application of the simple interest formula underpinned by related algebraic manipulative skills. The pre-test, therefore, had a fair mix of authentic and non-authentic contexts built around concepts such as ratios and percentages, supported by skills such as unit conversions, substituting in a formula and changing the subject of a formula. The essential skills and concepts (ESCs) and the contexts built into the tasks, thus presented an interesting set of tasks by which the participants’ current level of proficiency in the relevant areas of ESCs and related context-based problems could be investigated.

MATHEMATICAL LITERACY CURRICULUM DEVELOPMENT PROJECT

PRE-TEST ADMINISTERED TO PARTCIPANTS

ON 27 th AUGUST 2014 AT 2-30 PM

1. The graph shows the nutrients that are present in an adult salmon.



a) What is the ratio of protein to nitrogen to fats in an adult male salmon? 2

b) If another salmon contained 690 g of protein, how many grams of grams of fats (lipids) and nitrogen would it contain? 5

c) Convert 20 000 KJ of energy to calories. 3

2. Liza is a university student. She arrived on campus at 08:00 for her first class. Her last class finished at 17:00. She spent her time at university in class, having lunch, socializing and exercising in the gym in the ratio 4 : 2 : 5 : 1 . Calculate the time (in hours and minutes) she spent on each activity. 5

3. According to the Engineering Council of South Africa's records, between 1998 and 2014 altogether 50570 students enrolled in south African universities for engineering courses and 8900 graduated.

   a. Would it be correct to say that one out of every six first year engineering students will

Figure 6 Pre-test

One of the participants by the pseudonym 'Herbert' had his script analysed, as shown in the following attachment. While this researcher is in possession of all ten participants' responses to the pre-test, four of the ten scripts were intensely scrutinized, and hence are used for illustrations in various sections of this chapter and the following chapter of this thesis. However, all ten units of analysis will be used in the analytical processes leading to the conclusions reached in this thesis. Detailed descriptions of all units of analysis are therefore included in the 'Appendix' section of this thesis.

Q.1) (a) 800 : 132 : 120

400 : 66 : 60

20 : 35 : 30

2 : 2 : 1

Error in reducing ratio

Lack of basic skill of manipulation of ratio

Lack of skill of solving for the unknown from equivalent ratios (ESC's)

(b)

(Lipid) $\frac{690}{120}$ = 5.75 grams (ii) $\frac{690}{132}$ (Nitrogen) = 5,227 grams

Lack of skill of solving for the unknown from equivalent ratios (ESC's)

(c) 20 000 kJ = 20 000 ÷ 800

≈ 25 calories

Lacking in the concept of units and the skill of conversion of units

Q.2) (13) 4 : 2 : 5 : 1

(i) 12÷4 = 3h correct

(ii) 12÷2 = 6hr

(iii) 12÷5 = 2 hr, 24 minutes

(iiii) 12÷1 = 12hr

Lacking in the skill of dividing a quantity in a given ratio as applied to a context

Q.3) (14) (a) Yes, because the total number of graduated students it below even the average

(b) 50570 ÷ 8900

= 5,7 graduates students in engineering

Lack of understanding of the concept of ratios

Lack of skill of reducing a ratio

Not able to convert "one out of every six students" to a mathematical statement (lack of conceptual understanding)

Q.4) (17) (a) Depreciation

(b) V(t) = 38 000 (0,82)

= 31160

Not able to convert the decimal to a percentage (the skill), does not understand the concept of 'rate of depreciation'

(c) Current Value = 38 000

(d) 38 000 $(0,82)^5$

= 14088, 11404 in five years

Q.5) (18) I = P x N x R

(i) 5 800 x 2 x 9/100 (ii) 47000 x 2 x 11,75/100

= 1044 = 11045

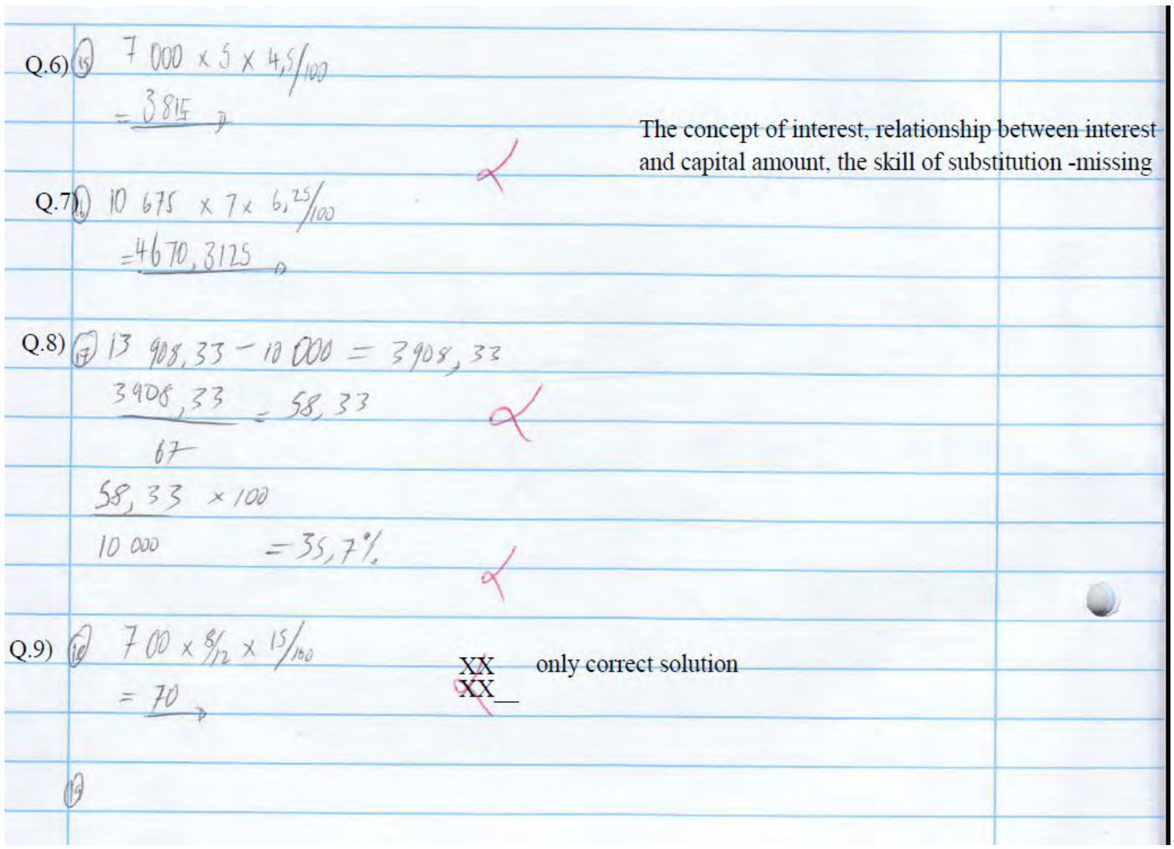


Figure 7 Herbert's pre-test script

An inspection of Herbert's script revealed that he had serious conceptual deficits within the domains of calculations involving percentage, ratio, fractions, and simple interest. A series of errors found in almost all the tasks presented indicate the underlying skill deficit the participant has accumulated over the years. Lack of proficiency in certain basic skills and concepts, as indicated in Herbert's script attached to the appendix, resulted in the participant not being able to fully exploit the contextual authenticity and richness which would otherwise have contributed to the level of engagement tasks of this type generally demand from the students.

It is worth viewing one more pre-test script belonging to a participant by the pseudonym 'Robert'. The script attached in Figure 8 indicates the level of mathematical-literacy-related conceptual and procedural skills that Robert demonstrated during the pre-test. Robert clearly demonstrated significant mathematics-related conceptual and skill deficits which created huge stumbling blocks for him in his attempt to make sense of the interesting authentic contexts some of the tasks presented.

NAME- ROBERT

1) a) 800 : 132 : 120

400 : 66 : 60

40 : 6.6 : 1

managed to get an equivalent ratio but failed to solve

B) 690 ÷ 120 = 5,75

lacks skill to manipulate ratio

~~6990~~ ÷ 690 ÷ 132 = 5,23

~~13 4 : 2 : 5 : 1~~

C) 1 calories = 4,186 kj

x 20 000

4,186 x 20 000

= 83720

lacks the skill of converting units

2) ~~13~~. 4 : 2 : 5 : 1

60 x 9 = 540

540 ÷ 4 = 135   540 ÷ 2 = 270   540 ÷ 5 = 108   540 ÷ 1 = 540

2,25 : 4,5 : 1,8 : 9

lacks the understanding of the conceptual meaning of ratios

14

3) a) yes, because students who graduated are less compared to the total number of student.

why?

not able to mathematically express "one out of every six"

B) 50570 ÷ 8900

= 5,7

does not understand "graduation rate" in its mathematical sense (skill of converting to a percentage)

4) a) yes

lacks understanding of 'appreciation' and 'depreciation'

B) 38 000 ÷ 0,82

= 46341,46

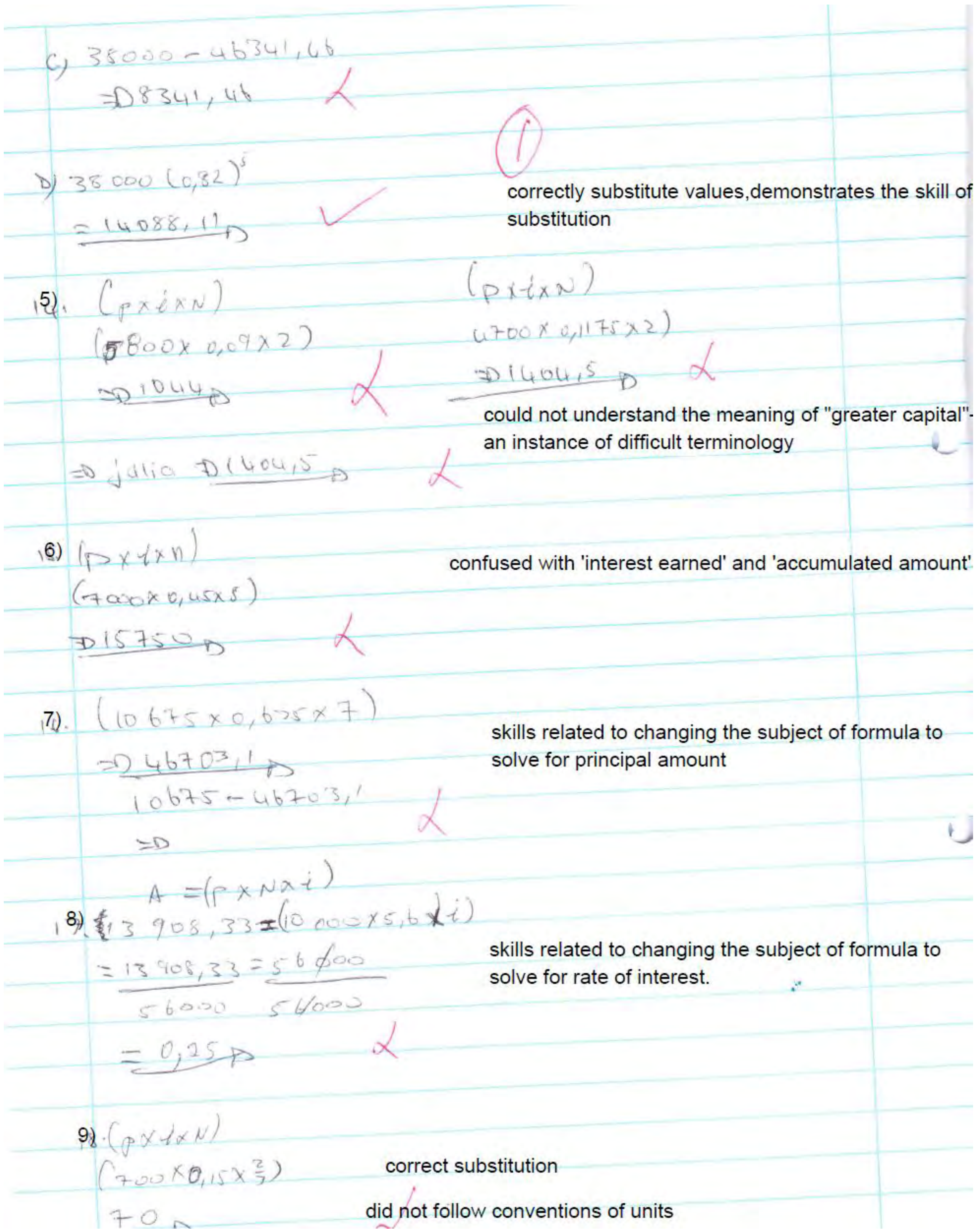


Figure 8 Robert's pre-test script

While Herbert's and Robert's scripts revealed interesting aspects of the participants' conceptual and skills deficits, other participants' responses to the pre-test also revealed various aspects of such deficiencies. For the reader to have a comprehensive view of all the participants' responses to individual items in the pre-test; and to have a panoramic view of their levels of mathematical-literacy-related competencies, a table of qualitative codes attributed to the items is included below. The table is tabulated with the quality of written responses, determined according to a qualitative rating scale, against the mathematical concepts entrenched in the problem tasks. A table of this nature will also help the reader assess the participant's relative improvement, or the lack thereof, in the particular domains demonstrated over and after the curricular intervention period. The Table 16 also includes, purely for comparative purposes, a list of marks awarded for the pre-test, which is, however, insignificant from the qualitative analytical perspective adopted for this thesis. For the sake of convenience, tasks are divided into four groupings based on their coverage of concepts and skills. The grading scale used here is as follows:

Table 16 Qualitative grading of written responses to pre-test

	Task 1,2 and 3	Task 4	Tasks 5 -10	Task 11	Over 45	Score %
HERBERT	4	4	4	4	3	6
ROBERT	4	4	4	4	1	2
PETER	4	4	4	4	7	15
SARAH	3	3	2	2	25	55
MBALI	2	4	3	4	16	35
SIPHESIHLE	4	2	2	2	29	64
NELISIWE	3	3	4	4	7	15
NOKUPHILA	4	4	2	2	18	40
NOKUBONGA	4	4	3	4	8	17
MBALENHLE	4	4	3	4	9	20

<u>Rating scale</u>

Level	1	2	3	4
Descriptor	Very high proficiency	Familiar with skills and concepts at a satisfactory level	Just managed to solve problems with limited proficiency	Unsatisfactory level of proficiency

5.4.1 Contact session script analysis

There were fifteen formal contact sessions of two hours' duration each with the participants, apart from numerous informal contacts the researcher had with students. The formal and informal contact sessions collectively contributed to the understanding of how the participants responded cognitively to certain mathematical-literacy situations. Such situations were devoid of any academic pressure students might feel in normal lecture sessions. Academic activities carried out for purposes other than assessment evoke natural responses from students, which this research made use of quite substantially. Informal working-out as seen in the workbooks thus contributed to the understanding of students' mathematical thinking or its lack thereof. An example of one such working out is given in Figure 9.

The task in this case was to plot the graphical representations of two types of investment, namely, simple-interest-based and compound-interest-based. This task was given after a short discussion on the concepts of linear and exponential growth associated with the financial literacy concepts of simple and compound interest calculations, respectively. The discussion overlapped with an explanation of the basic characteristics of linear and exponential functions. However, the participants' response to this task, as shown above, was an indication that significant conceptual deficits existed with related competencies in this case. This further indicated the need to have graphicacy as a skill to be consolidated prior to or concurrently with the treatment of context-based problems in which graphicacy, as a skill, dominates. Another participant's working out of the same problem gives further insight into the diverse nature of student thinking among the same group of more or less equally competent students.

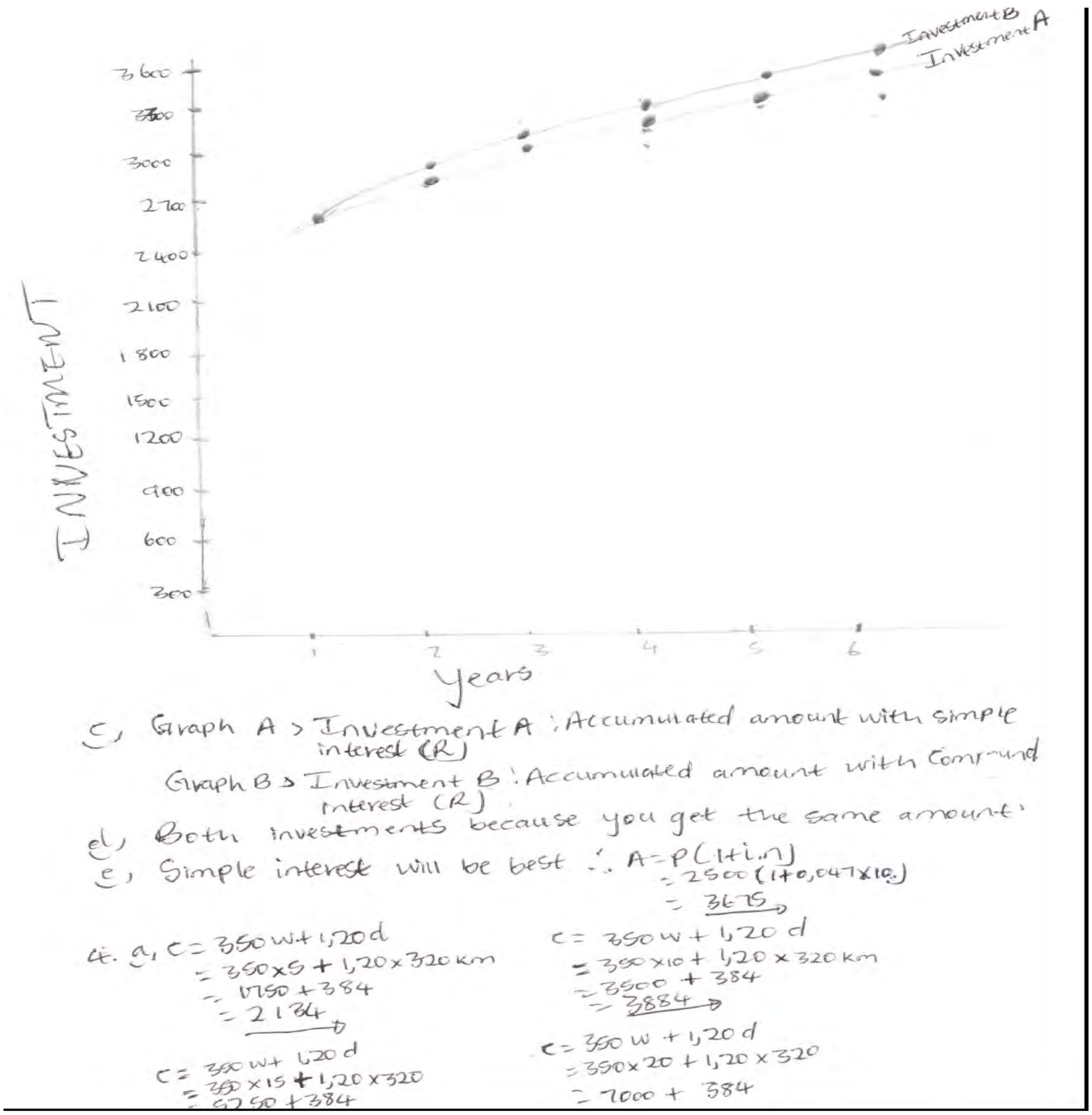


Figure 9 Example of participant's informal working out

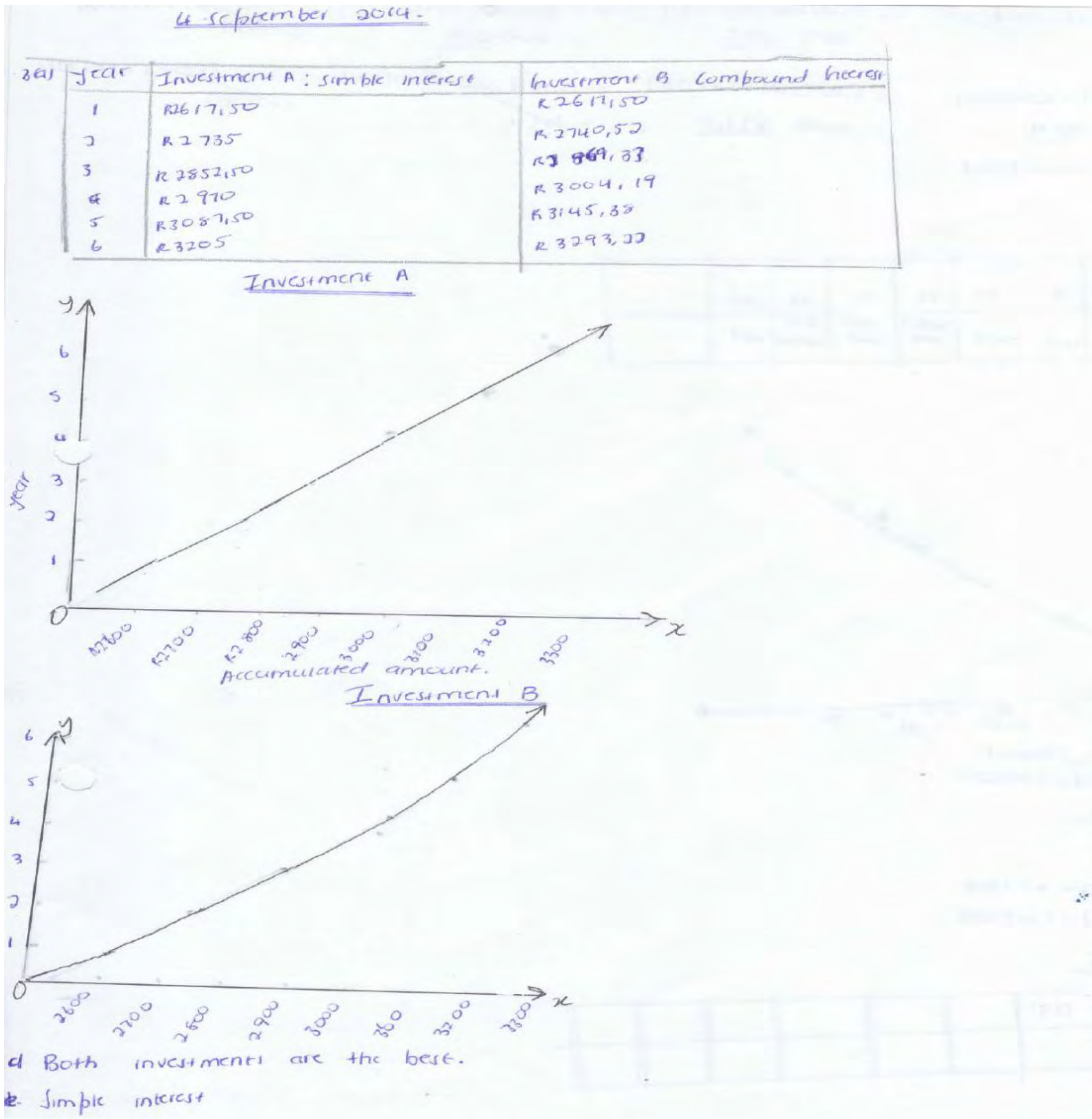


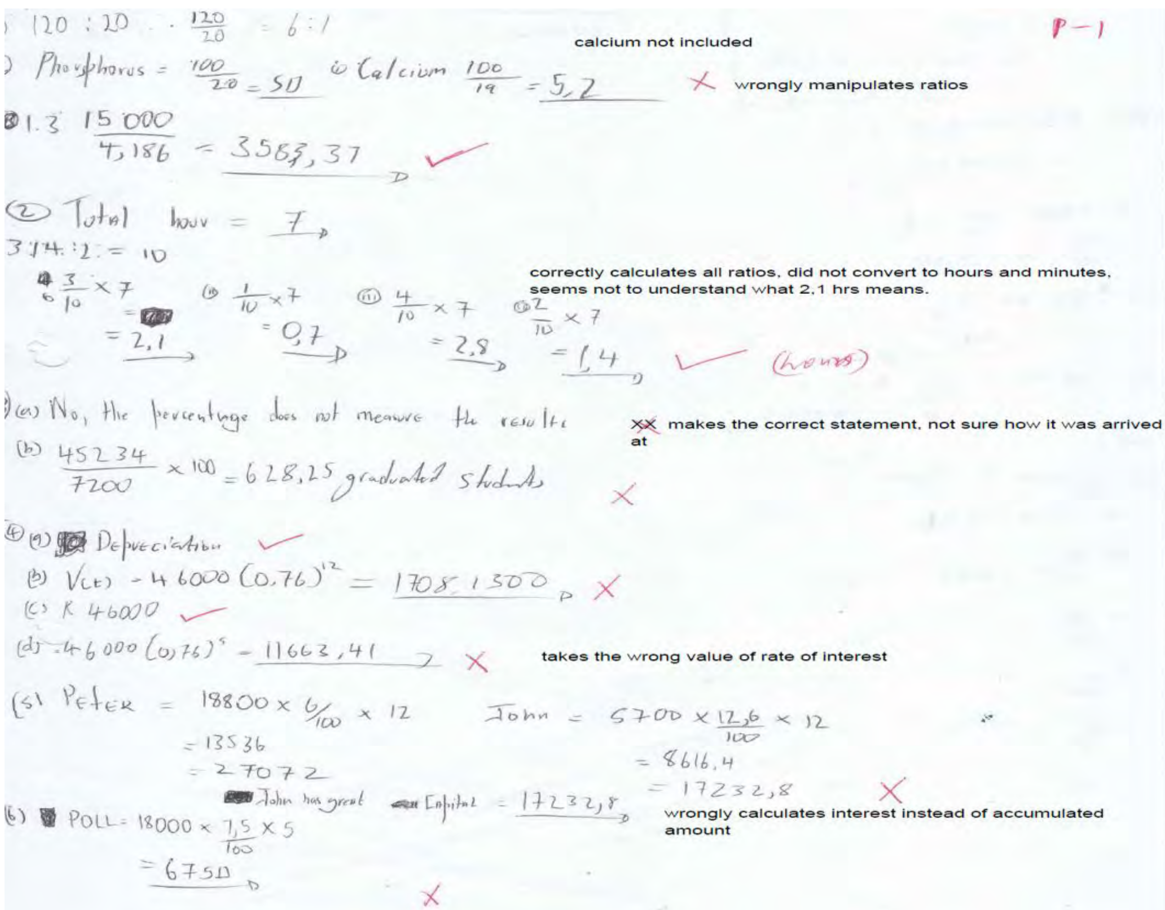
Figure 10 Participant's informal working out

In the second case, as shown in Figure 10, the student demonstrated a fair understanding of the two types of investment with the help of a set of sketches, drawn with a relatively higher degree of accuracy. Despite incorrect statements that are attached underneath the sketch, the graphs show a fair demonstration of the skill involved. Instances of this nature in which the participants showed a clear understanding or misunderstanding of certain skills or concepts underscored one of the theoretical assumptions made in this thesis, that consolidation of such skills and concepts is paramount to the fostering of mathematical-literacy-related competencies. The question of how and when that may be integrated with the contexts thus remained critical to the implementation of the curriculum. An examination of the students' work consistently revealed that deficiencies related to Essential Skills and Concepts accumulated over time become stumbling blocks in the student's path towards achievement of numerate behaviour. This argument is, however, to dominate the discussion in the rest of this thesis. A reference to it at this juncture was to indicate the frequency with which ESCs were conspicuously absent in the participants' informal working out, as shown above.

5.4.2 Post-test script analysis

One of the most critical aspects of the data-collection exercise in this research was the post-test administered to all the participants after the contact sessions. The post-test was designed with a multitude of purposes. It was intended qualitatively to measure, with a fair degree of accuracy, the extent to which participants developed mathematical-literacy competencies and Higher Order Thinking Skills as a result of being exposed to lessons based on the Semi-Integrated Curriculum framework. The difference in the ways of mathematical thinking that SIC caused or did not cause were the critical issues to be explored using the post-test as a research instrument. While the pre-test consisted of a set of context-based problems designed in the conventional format, the post-test consisted of a set of problems that utilized the same contexts and the same ESCs. The post-test also consisted, in part 2, of a set of problems that used the same concepts but different contexts. The purpose of the part 2 questions was to check the participants' ability to transfer the attained skills and conceptual knowledge to a different context. This was yet another aspect of the theoretical assumption that the set of ESCs, once attained, would help the student transfer them (the ESCs) to any other applicable context, thereby keeping them context independent. The complexity of the context and the influence it may have on the participant's ability to transfer ESCs was, however, not explored in the post-test. A third aspect of the post-test was to explore the extent to which the participants attained HOTS. A separate set of questions designed to check the degree to which HOTS were attained also formed part of the post-test. A sample of the post-test analysed that belonged to the same participant whose pre-test was analysed for illustration in this chapter is shown in Figure 11. This illustration may help the reader gain a quick comparison between the levels of performance of the same participant in the two instances. However, as noted earlier, all the ten participants' post-test scripts were scrutinized to substantiate arguments in the next chapter; even though only two such scripts are illustrated in this section because of restrictions of space. Also, post-test scripts are not given any numercial aggregate scores. This is because of the emphasis being equally on the right and wrong answers, and the participants' thinking behind those answers, rather than on a total score that does not make any qualitative sense in the context of this research.

Herbert's post-test script was scrutinized for underlying influences that exposure to SIC-based lessons had had or had not had on the participant's mathematical-literacy-related competencies.



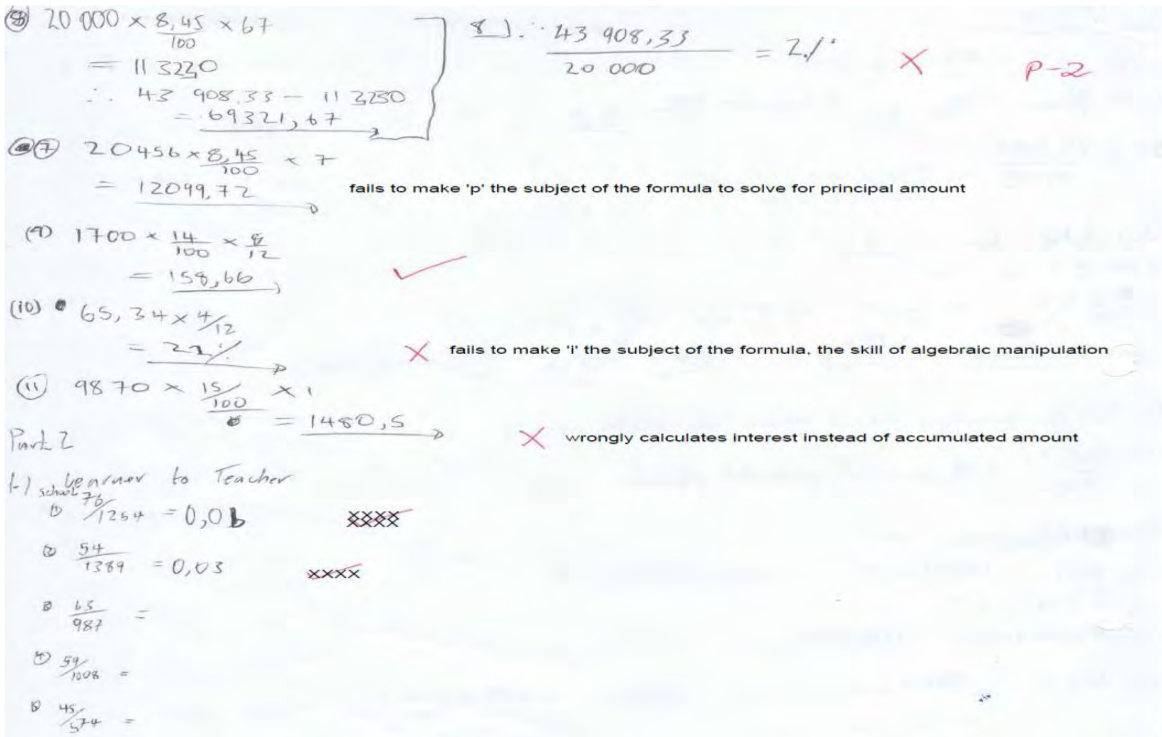


Figure 11 Herbert's post-test script 1

Herbert achieved a slightly higher degree of conceptual and procedural understanding than he had achieved prior to the commencement of the project, while his skills-based computational ability was still stagnant. The slight improvement in other aspects of his mathematical-literacy-related competencies may be attributed to the overall development resulting from the exposure to contact sessions. However, his ability to comprehend contexts and the degree to which he is dextrous in basic mathematical operational skills still remained underdeveloped. These two aspects are evident from the above excerpts. Errors committed in the first part in which the context used was the same as that in the pre-test, were mainly owing to lack of essential skills fundamental to mathematical-literacy problems. However, the familiar contexts used in the first part of the post-test did make a significant difference in terms of an awareness of what is expected. In questions 1 to 3 Herbert achieved only a quarter of the correct answers, indicating that he struggled with the essential skills of manipulation of ratios involving more than two quantities. He also struggled with the way in which and when such manipulations are carried out, to solve for unknown quantities. In the first question, involving three quantities, Herbert could not correctly determine their correct ratio as required by the question. In question 2, the skill of converting 2.1 hours into corresponding hours and minutes was also not demonstrated. Herbert failed to understand what 2.1 hours meant and hence could not translate it to hours and minutes, as expressed in a quantity in authentic contexts.

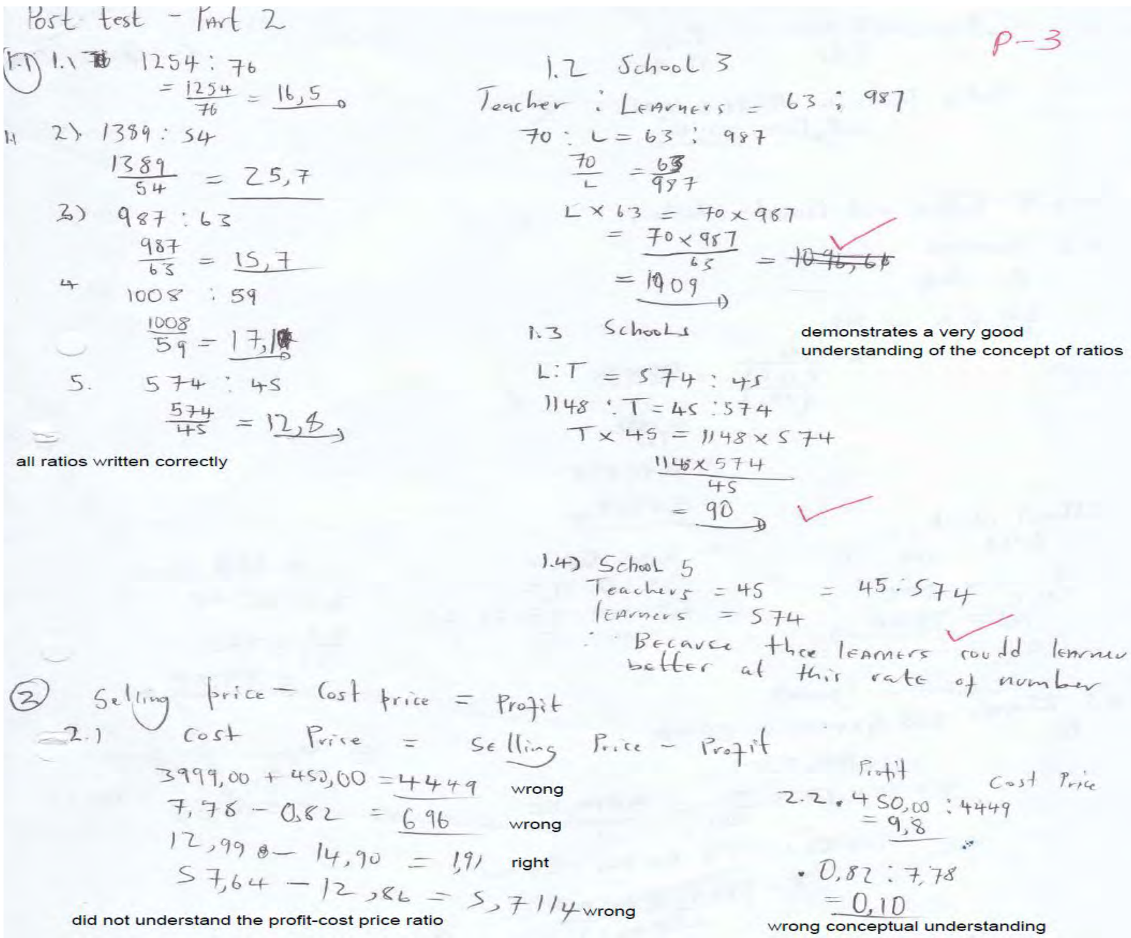
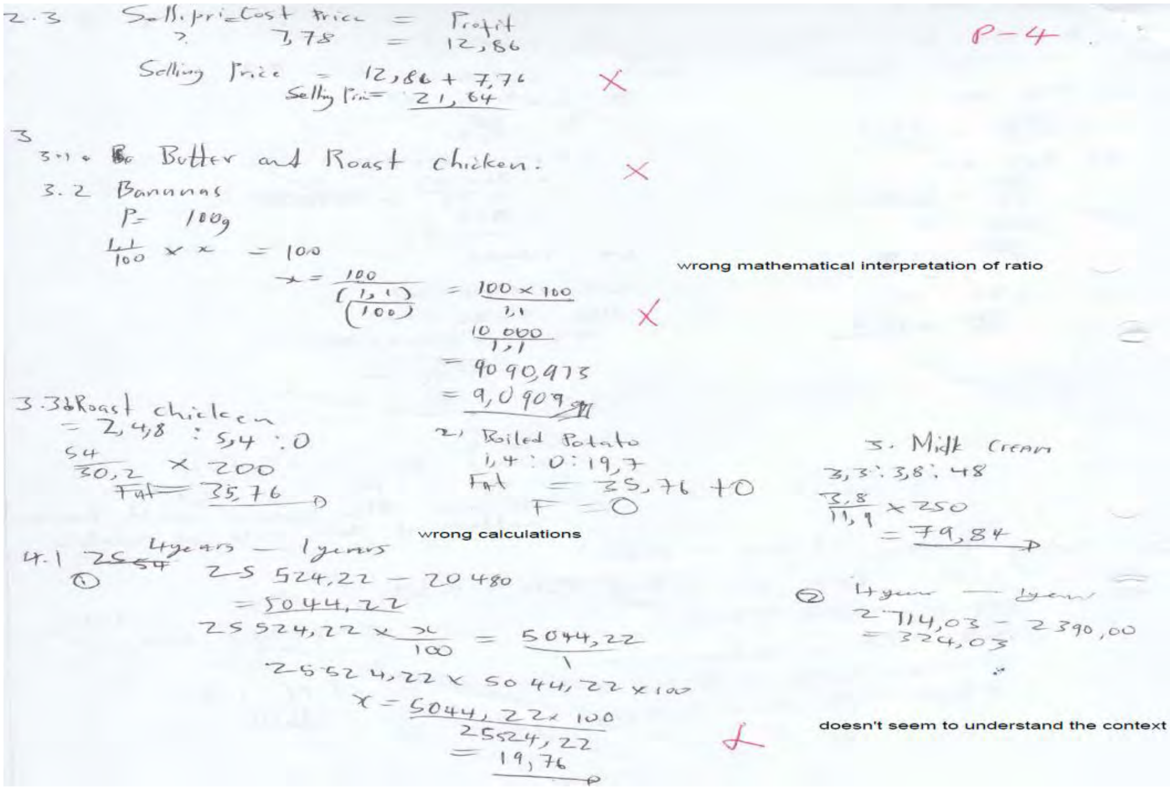
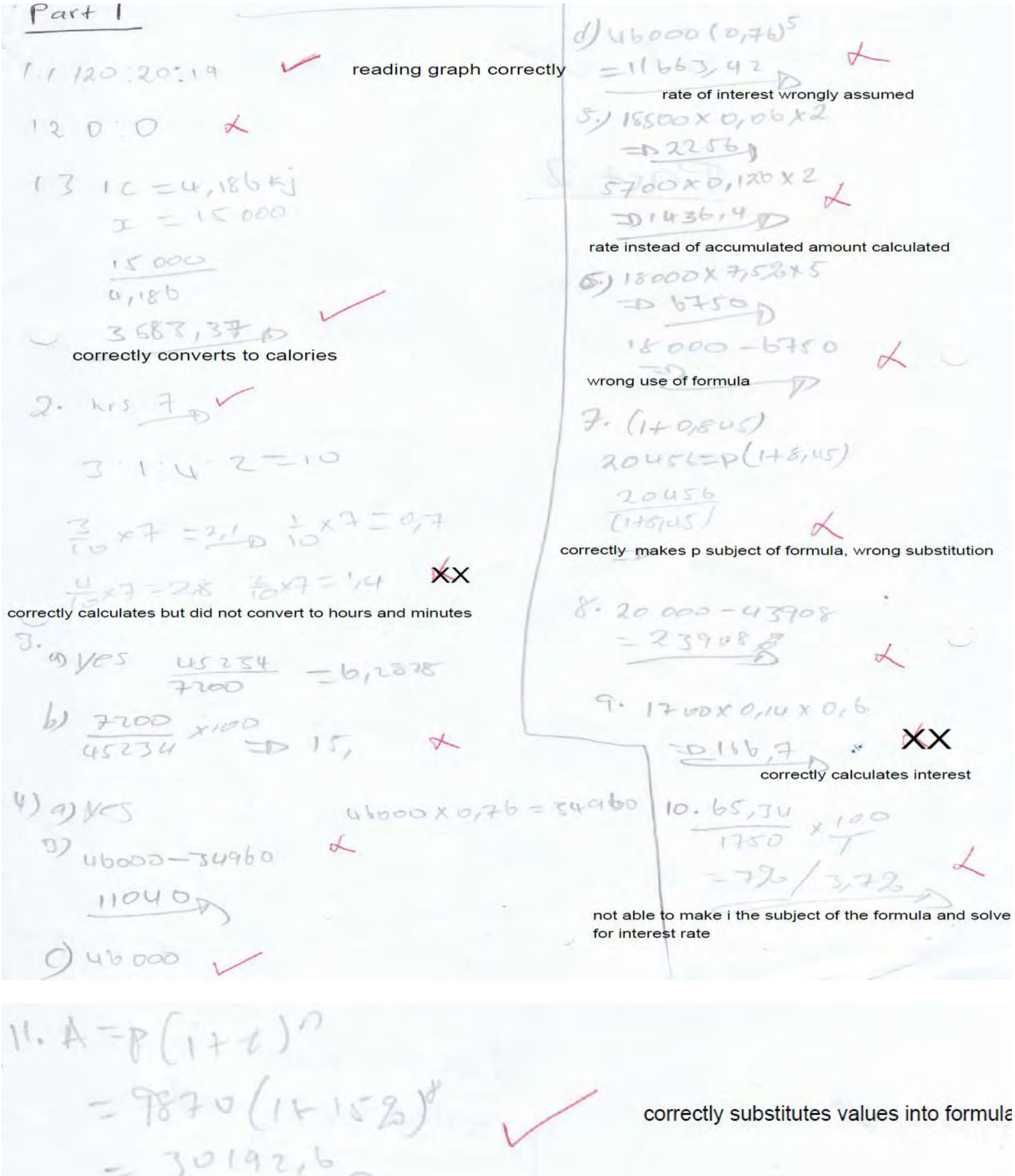


Figure 12 Herbert's script 2



In part 2, in which the contexts used were not familiar, Herbert managed to obtain correct solutions for only the sub-questions 1.2, 1.3, and 1.4, while his responses to the rest of the questions were totally incorrect. The relatively poor performance in the second part was primarily owing to, as observed in the type of errors that Herbert made, a serious lack of understanding of both the essential skills and concepts, as well as the contexts. In spite of a significant amount of practice that Herbert was taken through, related to the mastery of skills such as manipulation of ratios, calculations with percentages, and the conceptual mastery of terms such as ‘ratios’ and ‘percentage’, Herbert still experienced serious conceptual and skills-related deficits. This aspect of his and other participants’ learning experiences will be subject to further scrutiny in the rest of this thesis.

Robert’s post-test script, as shown figure 12, indicated a learning experience that he had which was slightly different from Herbert's because, presumably, of the difference in general mathematical ability levels that the two participants demonstrated initially.


Part 1
reading graph correctly
correctly converts to calories
correctly calculates but did not convert to hours and minutes
rate of interest wrongly assumed
rate instead of accumulated amount calculated
wrong use of formula
correctly makes p subject of formula, wrong substitution
correctly calculates interest
not able to make i the subject of the formula and solve for interest rate
correctly substitutes values into formula

Part 2

1.1 ① 1254 : 76 ② 1389 : 54 ③ $\frac{987}{63} = 15,66$

$\frac{1254}{76}$ ⇒ 16.5

$\frac{1389}{54} = 25,72$

correctly calculates decimal f

④ $\frac{1008}{59} = 17,08$ ⑤ $\frac{574}{45} = 12,75$

1.2 School 3

~~T : L = 63~~

Teacher : Learner = 63 : 987

70 : leaner : 987

$\frac{70}{L} = \frac{63}{987}$

$= L \times 63 = 70 \times 987$

$= L = \frac{70 \times 987}{63}$

$= 1096,66 = 1097$

1.3 School 5

Leaners : Teache

574 : 45

1148 : T = 574 : 45

$\frac{1148}{T} = \frac{574}{45}$

T × 574 = 1148 × 45

$T \times \frac{1145 \times 45}{574}$

= 90

demonstrates a clear understanding of ratios

1.4 School 5

Becouse it has less number of students

not a very accurate explanation

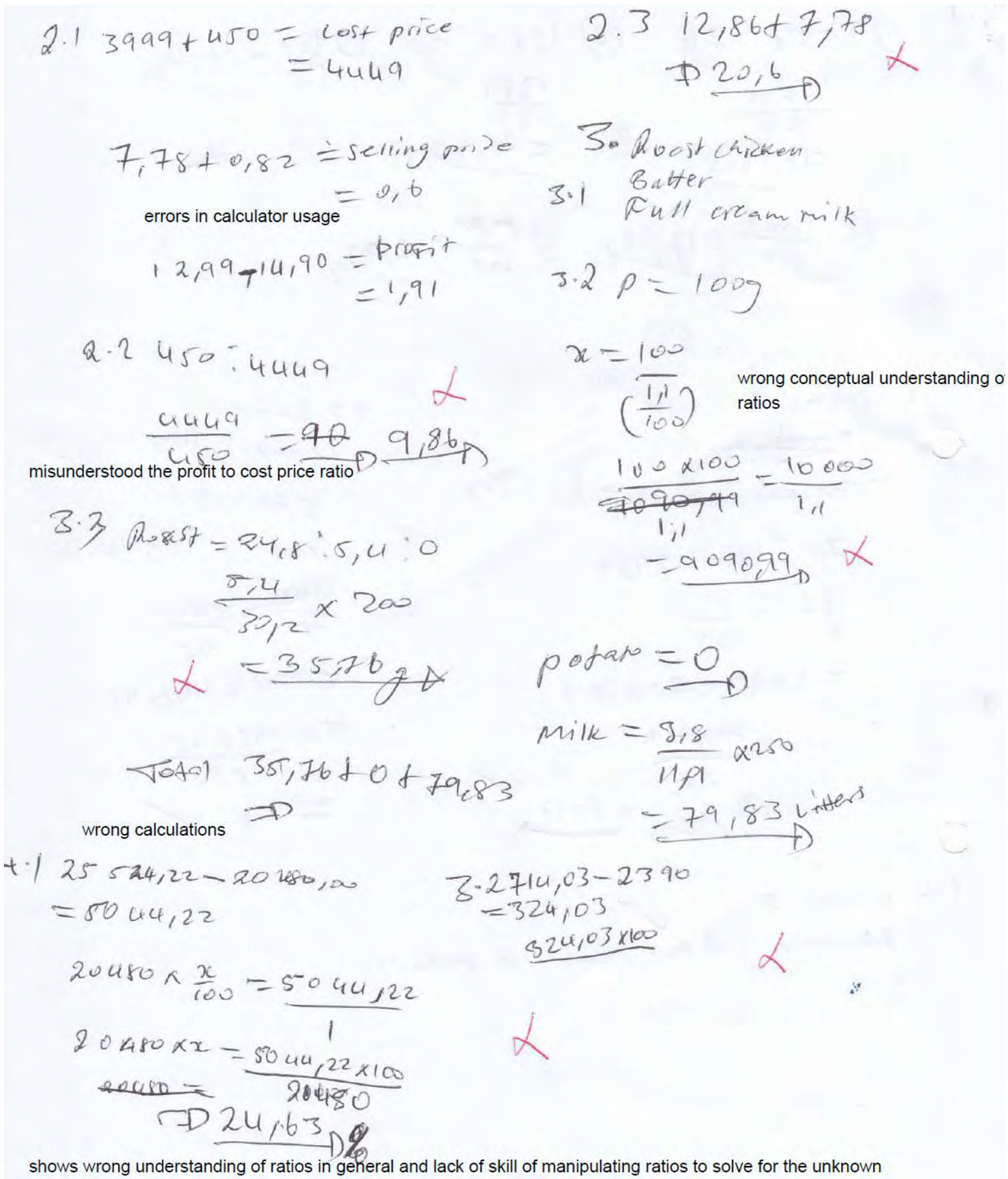


Figure 13 Robert's post-test

In part 1 Robert struggled with all aspects of interest calculations including the writing of the formula correctly, changing the subject of the formula as and when necessary, and conducting algebraic manipulation to solve for the required quantity. A lack of skills related to the basic operations with fractions, numerical and algebraic, contributed to the problem. A significant aspect of students' learning, as seen in all the units of analysis considered for this research, was that a lack of basic arithmetic skills such as operations with fractions and decimal fractions had a hugely negative impact on the slightly more complex calculations involving solving of equations, changing the subject of a complex formula, and cross multiplying to solve for an unknown quantity. Robert had serious computational difficulties in all these aspects, despite his making a concerted effort to overcome such learning deficits. The positive effects of his effort were, however, seen in the occasional correct solution that he managed to arrive at in both sections of the post-test.

5.4.2.1The case of Sarah

The case of Sarah differed slightly from those of Robert and Herbert. Of the three participants, Sarah showed significant differences in her approach; and hence her understanding of the concepts, covered during contact sessions, also differed. Her case, therefore, is considered here, giving the reader a better holistic picture of the impact the contact sessions had on participants. A close examination of her script has revealed why her understanding differed from that of the others.

Part 1 POST TEST P-1 SARAH

1.1. lipids to phosphorus to calcium
120 : 20 : 19 ✓ correctly reads the graph

1.2. ~~lipids to phos~~

1.2.

1.3. 15000 kg of energy = 3,58373 Calories

2. at the university class = 3/10 x 7
= 3/10 x 7
= 2ho

gets the decimal values correct, unable to interpret what 2,1 hours mean or what 0,7 hours mean.

having lunch = 1/10 x 7
0,7 minutes

Socializing = 4/10 x 7

exercising gym = 2/10 x 7 equal to ?

3. a) No ✓

b) 45234/7200 x 100
=
7200/45234 x 100
= 16% ✗

4 a depreciation of a car ✓

b 46000 (0,76)^(1)
= 34960 ✗ could not compare with the formula and take the correct value of rate of interest

c.

d. 46000 (0,76)^5 ✗

5. A = P(1 + i.n)
Peter = R18800 (1 + 0,06.2) ✓
=

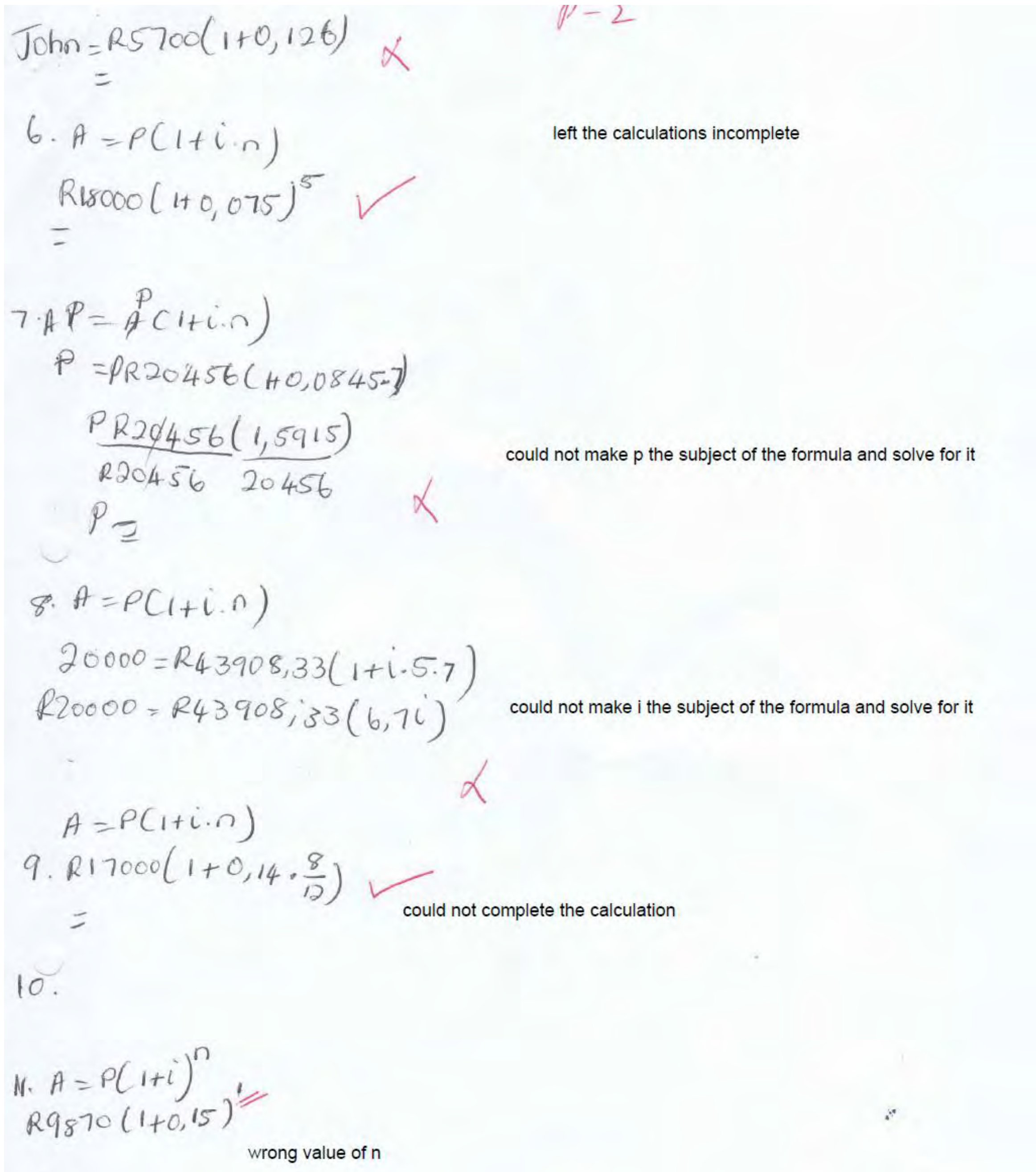


Figure 14 Sarah's post-test

For example, in questions ranging from 1 to 10, Sarah managed to obtain a few correct answers. Most importantly, Sarah managed to achieve partially correct steps towards the right solutions. Her procedure was therefore partially correct, even though, in most cases as shown in the Figure13, she could achieve the final solutions. This was because she had incomplete understanding of the procedure or the concepts involved. In most cases the formulae chosen were correct, the solution strategy also being correct. In Sarah’s case, as in other cases also, the fundamental problem was with the inadequate attainment of those essential skills and concepts, usually conducted at school level. Such skills and concepts pave the way for mathematical-literacy competencies attained at a later stage in the student's career. Sarah's case was no exception. Her strong area seemed to be the way she understood contexts, and the ease with which she used that strength in reaching half-way through the solutions, despite an insufficient understanding of the concepts and skills involved.


P-3

Part 2.

1. 1254 : 76
$= \frac{1254}{76} = 16,5$

2. 1389 : 54
$\frac{1389}{54} = 25,7$

3. 987 : 63
$\frac{987}{63} = 15,7$

4. 1008 : 59
$\frac{1008}{59} = 17,1$

5. 574 : 45
$\frac{574}{45} = 12,8$.

correctly calculated all ratios

2.0
2.1. Selling price - CPrice = Profit
3999,00 + 450,00 = 4449
7,78 - 0,82 = 696
12,99 - 14,90 = 1,91
57,64 - 12,86 = 5,7114.

1.2. School 3.
Teacher Learner = 63 : 987
70 : L = 63 : 987
$\frac{70}{L} = \frac{63}{987}$
$= \frac{70 \times 987}{63}$
= 1909

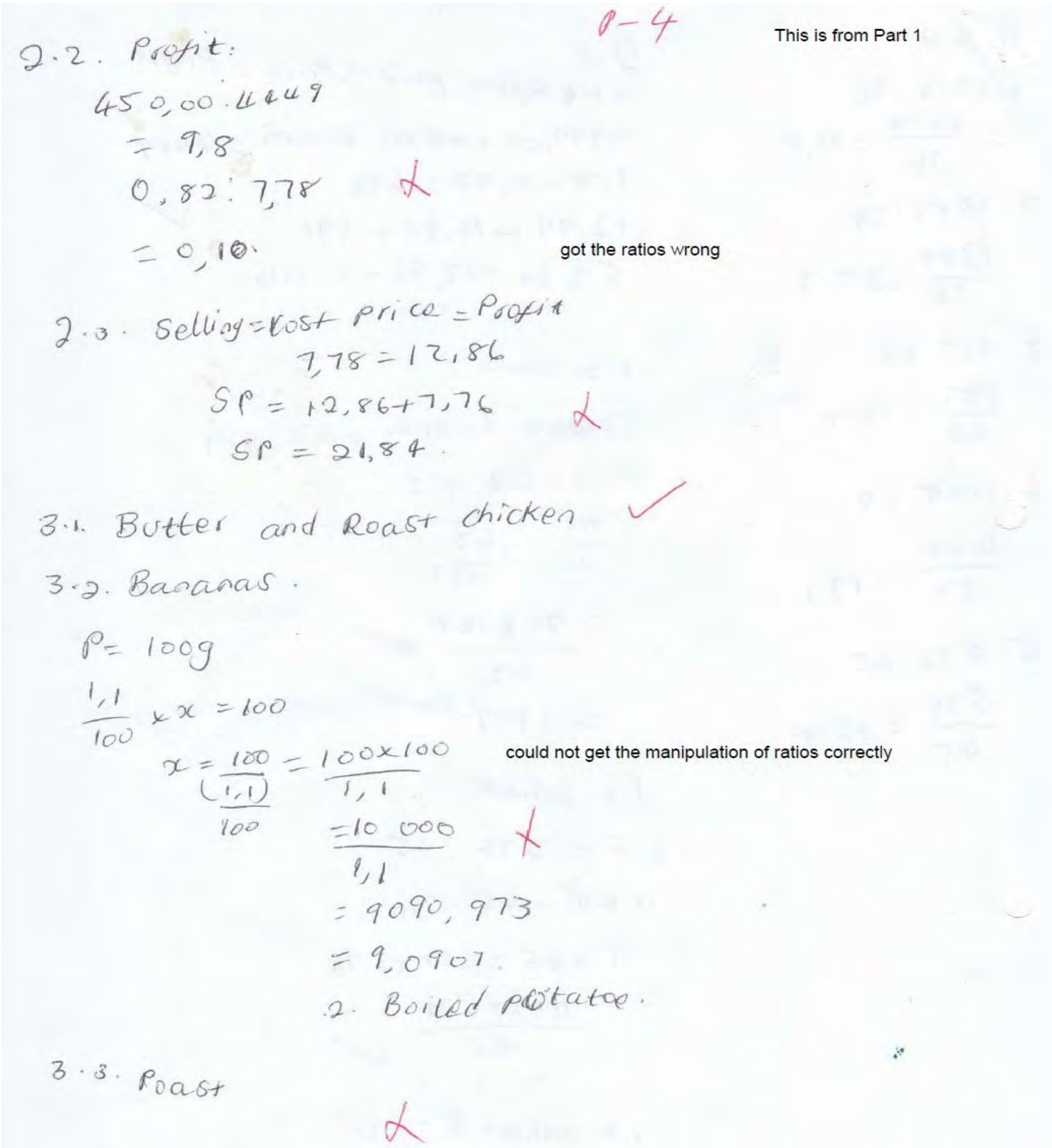
correctly manipulates ratios to solve for the unknown

1.3. Schools
L : T = 574 : 45
1148 : T = 45 : 574
T x 45 = 1148 x 574
$\frac{1148 \times 574}{45}$
= 90

1.4. School 5.
Teacher = 45
Learners = 574 = 45 : 574
∴ Because this learner can learn better than this rate of numbe.

Figure 15 Sarah's post-test

As seen in Figure 15, some aspects of the essential skills have been mastered quite substantially; for example, the calculations of ratios were mostly correct, proving that the essential skills related to ratios were her areas of relative computational mastery.



P-4

This is from Part 1

2.2. Profit:

450,00.4449

= 9,8

0,82 : 7,78

= 0,10.

got the ratios wrong

2.3. Selling = cost price = Profit

7,78 = 12,86

SP = 12,86 + 7,76

SP = 21,84.

3.1. Butter and Roast chicken

3.2. Bananas.

P = 100g

$\frac{1,1}{100} \times x = 100$

$x = \frac{100}{\left(\frac{1,1}{100}\right)} = \frac{100 \times 100}{1,1}$

$= \frac{10\ 000}{1,1}$

= 9090,973

= 9,0907.

could not get the manipulation of ratios correctly

2. Boiled potatoe.

3.3. Roast

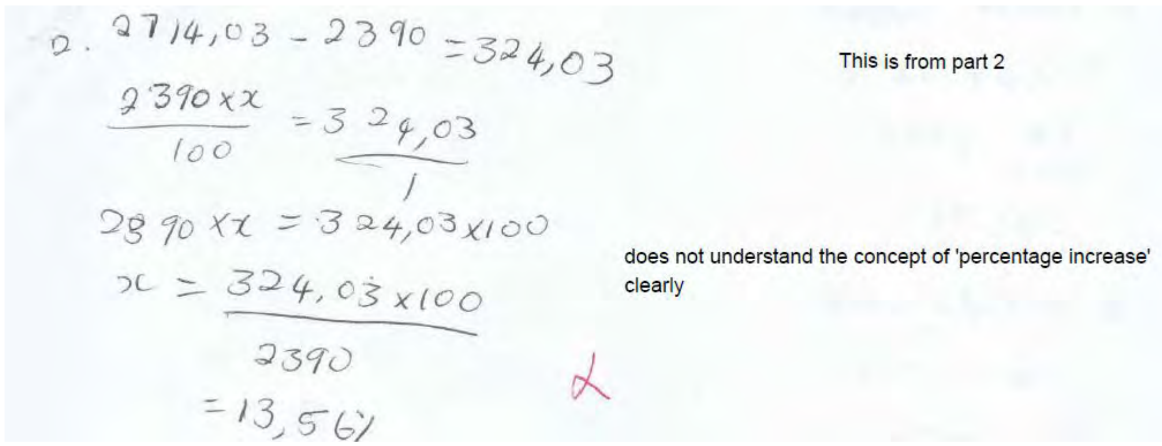


Figure 16 Sarah's post-test

However, even within those areas of her apparent mastery there were still some aspects that she struggled with, indicating that very few participants had developed a satisfactory level of mathematical-literacy competencies either naturally or as a result of the contact sessions undertaken. What may be clearly stated is that, of the three cases analysed above, Sarah's case, as indicated in Figure 14, seems to be the most significant. This is because of clear and tangible competency-related positive influences that an emphasis on essential skills and concepts has produced on participants' mathematical thinking apropos of authentic contexts.

5.4.3 Post-test on HOTS and sustainability of SIC

This test was administered to participants during the second semester of the year 2015, after a significant academic period had elapsed since the initial contact sessions. The post-test was aimed at checking the influence of SIC on participants' mathematical literacy competencies that the interventions either were or were not able to sustain. Part of the test was designed in the conventional mathematical literacy format of context-based problems with an overall emphasis on HOTS. The difficulty level was therefore slightly higher than that at which the post-SIC test was designed. The purpose was also to explore the participants' ability to sustain skills attained, using such skills in appropriate contexts. The test comprised three context-based authentic questions which had 'proportions', 'ratios', and 'percentage', as the underlying topics of mathematical concepts and skills. The concepts and skills covered were similar to those covered in the pre-test and post-test administered previously. The scope of the post-test on HOTS was therefore limited to these topics, to trace the effect of particular concepts and skills that had been emphasized during the contact sessions.

The cases of Peter, Herbert, and Robert are considered here for a quick illustrated review of their performance in this particular assessment. All three participants performed extremely well, as indicated in the following excerpts of their scripts. This posed numerous questions to this researcher with regard to the causes of such unprecedented levels of competences. While the increased levels of attainment cannot be entirely attributed to the participants' exposure to the SIC-based contact sessions, the role that the exposure actually played and other possible contributing factors in raising the levels of attainment will be examined further in the next chapter. However, a closer look at one of the questions and Herbert's response to it, as provided in Figure 5.10, gives us a glimpse of a relatively increased level of performance by the participant.

5.4.4 Excerpt from the post-test on HOTS

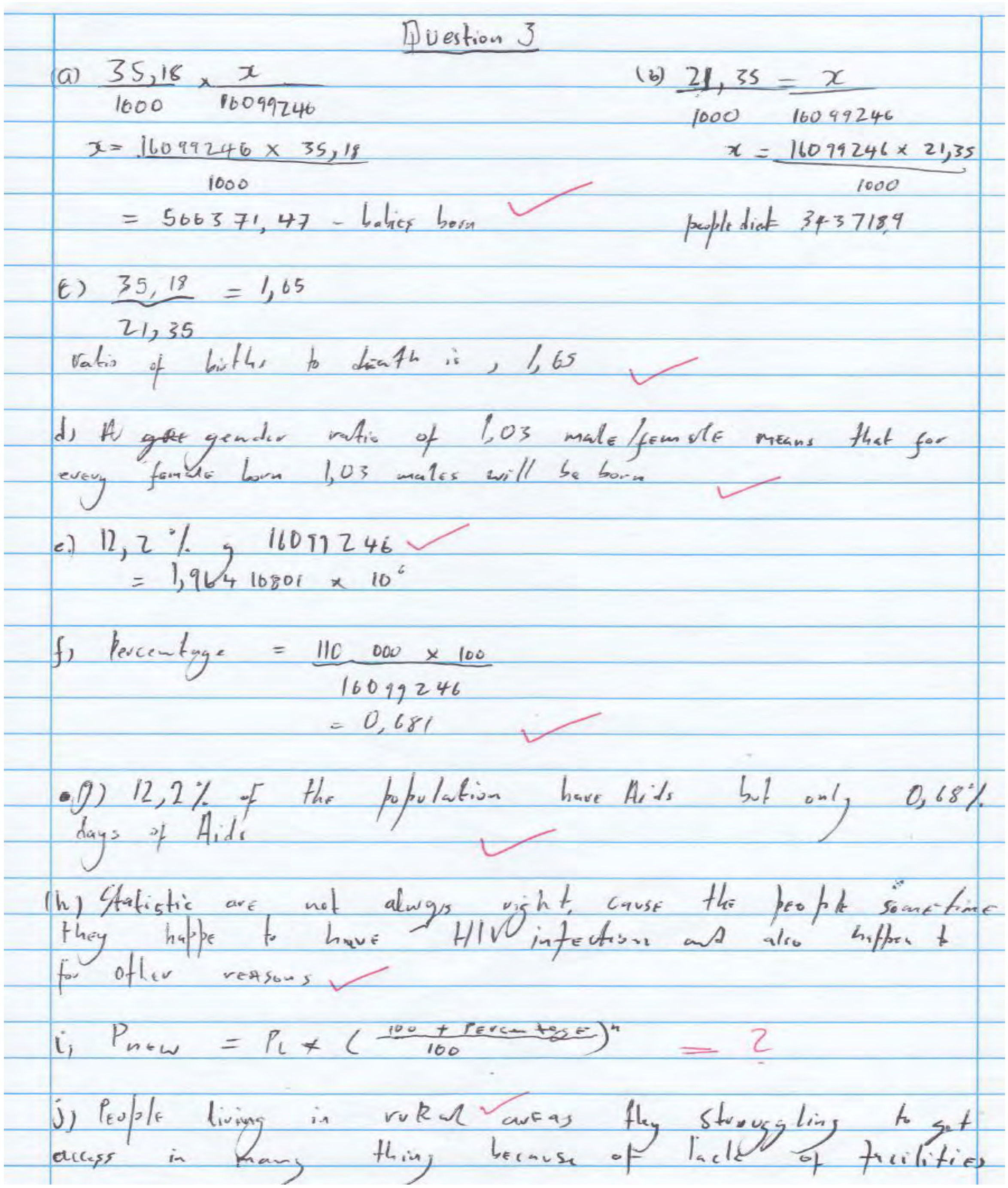
Before departing on a school tour to Mozambique, the teacher decided that all learners should learn more about that country. They started by scrutinizing the population. Answer the following questions based on this context.

a. In 2012 the birth rate was 39,34 births /1000 people. At this rate, how many births are expected in a population of 23 525 934?
b. In 2012, the death rate there was 12,79 deaths/1000 people. At this rate, how many are expected to die, of a population of 23 525 934?
c. What is the ratio of births to deaths?
d. The gender ratio at birth is 1,03 male/female. Explain what this means in your own words.
e. The HIV prevalence is 12,2%. How many adults are infected, in a population of 23 525 934?
f. In 2009, there were 74 000 HIV deaths in that country. What percentage of the population was this?
g. Do you think there are more or fewer people who live with HIV than those who die of HIV in that country?
h. In your opinion, are statistics accurate? Give reasons for your arguments.

i. Why do you think most of the figures on population in that country are estimates?

The question was built around the broad theme of 'population'. The question depicted a set of authentic problem situations with the underlying mathematical concepts and skills related to percentage, ratio, and growth rate. While the first few sub-questions were based on conceptual understanding and algorithmic skills of ratios and percentage, d, g, h and i are excellent examples of HOTS. For these questions participants have to use mathematical discretion and subjective interpretations of mathematical ideas with the associated analytical skills. Apart from phrases such as "what it means in your own words", "Do you think …", "In your opinion" and "What do you think" that indicate obvious associations with subjective interpretations based on sound mathematical arguments, the concepts and skills involved are also equally appropriate for the mathematical-literacy competencies the task aimed to assess. This indicates that HOTS such as those listed below were explicitly or implicitly, at varying levels of complexity, interwoven into the structure of the task.

- Analysis, evaluation, and creation (the "top end" of Bloom's taxonomy)
- Logical reasoning
- Judgment and critical thinking
- Problem solving
- Creativity and creative thinking



Question 3

(a) $\frac{35,18}{1000} = \frac{x}{16099246}$

$x = \frac{16099246 \times 35,18}{1000}$

= 566371,47 - babies born

(b) $\frac{21,35}{1000} = \frac{x}{16099246}$

$x = \frac{16099246 \times 21,35}{1000}$

people died 343718,9

(c) $\frac{35,18}{21,35} = 1,65$

ratio of births to death is, 1,65

d) A gender ratio of 1,03 male/female means that for every female born 1,03 males will be born

e) 12,2 % of 16099246

= 1,96410801 × 10^6

f) Percentage = $\frac{110\ 000 \times 100}{16099246}$

= 0,681

g) 12,2% of the population have Aids but only 0,68% dies of Aids

(h) Statistic are not always right, cause the people sometime they happe to have HIV infection and also differ t for other reasons

i) $P_{new} = P_L \times \left(\frac{100 + \text{percentage}}{100}\right)^n$ = ?

j) People living in rural areas they struggling to get access in many thing because of lack of facilities

Figure 17 Herbert's responses to post-test on HOTS

Herbert's response to the test shows a reasonable level of attainment of HOTS. A similar level of correctness was also observed in the responses from other participants to the same set of questions, indicating possible attainment of desired skills.

To conclude this section on the observed levels of HOTS, the participants in general demonstrated particular levels of attainment of skills indicating the effects of interventions focussed specifically on HOTS. The cumulative effects of curricular emphasis maintained during the intervention period on essential skills and concepts that permeate the mathematical literacy themes and contexts were therefore noticeable in the above analytical units.

The next chapter (Chapter 6) deals with the answers to the research questions, the conclusion, and recommendations offered by this research. Chapter 6 will include the answer to the main research question, as well answers to all the sub-questions. The answers will be drawn mainly from the analysis of data supported by appropriate references to the literature.

5.4.5 Appropriateness of the conceptual framework

The conceptual framework used in this research helped this researcher contemplate the practice of this research in its entirety as an activity that was guided by a set of inter-related concepts. The connections among those concepts and the influences such concepts had on one another were theorised to help guide the analytical process in this research. The degree to which the framework proved useful was thus worth exploring. It is also to be noted that the framework formulated was the result of a long thought process engaged in by the researcher which involved repeated alterations and refinements. The framework however still remains to be refined for future research that might be focussed on related topics in which case, this author anticipates, it will encompass more complex hitherto unknown dimensions of those concepts and the relationships thereof.

An interesting aspect of the framework that explicitly underpinned the analysis was the premise that the current curriculum was defined by a mix of concepts and contexts that served no fruitful purpose. This was because, as the framework indicated, of lack of essential skills that the first year students inherited. Attached to this premise were the prospects of a curricular alternative called SIC. The influence of SIC was theorised to manifest at the level of heightened numeracy competencies as well as Higher Order Thinking Skills.

The framework was useful in the sense that it helped interpret the observed variations in numeracy competencies that resulted from the SIC intervention. A tangible effect of consolidating essential skills and concepts prior to introducing context based problems was noticed, as the framework envisaged, among the participants. However this researcher was cautioned not to overstate the aptness of the framework by the lack of overwhelming positive indications. This is because numerous factors such as varied learning abilities of the participants, pre-knowledge levels of the participants and the levels of personal interests in the participation itself may all have contributed to the levels of attainment the participants demonstrated. The prevalence of such overt factors effectively limited the effectiveness the framework in comprehensively explaining the outcomes of the curricular intervention. This is not to underestimate the positive changes in learning approaches the participants demonstrated and the level of enhancement of HOTS observed among them. The framework could therefore be considered useful in the context it was used even though numerous external factors surfaced during the process of this research, some of which could potentially change the very conceptualisation of this framework. Such unexpected factors included presumed difficulty of mathematical concepts and the participants' reluctance to stick to a pre-determined course of academic engagement. Future research could benefit from a refined version of this framework that can effectively incorporate factors such as variations in learning abilities and characteristics, inherited skills deficiencies and factors that contribute to a sustainable curricular intervention.

CHAPTER 6
DISCUSSION OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter comprises answers to the research questions that this research embarked on. It opens with the answers to the sub-questions in the order in which they were initially formulated, followed by the answer to the main research question. The principal research question is responded to in such a way that answers to the sub-questions are collectively considered for its formulation. Having a set of predetermined conceptual boundaries for each question and its answer was not a logical approach that could be followed in the process of answering. Rather, the approach adopted acknowledged the overlap of arguments supporting the multiple questions. However, an explanation of findings has not been compromised despite the segmented nature of presentation of arguments for various questions in this chapter. The arguments are inextricably linked to data and literature so as to help the relationship between the two evolve naturally, providing an authentic basis for the answers (Aldeo, 2014). This was achieved as a result of "managing the analytical process to transform data into information and information into knowledge and knowledge into wisdom" (Ronald, 2012, p. 248). The overall presentation of arguments was, however, guided solely by the conceptual framework, while data and literature provided the building blocks for the arguments. Such arguments were also immensely influenced by the [19]reflexivity of this researcher, exercised with the intention of "limiting the bias of the researcher and their subjectivity" (Darawsheh, 2014, p. 561).

[19] Reflexivity is the process of continuous reflection the researchers engage in to generate awareness about their actions, feelings and perceptions. Reflexivity improves transparency in the researcher's subjective role of ensuring credibility of findings (Darawsheh, 2014).

The discourse technique used in this chapter is, as Yin (2009) advocated, that of having no separate sections devoted to individual cases and, instead, having cross-case analysis underpin the entire narrative. Each section is therefore devoted to "a separate cross case issue while the information from the individual cases would be dispersed throughout each section" (p.172). The individual cases were then considered "evidentiary base for the study and hence cited sporadically in the cross case analysis" (p.173). Each individual unit of analysis "revealed a discovery in which the replication across cases led to a significant theoretical breakthrough" (p.186). In other words, interpretations and conclusions reached took notice of alternative plausible interpretations. An effort was made to provide an empirical basis for rejecting or accepting such alternatives through "both supporting and challenging data" (p.189).

6.2 Cross-unit interpretive synthesis of the study

An attempt is made here to synthesize relevant aspects of all units of this case study related to the various research questions. This synthesis is drawn from the analysis of documents, interviews, pre-test scripts, contact-session notes, and post-test scripts of participants, a process modelled after similar research with similar purposes (Hossein, 2015). The purpose here is, therefore, to give the reader a broad synthesis, and its legitimation[20] therein, of the way in which the units of analysis collectively contributed to the answers to the research questions that follow this section. The arguments here are formulated purely on the basis of what was observed, learned, and interpreted prior to, during, and after the data analysis through the use of an "audit trail" which is "an accurate, comprehensive record of the approaches and activities employed in the study, both in data collection and data analysis" (Debbie, Nelly, & Steven, 2012, p. 247). The reader is then taken through a summary of the entire investigative process focussing on the interpretative aspects of what was learned from that process, preparing a preamble to the answers to the research questions that follow (Julie, et al., 2007).

The units of analysis (i.e. the participants) in this study were chosen from the same cohort of students that this researcher taught; while the single factor that governed the choice was that the

[20] Legitimation refers to the "credibility, trustworthiness, dependability, conformability, and/or transferability of synthesis made" (Anthony, Nancy, & Kathleen, 2012, p. 8)

units were to be of mixed mathematical-ability levels. The pre-test administered indicated this variation in ability levels which continued to be conspicuously prominent throughout the contact-session period. The responses to the pre-test further revealed the various levels at which the participants' mathematical thinking were positioned. The responses, most importantly, exposed the underlying procedural, conceptual, problem-solving and mathematical-communication-competences-related deficits the participants accumulated over the years. When scrutinized from the particular analytical perspective adopted by this research, the responses revealed errors in basic arithmetical calculations and simplification procedures involving fractions and decimals. The responses also revealed serious conceptual flaws pertaining to fundamental numeracy-related ideas usually taught at junior-school level. What was collectively termed as Essential Skills and Concepts (ESCs) in this research involving the elementary mathematical skills and concepts, were lacking in the responses. The lack of ESCs thus revealed were somehow overcome by the unrestricted use of calculators, despite the responses being riddled with misconceptions, lack of mathematical knowledge, lack of skills, and misunderstandings accumulated over the years. In the context of mathematical literacy calculations, while the pre-test involved concepts of a very elementary nature, the 'burden' of manually performing the basic operations involving fractions, percentages and proportions was ameliorated to some extent by the use of calculators. The calculator thus obscured the elementary procedural competence-deficit participants had inherited from the past. While the participants neither understood the meaning of 'the sum of a quarter and a half', nor could they manually demonstrate the algorithm involved in the addition of two fractions, they (the participants) managed to arrive at correct solutions to contextual problems, provided the context involved was of a low-complexity level. However, a few of the ten participants considered did manage to demonstrate a certain degree of mathematically literate behaviour; while the majority of participants dismally failed to indicate any previously attained mathematical literacy skills. Thus the pre-test turned out to be a revelation to the researcher, helping him correctly assess the gravity of the situation.

6.3 Pre-test curriculum

The curriculum practised at the time of the pre-test, and the associated teaching and assessment practices, after being scrutinized by this researcher, were found to be contributing factors to the low mathematical literacy levels of students. While the module outline claimed to have various numeracy-related competencies systematically integrated within the context base, together with context-free problems, such claims did not filter down to the students. Students did not have a satisfactory degree of competency in any aspect of the mathematical literacy related topics. This was clearly seen in the pre-test responses. The standard of pre-test responses was also indicative of the academic background from which the participants came, most of whom were marked by low achievements in mathematics and mathematical literacy, and an apparent lack of exposure to school mathematics. Therefore, the academic deficiencies pointed to by the pre-test were deeply rooted in systemic, instructional, and curricular characteristics of educational experiences the participants had undergone. However, the mathematical literacy curriculum the participants experienced at first-year level was not completely tailored to meet the particular deficits inherited by the participants. This was because the current curriculum superficially catered for a few mathematical literacy competencies by way of a limited number of topics, while the students were deficient in a multitude of areas of which the curriculum made no mention. The pre-test responses were therefore indicative of a variety of cognitive and content aspects of the curriculum, hitherto unknown to the researcher, in addition to numerous other factors that determine the numeracy levels of students. Those factors include the degree of effectiveness with which the current curriculum functioned, the mathematical aptitude of students, and the pre-university mathematical learning experiences that contributed to such aptitude levels. The quality of prior mathematical learning experiences as indicated by the participants had a direct influence on the numeracy levels the participants brought with them. This was evident when those with rich prior learning experiences, even while operating at an average mathematical ability level, managed to complement the prior learning with the university learning, achieving higher levels of mathematical literacy competencies. This could be seen in contrast with those with very poor learning experiences at school, who, in spite of having a reasonably good taste for mathematics, continued to struggle with mathematical literacy problems. However, as this researcher found out during SIC contact sessions, the latter group made far more significant progress than the former group, indicating the influence which focussed instruction can have on student learning.

While the pre-test exposed numerous issues related to students' mathematical literacy learning and the associated causes and effects, the contact sessions were another set of opportunities through which the participants exposed themselves in terms of their learning styles, individual misconceptions, and a general approach to mathematically demanding contexts. The twenty-odd hours the researcher spent with the participants revealed the levels at which participants responded to the consolidation of Essential Skills and Concepts (ESCs). The ESCs included the concepts of fractions, percentages, ratios and proportion, in addition to numerous sub-skills such concepts inherently make use of. The discussions, practice problems, and iterative practices of skills development were followed by context-based problems which the participants solved with partial success. The skills and concepts deficit was so huge that it took enormous efforts from the researcher to surmount the initial hurdles of misconceptions so that learners could unlearn what had been wrongly learnt. However, despite the daunting task of filling the conceptual and skills-related gaps of many school years, this researcher found it an overwhelming experience when participants responded positively even to the simplest concept/skill as if they were learning it for the first time. The passion, the enthusiasm, and the synergy the participants thus displayed raised questions of missed opportunities that could have made major differences in their lives.

6.4 Post-test SIC

The post-test, on the other hand, investigated the effectiveness of the SIC-based teaching and learning. While no major claim for significantly increased mathematical-literacy related competencies could be made in the performance of the participants, noticeable positive developments were noted in the levels of understanding. There were some aspects that were clearly indicative of positive developments, such as the mastery of skills taught, and accuracy of numerical calculations. However, a thorough understanding of contexts and the associated intricacies of adaptations of known procedures was still a major problem faced by the participants. While some skills and concepts were appropriately learnt as a result of SIC-based teaching, participants' ability to manipulate methods, procedures, and algorithms to suit particular needs of particular situations still remained questionable. There was thus, as this researcher found, enormous ground to be covered before the participants could be safely regarded as mathematically literate. Curricular innovations of a large-scale nature, making use of similar approaches to that proposed in this thesis, will have to be introduced in bringing about a major positive shift towards increased mathematical literacy competencies. This was evident in the positive changes, though noted in small measure, of the participants' levels of understanding, and their ability to handle mathematically rich context-based problems encountered in authentic situations.

To conclude this section, a remark made by this researcher on the overall interpretations of the data being an effort to "convert data into findings", may be appropriate here (Marianne & Lena, 2014, p. 1090). It is beyond the scope of this section to draw conclusions with regard to the results of this research-based exploration. However, a tentative, synthesized conclusion, at this stage, is that the current curriculum needs an extensive reshuffle to meet the numeracy demands of the academic life of non-science or non-mathematics major students in the faculty of education at the University of Zululand. Given the fact that almost all disciplines require the students to have a certain degree of mathematical literacy competencies so as to fit well into professional contexts, the curricular response to such a situation must be given on research-based curricular explorations. What was studied in this research was, therefore, the feasibility of just one of those possible curricular innovations carried out with the above-mentioned purpose of helping students of the faculty of education achieve a higher level of mathematical-literacy-related competencies.

From the next section the answers to the research questions are formulated, beginning with the sub-questions leading to the answer to the main research question. An attempt is also made in the formulation of answers to link the findings, interpretations, and conclusions to "extant literature", thus providing a firm grounding for the arguments on published research (Anthony, Nancy, & Kathleen, 2012, p. 3).

6.5 Answers to research sub-questions

This section focusses on the answers to the five research sub-questions.

6.5.1 Question 2.1: What is the purpose of the mathematical-literacy module taught as part of the BEd programme at University of Zululand?

The arguments establishing the purpose of a mathematical-literacy module, formulated on the basis of analysis of data in this research, were drawn from multiple sources (Laya, 2011). These included current literature, the researcher's personal experience, reflections on classroom practice, interactions with colleagues and students, field notes from contact sessions, documents, tests, and interviews. The very notion of 'purpose of a module', as a construct that defies concrete articulation, is inherently bound to the particular institutional context in which the module is offered. The purpose of a mathematical-literacy module conceptualized here is therefore mainly context specific. Certain broad educational aspects of the purpose, however, cut across institutional contexts, making such aspects the common factors of mathematical-literacy modules in general. In other words, the purpose of the module specific to the University of Zululand may be seen as the backdrop to the purpose of such modules as conceptualized elsewhere. While the formulation of the former is situated within the research site and the data collected locally, the identification of the latter is dependent on the literature. Both, however, contributed to the exploration of the design of a Semi-Integrated Curriculum, which is the aspect covered by the main research question.

6.5.1.1 Purpose as seen in literature

Quantitative reasoning (QR) is a "capstone capability" tertiary institutions expect their students to acquire to face the challenges of the modern quantitative world (Jinchang, Gurprit, & Shaoping, 2008, p. 155). Many institutions have programmes and procedures in place to help their students achieve that capability, which includes assessing the students' existing capability, and examining the efficiency of programmes to promote QR competencies (p.155). Such competencies somehow place the learning of related mathematics in a different cognitive setting, making it significantly different from the learning of 'pure mathematics'. The general belief held by students is that being successful in mathematics essentially means being able to do "algorithms, formulae and mathematical rules" (Gurudeo & Kees, 2013). The purpose of learning mathematical literacy is therefore greatly different from that of learning pure mathematics. However, the advancement of Higher Order Thinking Skills and critical thinking skills is considered a fundamental purpose in both aspects of mathematical learning (p.220).

The fact that mathematics is now part of many "non-specialist math degree programs" worldwide, indicates that the quantitative demands of non-math programmes in disciplines such as health, finance, business, planning, and education, have increased (p.220). While the quantitative demands of non-mathematics major courses have increased, institutions worldwide have created instruments and processes to assess quantitative literacy as an institutional learning goal (Stuart, Caren, Shannon, & Bernard, 2011). The purpose of having quantitative literacy courses is well reflected in those instruments, even though, according to those authors, most of the learning materials for quantitative literacy contained a significant portion that could be equated with, at a cognitive level, "interpretations", which is a Higher Order Thinking Skill (p.3). The point here is that, while assessments have a heavy weighting for HOTS, the study materials still remain focussed mainly on procedural and conceptual competencies (p.3). This contradiction is noted because, according to the SIC-based materials proposed for mathematical literacy, course materials are designed in alignment with assessments with corresponding weighting for HOTS in both aspects (the study material and assessments) of the course. The purpose of a mathematical literacy module was therefore, as conceptualized in the above instance, the development of quantitative literacy as a competency, as well as the development of HOTS. This is well reflected in the assessment rubric called Quantitative Literacy Assessment Rubric (QLAR) prepared by the Association of American Colleges and Universities (AACU) (p.4). QL core competencies reflected in the rubric are: interpretation, representation, calculation, analysis/synthesis, assumptions, and communication. The list of competencies clearly indicates the purpose of the QL courses underpinned by the advancement of HOTS, as well as competencies of concept, procedure, and communication (p.5). These competencies and their underpinning purposes could be used, as those authors noted, in the development of QL study materials (p.9).

Another dimension of mathematical-literacy-course purpose is conceptualized around exposing students to a wide range of contexts with the underlying intention of promoting transfer skills (Quality Council for Trades & Occupations, 2012). From that perspective, the purpose is to help students work within a variety of contexts. The curriculum should be so structured that students, while working within both familiar and unfamiliar contexts, are concurrently focussed on acquiring mathematical skills and concepts "that are fundamental to mathematical literacy" (p.23). This purposeful integration of contexts, skills, and concepts, is carefully executed to enhance mathematical-literacy-related competencies, including problem-solving and HOTS, a process which is at the heart of the Semi-Integrated Curriculum (p.25). While integration of contexts with concepts and skills is vital for the mathematical-literacy curriculum, another aspect that deserves special mention is the use of "standard algorithms, calculators and spreadsheets which are very useful for accurate computations" (p.26). According to QCTO (Quality Council for Trades & Occupations), an organ of the Independent Education Board (South Africa), indiscriminate use of computational tools mentioned above can be counter-productive. This is because the purpose of the mathematical literacy curriculum is to promote thinking skills and understanding, while the blind use of computational tools could lead to the reverse. The selective use of computational tools to help students devise their own strategies and tools leading to the development of original thinking is integral to mathematical literacy lessons. This is not to dismiss the use of tools altogether, but to advocate such tools' discretionary use in maximizing student learning, while the natural development of essential skills is not compromised. There will be instances when learning will be compromised by the absence of efficient computational devices. When complex problem-solving is central to the learning activity, computational tools become handy in the "promotion of HOTS, reasoning and decision making" (p.27). Those are instances in which students must not be over-burdened with the intricacies of complex calculations. Instead, the use of computational tools should help students handle problem-solving with ease. The curricular purpose is, once again, the promotion of mathematical literacy competencies backed up by the consolidation of essential skills enhanced, and not replaced, by computational tools.

Conceptualization of purposes of numeracy courses at curricular level often become the basis for curricular interventions aimed at improving student's competencies. One such intervention, that used a methodology similar to that used in this research, was conducted to improve the ability of Spanish undergraduate students to apply mathematics in biology (Francisca & Amparo, 2013). Those authors, however, conceded that the intervention was only partially successful. Students' competency in mathematics-related problems in biology did not improve significantly despite the intervention, even though the intervention helped maintain the initial levels of the students (p.902). That intervention, however, underscored the purpose of the curriculum to constantly improve students' mathematical proficiency in applied contexts of other non-mathematics disciplines. There is also evidence that interventions of this nature using "persistent, intentional instruction" can improve students' quantitative reasoning skills (Nathan, 2013, p.1). Apart from purposeful interventions, some institutions have gone to the extent of having compulsory credit-bearing quantitative-reasoning courses outside of normal mathematics courses with the sole purpose of making sure that graduates across disciplines are to a certain extent quantitatively literate (p.8). This trend is seen primarily because of an awareness that disciplines of economics and social sciences in general increasingly demand that students “explore quantitative evidence in the context of arguments” (p.8). That research conducted at the University of Carleton, Canada, also recorded that, even certain natural-science courses at some universities require their students to attain quantitative skills outside of mainstream courses. The name assigned to the courses was “Measured Thinking” signifying perfectly the underlying purpose of inculcating mathematical ways of thinking among students. This includes reasoning with numbers and mathematical concepts, so as “to be comfortable with logic and reasoning” (p.11). “Measured Thinking” was therefore a perfect example of institutional emphasis placed on a purposeful enhancement of quantitative-reasoning competency among students majoring in non-STEM disciplines (Louis, Amber, Alexander, & Shimon, 2013). Curricular and co-curricular features purposefully incorporated into the curriculum, according to those authors, fostered quantitative reasoning skills among students majoring in non-STEM fields such as education and humanities (p.17). SIC conceptualized in this thesis may be considered an example of one such feature in which “thoughtful course sequencing is combined with effective pedagogical approaches” to promote quantitative literacy (Esther, 2009).

The purpose of mathematical literacy curricula is also conceptualized around issues of “interdisciplinarity, education of concerned citizens and fostering of nonlinear thought” (Yehuda, 2009, p. 937). "Interdisciplinarity" refers to the most striking characteristic of having cross-disciplinary contexts drawn from a variety of disciplines interwoven into the mathematical-literacy curriculum. This purpose is built into the very structure of the curriculum by way of focussing on the basic quantitative needs of citizens. While the broader purpose in this context remains the quantitative skills enrichment of citizenry in general, a more academically oriented purpose is nonlinear thought (p.937). Non-linear thought essentially means the ability to deviate from a preconceived and programmed thought sequence to an intuitive and original thought process beyond the limits of disciplinary paradigms (p.938). Higher Order Thinking Skills, in this context, are another dimension of nonlinear thought, both of which, according to Yehuda (2009), are to be emphasized significantly in university curricula across disciplines (p.940). A mathematical literacy curriculum, therefore, with its newly found synergy in university campuses across the world is bound to have its fair share of HOTS intentionally built into its foundation. This is to have the "general collegiate skills of critical thinking, analytical reasoning and the writing of quantitative arguments" which belong to the category of HOTS successfully integrated with higher education curricula (Thomas, 2013). The increased importance of HOTS is further endorsed by universities in their mission statements; while the public in general regards them as important for "good jobs" (p.244). The purpose of having the advancement of HOTS as one of the core curricular objectives in a first-year curriculum such as mathematical literacy should therefore "restore what is genuinely higher in higher education" (p.243).

To conclude this section on the purpose of mathematical literacy curricula, a reference to the construct 'connections' is appropriate. Connections simply refer to the level of integration the mathematical-literacy curriculum naturally comes with. From the perspective of the purpose of mathematical literacy as a module taught at first-year level, the idea of connections may be considered prevalent throughout the curriculum. Such connections involve "connecting mathematics to the real world, to other disciplines and to other concepts of mathematics" (Kema, 2013, p. 305). The Semi-Integrated Curriculum model proposed for mathematical literacy in this thesis incorporates the three aspects of the connections mentioned here. While the concept of integration as envisaged in SIC predominantly involves the integration between content and context with the incorporation of a set of Essential Skills and Concepts (ESCs), the idea of connections is also relevant to SIC. Therefore SIC inherently remains predisposed to connections. The very conceptualization of SIC and its associated posits may all be subsumed under the idea of an interdisciplinary curriculum. The purpose of the mathematical literacy curriculum therefore inadvertently involves making 'connections', SIC being one of the many ways of achieving such connections.

6.5.1.2 Purpose of mathematical literacy module as reflected in the data

The purpose of mathematical literacy as a module offered at tertiary level in non-science and non-mathematics major Bachelor of Education courses is conceptualized, according to the literature, around fostering students' mathematical literacy competencies to prepare them for increasingly quantitatively demanding situations in professional contexts (Vicki, Pamela, Sian, Yvon, & Lynne, 2013). This sub-section, however, investigates how this purpose was envisaged as reflected in the data collected, and hence explores the manner in which the purpose was formulated, practised, and assessed at the University of Zululand.

"Mathematical literacy in the context of higher education is essential if students are to achieve their full potential, since a proficiency in both functional and more academic mathematical skills underpins achievement in many undergraduate programmes, not only in science, technology, engineering and mathematics, but also in many social science and health programmes" (Vicki, Pamela, Sian, Yvon, & Lynne, 2013). Those proficiencies operating at both academic and functional levels and their advancement were the curricular emphases indicated on the documents analysed. For instance, the module outline for the first semester indicated as the purpose, "to consolidate essential mathematical skills and understanding with a heavy emphasis on academic and non-academic contexts in which such skills are embedded". It further indicated that "the development of mathematical skills and understanding deemed appropriate for the non-science major students to efficiently manage mathematically rich academic and non-academic contexts" remained the focus of the curriculum.

Focussing on two broad areas of 'Number and operations in context' and 'Functional relationships' the outline listed concepts of percentage, ratio, interest rate and profit margin as the instructional focus. The second semester module outline indicated financial mathematics, statistics, and geometry as the broad topics to be covered. While there was a clear purpose of building basic skills and concepts in the first semester, focussing on relatively more context-based applications in the second semester, concepts and skills in the two modules were not aligned in terms of 'making sense' and hence remained scattered, serving no particular purpose. A complete lack of structural alignment kept the two modules apart as if the two semester modules were meant for separate courses. This was also because the second semester topics were not properly ordered to suit the concepts and skills covered in the first semester. The module outlines were poorly conceived and inherently flawed, to the extent that the envisaged purpose of making use of skills and concepts, learned at certain point in time, in contexts encountered later did not materialize. This non-alignment was the major contributing factor by which the purpose of the module remained separated from the content topics, whereas, ideally speaking, the purpose should have determined the content. This is not to underrate, however, the ambitious curricular goals set out in the module outlines and their relevance in the context of research discourse that governs such goals. The point of contention is, therefore, the extent to which such goals are translated to a tangible and workable content structure, as reflected in the outline. It is in this aspect that the course outlines were found wanting.

A reference to the initial categories and themes arrived at as a result of the analysis of the outlines is noteworthy at this stage. Analysis of various excerpts of the outline revealed the underlying purpose of development of mathematical literacy as a competency with its constituent components such as statistical literacy and financial literacy. In other words, multiple aspects of the same competency were envisaged which indicated a cognitive approach to designing curriculum objectives (Peach, 2010). An overall emphasis on context that drives the content also indicated the progressive outlook the module tried to project in its vision. The integrative nature of the mathematical literacy curriculum was also an aspect that was underscored in the outline, clearly conveying the message to the recipients of the curriculum that cross-disciplinary nature of both concepts and contexts was fundamental to the curriculum. The expectation that mathematical literacy as an attainable competency "could be used in all aspects of their (the students') day to day lives" indicated a utilitarian approach to the attainment of knowledge and skills. It indicated that what could not be used in day-to-day lives was not worth knowing. This aspect might have contradicted the overall impression of the curriculum's being progressive. A counter argument would hold that the worth of a curriculum cannot be trivialized and hence measured by material standards of utility.

The module outline also indicated the coverage of a set of algebraic and geometrical concepts proposed to be taught in the conventional format, devoid of any context, which indicated a traditional approach to curriculum. The reference to conceptual mastery and computational accuracy as objectives was a clear indication that the module expected the students to have a "hard work leads to success" kind of predisposition, which was more traditional than progressive in its perspective. The question of whether all the dimensions of mathematical literacy as a tertiary level module should be translated in this way to clearly defined attainable objectives is an aspect that deserves further exploration. This researcher found such overarching focus on utility, measured focus on concepts, contrived contexts, skills to be drilled and mastered, and an overall instrumental approach to teaching and learning, to have trivialized the sublimation of learning as an intellectually enlightening activity. This aspect, as this researcher strongly felt throughout the research process, calls for further investigation.

6.5.1.3 Purpose as indicated in the faculty handbook

Analysis of information given in the handbook revealed major differences in module characteristics, indicating intentional or unintentional shifts in purpose and contents of the module from those given in the course outlines. In a relatively short structural description of the module, the handbook indicated that the purpose was to "use situations or contexts to reveal the underlying mathematics while simultaneously using the mathematics to make sense of situations or contexts". This proposition indicated clearly the intention to have 'contexts' and 'mathematics' emphasised equally so as to complement each other. While a specific reference to which of the two should dominate or which of the two should take precedence over the other was avoided, the formulation of purpose as a whole differed significantly from that given in the course outline. This was indicated in the aspects of progressive and integrative characteristics of the curriculum envisaged by the course outline, which were not reflected in the traditional curricular perspective projected by the handbook. This incompatibility may be considered the most striking aspect of discord that the two documents failed to dispel and hence become reconciled with one another.

6.5.1.4 Purpose as reflected in the study guide

The overarching purpose of the module as reflected in the study guide by way of its presentation of content topics was marked by restricted scope, breadth, and depth. The ambitious nature of purpose that the course outline tried to project, and the relatively limited curricular scope the handbook referred to, were conspicuously left unsupported in the study guide. The study guide thus projected a totally different picture of purpose from that which the module outline and the handbook tried to portray. A content structure limited in breadth and depth that appeared in the study guides would not match the purpose envisaged in either the outline or the handbook. The concepts and skills covered in the study guides fell short of what the other documents claimed to cover. The study guide failed to present contents in alignment with the other curriculum documents. The conceptualization of the purpose of the module as appearing in module outlines, handbook, and the study guides, and the extent to which the purpose was supposed to materialize in practice, were in complete discord with one another. This represented a profound sense of ill-conceived purposes, non-aligned content structure, and limited coverage, that collectively characterized the present curriculum, the collective "sense making" of which was therefore difficult (Megan, Ian, & Helen, 2013, p. 10).

6.5.1.5 Purpose as reflected in assessments

Analysis of the assessments which explore the purpose of the curriculum as reflected in the assessments, revealed certain interesting features. Such features had a profound influence on the very purpose which the assessments tried to promote. The fact that a major part of tests and examinations was multiple-choice questions limited the scope of assessments by way of assigning a credit only to the final answer. This restricted nature of multiple-choice questions influenced the extent to which skills and concepts attained or mastered could be assessed. The result was that a wrong answer appearing at the end of a correct procedure would yield zero credit; and a correct answer produced in spite of using a wrong procedure would yield a credit. Multiple-choice questions also could not measure the learning of skills and concepts that underpin complex solutions to problems. It could be argued that lack of attained skills and concepts or their wrong usage would not generally lead to correct solutions. However, the unrestricted use of calculators obscured the absence of certain fundamental numerical concepts and skills which the students successfully bypassed and continued to do so in assessments. This is not to dispute the fact that, while students' conceptual understanding is greatly enhanced by the use of calculators in complex mathematical calculations, their use in the early stages of mathematical-literacy development remained an impediment to the natural build-up of mastery of essential skills. Calculators thus deprived the students, at least in the first semester, of opportunities for nurturing a sense of numbers so vital for numerate behaviour, and exploring the terrain of mental arithmetic to their mathematical advantage.

While the use of calculators may have influenced the attainment of mathematical literacy competencies in multiple ways, such influences also filtered down to assessments in general. Coupled with the extensive use of calculators was the fact that contexts used were largely contrived and hence trivial. Such contexts failed to provide a true mathematical literacy challenge to the students. Unrestricted use of calculators, contrived contexts, and the level of complexity of concepts assessed, therefore collectively placed the assessments in the precarious position of questionable validity and relevance. The purpose of the mathematical literacy curriculum initially stipulated in faculty documents was neither aligned with the objectives of the assessment nor integrated with the difficulty level, concepts, and skills assessed, nor with the contexts used in such assessments. The ideals and purposes the faculty documents envisaged were therefore not realized in assessments.

6.5.1.6 What should be the purpose of a mathematical literacy module offered to Faculty of Education (non-mathematics major) students at a tertiary level? – the way forward

The purpose of the mathematical-literacy module as conceptualized in faculty documents, and the extent to which such conceptualizations were realized at instructional and assessment levels, were scrutinized in the previous sub-sections. It is also a worthwhile exercise to contemplate and articulate a set of propositions that will serve as a preamble to the formulation of SIC-related curricular principles that appear later in this chapter. These propositions may be considered the preliminary step in the thought process that led to the final conceptualization of SIC as a curriculum alternative. These propositions evolved from the experience and personal reflections this researcher accumulated over the entire exploratory journey undertaken up to this point.

While what constitutes effective numeracy teaching is still a developing field of study, the relevance and educational worth of having a research-based and hence well-designed mathematical-literacy curriculum offered to the first-year students in a faculty of education is beyond dispute (Janeen & Vince, 2012). It is a fact that teacher trainees majoring in all subject areas, except perhaps those majoring in mathematics and physical science, are to cope with the unprecedented numeracy demands of the social sciences, economics, and management sciences, and to some extent, languages. A sustainable research-based progressive curriculum is therefore absolutely essential, for the teacher trainees in those fields to be professionally complete, and, broadly speaking, mathematically and scientifically literate (Jon, 2012). The above argument does not intend to overstate the importance of mathematical literacy for educators. This is because numeracy levels, especially the level of statistical literacy, across campuses and disciplines, is of utmost importance: universities around the world now offer credit-bearing programmes to increase the "financial wellness" of their students (Kristen, 2011).

The purpose of such a curriculum should, therefore, be built around the factors that make the teacher-educator confident and successful in his or her mathematical encounters in a pedagogical context. Three factors are of paramount importance in this regard, namely, an emphasis on Essential Skills and Concepts, use of interdisciplinary authentic contexts, and the integrative nature of the resulting curriculum linking Essential Skills and Concepts to the associated contexts at appropriate levels. All these aspects are well contained within what is called "realistic mathematics tasks" in literature (Janette, 2014, p. 79). According to Janette (2014), the fundamental idea of Realistic Mathematics Education (RME), originally credited to Schoenfeld (1994), is to learn to think mathematically, which in turn means "the development of a mathematical point of view and developing a competence for mathematical sense-making" (p.99). These two objectives fit well within the conceptualization of mathematical literacy as a first-year university module.

In other words, the way forward should be that the curriculum must be re-conceptualized around significant short-term as well as long-terms goals. The short-term goal of filling the conceptual and skills gaps − which the students inherited, and are hence impediments to their professional success −may be achieved by the identification and compilation of a set of ESCs, and the subsequent teaching and learning of such ESCs integrated with context-based thematic units of interdisciplinary content. An overarching problem this researcher experienced was the students' unfortunate predicament of being intellectually restrained because of lack of ESCs. Apart from going through the presumed embarrassment resulting from lack of ESCs, the student builds up, though for quite unfounded reasons, negative self-efficacy belief systems, leading to the cumulative build-up of a sense of inferiority.

The long-term goal, on the other hand, should be that of building up HOTS-based sustainable instructional units, so vital for modern-day educational settings, integrated within the SIC framework. Even though this research could not establish the sustained long-term effect of SIC on HOTS, unquestionably, the influence at least in small measure, could be seen in participants' performance. This leads to the question of how HOTS can be made a fundamental, rather than peripheral feature of SIC, so as to help student teachers operate sufficiently confidently to meet the quantitative demands. An emphasis on having every instructional unit embedded with a certain number of HOTS would be the answer to that question. The pedagogically consolidated set of ESCs is, however, a prerequisite for such an emphasis. This is not to presuppose in any way the primacy of ESCs but to advocate for their relative priority among the elements that constitute the SIC framework. The long-term goal within the SIC curricular model should thus be that of a provision for constant improvement, by which ESCs, HOTS, and the context-based curricular content remain intertwined, so as to produce the optimum benefit for students. The different characteristics of the curricular model that should underpin such a complex mix of constructs are elaborated in the answer to the next research question.

6.5.2 Question 2.2: What are the characteristics of a Semi-Integrated Curriculum (SIC) in the context of teaching and learning of mathematical literacy in higher education?

The Semi-Integrated Curriculum (SIC) was conceptualized with the intention of providing a curriculum alternative for the mathematical-literacy curriculum currently followed by the Faculty of Education, University of Zululand. It was originally conceived by this researcher, who has taught this module ever since its inception three years ago. This researcher's own experience of teaching the module for the last three years, and his students' experience of being taught mathematical literacy as a university first-year course, have both contributed to this concept. The characteristics attributed to SIC, and hence its evolution as a curricular idea, were rooted in the actual classroom teaching, even though the philosophical basis of the integrated curriculum that SIC depended on was drawn from the literature. For the sake of convenience the description that follows is built around aspects of characteristics of SIC related to: content, concept, skill, context, instruction, assessment, HOTS, and sustainability. A short, illustrated description of each is attempted below, followed by a tabular summary of all aspects in conclusion. The reader here is cautioned that each of the characteristics mentioned below deserves to be an independent research topic. This was the view of the researcher; only research focussing specifically on those topics can substantially bring out the individual characteristics. The descriptions below are therefore drawn from the data and literature and are purposely contained within the scope and detail of a 'research question' and its answer.

6.5.2.1 Content characteristics

The mathematical content selected for SIC is fundamentally interdisciplinary in nature. Ideally, the content is theme-based on the whole, even though it is not strictly stipulated that each part constituting the curriculum should be theme based. This facilitates an occasional introduction of content matter that is not associated with any particular theme, for the purpose of its (the particular content matter's) elucidation, only to return to the theme-based teaching and learning later. SIC therefore envisages a flexible approach to theme-based integrated teaching and learning, in that focus is shifted temporarily to a different content matter from content integrated with the theme. A consistent, overall instructional adherence to the theme is, however, maintained, so that students are able to make sense of the theme as a whole. Students are able to realize why the particular theme was selected for the exposition of a particular content matter. The following example, taken from the post-test on HOTS (Question number 3), illustrates this aspect.

Before departing on a school tour to Mozambique, the teacher decided that all learners should learn more about that country. They started by scrutinizing the population. Answer the following questions based on this context. In 2012 the birth rate was 39,34 births/1000 people. At this rate how many births are expected of a population of 23 525 934?

a. *In 2012 the death rate was 12,79 deaths/1000 people. At this rate how many are expected to die, of a population of 23 525 934?*
b. *What is the ratio of births to deaths?*
c. *The gender ratio at birth is 1,03 male/female. Explain what this means in your own words.*
d. *The HIV prevalence is 12.2%. How many adults are infected in a population of 23 525 934?*
e. *In 2009 there were 74 000 HIV deaths in that country. What percentage of the population was this?*
f. *Do you think there are more or fewer people who live with HIV than those who die of HIV in that country?*
g. *In your opinion, are statistics accurate? Give reasons for your arguments.*
h. *Why do you think that most of the figures on population in that country are estimates?*

(Adapted from via Afrika Mathematical Literacy, p.26 Grade 12 Learner's Book, 2013)

The mathematical content around which the problem is designed is drawn from a collection of concepts such as ratios, rates, and percentages. It may be seen that the mathematical content as a whole is skilfully integrated with the context of the problem. The content knowledge with regard to the manipulation of ratios, working with rates, and calculating percentages, is therefore vital for the successful comprehension of the problem and its subsequent correctly executed solving process. This research explored whether a prior content consolidation of those three aspects would have expedited the solving process. Whether or not such a segregated effort in consolidation should precede every thematic unit is, however, best left to the discretion of the lecturer: different cohorts of students come to the class with different mathematical frames of mind that may have evolved from previous learning experiences. According to the SIC framework, an appropriate pedagogical decision in the context of the above problem would be to consolidate the content sufficiently with numerical examples, gradually helping the students work their way up to the context-based problem. A smooth transition from a solid understanding of what the content means mathematically, to an understanding of how such content matter plays out in an authentic context, is thus the fundamental content-related characteristic of SIC.

6.5.2.2 Concept characteristics

From the perspective of SIC, 'concept' differs from 'content' in the sense that a collection of individual mathematical concepts and the associated skills and procedures collectively constitute what is called the mathematical content underpinning a certain interdisciplinary theme. The individual mathematical concepts are therefore the fundamental building blocks of the curriculum. SIC envisages concepts to be of an elementary nature as opposed to advanced concepts that do not necessarily belong to the realm of mathematical literacy content, contexts, or themes. For instance, the mathematical concepts involved in the above example are percentages, ratios, and rates. The question of what makes an elementary concept, to a certain extent depends on the context considered to carry the concepts. The selection of concepts, and hence the content as a whole, is therefore carefully devised so as to strike the perfect balance between complexity and simplicity. This is an aspect by which the curriculum remains neither complicated nor oversimplified in terms of the concepts covered.

Reinforcement and consolidation of each concept is therefore subsumed under the broader aspect of consolidation of the content as a whole. In the above illustrative example, a comprehensive instructional coverage of all the three concepts presented individually and collectively through the iterative practices of numerical examples, would mean that the students are 'mathematical content ready' to take on purely context-based authentic problems.

6.5.2.3 Skills characteristics

In addition to the concepts, certain skills are also vital for the curriculum. Skills in executing procedures, manipulating formulae, computing sums, differences, products, and quotients of fractions and decimals, are some of the skills frequently applied in mathematical literacy. Within the concept of SIC, skills occupy a significant position. This is because lack of computational skills, as this researcher witnessed, often led to the concept and (hence) the context being completely relegated to underutilization. In other words, SIC envisages, as indicated earlier in this thesis, relevant skills to be identified and consolidated prior to the introduction of context-based problems. This facilitates the ease with which students attempt to solve problems; avoiding unnecessary obstacles preventing the solution process, that appear in spite of the students' apparent prior mastery of the concepts, and perhaps a reasonably well-understood context.

The skills identified in the illustrated example are operations with fractions, manipulating ratios, and calculating a certain percentage of an amount, or calculating what percentage of a certain amount makes up another smaller amount. A satisfactory level of mastery of these skills acquired elsewhere, or prior to the solution of this problem, would certainly put the students in an advantageous position. This scenario may be contrasted with one in which students who are completely unskilled in mathematical manipulations of the said nature, are trying to solve the same problem. The former group stand to benefit from the recently acquired skills and hence smoothly transit to the contextual problem; while the latter group will struggle to apply a set of unfamiliar skills in a context that may or may not be familiar.

Consolidation of computational skills that can often be done simultaneously with the consolidation of concepts is a significant characteristic of SIC. Skills associated with mathematical operations and computations are at the core of mathematical literacy. SIC is therefore designed to have such skills appropriately emphasized in the instructional design of the content matter.

6.5.2.4 Context characteristics

SIC, by virtue of its integrative design features remains predominantly context bound. Concepts, skills, and context, together make up SIC, even though each of these entities has a unique role in the whole curriculum. However, context on its own has, as seen in the various definitions of mathematical literacy the literature provides, a predominant role to play in the conceptualization of mathematical literacy curricula in general (Donna & Travis, 2010). Mathematical literacy is on the whole, considered conspicuously associated with authentic contexts, while the degree of association between context and concepts is what determined the special nature of the Semi-Integrated Curriculum. This may be seen from the backdrop of mathematical literacy tasks that require students' "flexible participation within and across both the contextual and mathematical domains in an intertwined manner" for them to be successful in such tasks (Sarah, Thokozani, & Patisizwe, 2012).

SIC envisages contexts to be of a 'familiar' nature. While what is familiar and what is not is a question of discretion exercised by the lecturer, contexts of reasonably familiar nature are generally drawn from the fields of activity that the students themselves engage in. Complexity of the context cannot be preconceived to fit a certain criterion; however, the degree to which students can associate themselves with the contexts is a factor that determines the effectiveness of the contexts. For instance, students' study-loan-related misconceptions in a campus scenario would be an ideal context in which to teach financial literacy (Mark, 2015). SIC further envisages that the concepts and skills consolidated prior to the introduction of a context-based problem, coupled with a familiar context appearing in the problem with which students can associate, can maximize the level of engagement. The students thus move with ease from one stage to another in the solution process, as the obstacles created by unfamiliar contexts, difficult concepts, and unpolished skills are eliminated. In the context of this research, no major differences in the performance of participants − after being given problems with both familiar and unfamiliar contexts based on the same concepts − could be noticed. However, participants' approaches in both instances were significantly different, indicating a positive effect of familiar contexts on problem-solving ability. The level of familiarity of the context with which the students associate themselves is therefore a significant factor contributing to the development of numeracy skills as envisaged in SIC. For instance, under the theme of 'campus finance' the topic of 'money missteps' could be an interesting context driving home the tips for saving money in a campus atmosphere (Stinson, 2014). In general, SIC envisages the incorporation of basic and broad themes, as well as the contexts that are suitable for learning about such themes. Concepts and themes collectively "subsume(s) a body of related sub-concepts" (Ammeret, Michael, & Marc, 2011, p. 411). An excellent example of the integration of concepts, sub-concepts, and themes, envisaged in this way, is provided by Keng & Kian (2012). These authors reported a curricular intervention involving a series of six one-hour lessons during which contexts such as hire purchase, profit and loss, and utility bills, were infused with "standard syllabus content" prescribed in the conventional format (p.306). The similarity of that intervention with that of SIC is noted here for comparable purposes underpinning both.

6.5.2.5 Instructional characteristics

Instruction in SIC is essentially conceptualized around the concept of holistic academic numeracy development in which "a balance between focussing on the mathematics and focussing on the context" with the purposeful simultaneous development of HOTS, is achieved (Roger & Robin, 2012, p. 41). Based on principles of constructivism and related pedagogical approaches, SIC is characterized by its instructional emphasis on collaborative, discovery-based learning. Instruction, therefore, is focussed on the students' development of certain learning behaviours that promote independent learning strategies at first-year level – so vital for such students' future endeavours at tertiary institutions that produce graduates "who are able to offer their employers more than the knowledge of their majors" (Mary & Margeret, 2015, p. 27). In other words, the formation of a numerate behaviour coupled with the shaping of an analytical mind to scrutinize, process and interpret quantitative information is central to the instructional methodology adopted for SIC. This may be achieved by the establishment of a solid foundation of basic skills in operations and concepts complemented and enriched later by explorations of the authentic contexts. Familiarity with basic skills and concepts invariably leads to a confident engagement with contextual problems, which in turn leads to the ideal state of independent construction of knowledge, a critical aspect of constructivist learning theory. Conversely, "exploring real world contexts will help students make sense of algebraic relationships", an aspect which, to some extent proves that SIC may work in both ways, meaning that either a movement from concepts to context, or a movement from context to concept, can enhance numeracy competencies (p.42). Even though this may sound contradicting of the initial assumption made in this thesis about SIC, the bidirectional relationship between context and concept is well established in literature. SIC, on the other hand, emphasizes the consolidation of ESCs as a precondition for context-based problems.

Another aspect of instruction in SIC is that, in spite of the idealized state of reinforcing concepts and skills prior to the context-based problems, a rigid instructional framework is not advisable. Back-and-forth movements between skills, concepts, and contexts, are often indispensable, because skills and concepts, once mastered, are not necessarily recollected all the time. However, Roger & Robin (2012, p.57) emphatically state that "timely reminders of previous mathematical knowledge necessary for the task" should be one of the characteristics of context-based problems. This aspect is perfectly aligned with the fundamental notion of SIC that calls for ESCs to be condolidated prior to the introduction of context-based problems. A "continuum of embeddedness" may also be considered to exist between concepts, skills, and context, progressing in the order: separate-partly; embedded-mostly; embedded-fully; embedded (Jay, 2012, p. 24).

6.5.2.6 Assessment characteristics

Assessment of mathematical-literacy-related competencies is often intertwined with the curricular format followed. While skills, concepts, contexts, and thematic units of content, together constituted SIC, the assessment of those aspects are integrated within the practice of teaching and learning of the thematic units. Broad-theme-based assessments are administered that encompass a set of concepts and skills. Assessments in SIC set for an extended period of time have broader multiple themes and a larger number of integrated concepts and skills.

A certain aspect of assessment that stands out is the use of calculators. Mastery of standard calculator functions is an extremely important aspect of numerate behaviour and is advocated for extensively in literature (Gemma, 2014). The benefits are said to be immense. However, "a calculator-aware approach cannot simply be improvised around a conventional curriculum" (p.7). The fact that the calculator is an efficient tool for developing mathematical conceptual understanding, does not guarantee its effectiveness. Rather, calculators, when supported by skilled pedagogy can accentuate conceptual understanding (p.8). In this context, this researcher maintains the position, in line with the most predominant view the literature provides, that the calculator should not be misused to the extent that mastery of basic arithmetic and a certain degree of fluency in mental arithmetic are compromised by the use of calculators (Joan, 2013). It is established in literature that mental arithmetic has its own effect on generative mathematical thought and comprehension. The inappropriate use of calculators, as Joan (2013) warns us, will only contribute to the perpetuation of innumeracy which continues to "burden our nation with citizens increasingly incapable of applying basic mathematical reasoning to issues such as health care, tax policies, voting procedures, mortgage and credit banking policies" (p.130).

On the whole, assessment in SIC is as important as the curriculum and instruction. A variety of assessment techniques is appropriate, while the formative aspect of such assessment is to be given significant weighting as well, through the use of alternative methods of assessments. Assessments such as projects and investigations carried out over an extended period of time, in addition to the tests and examinations set in the conventional format, carry significant formative relevance in fostering numeracy-related competencies, while carrying sufficient psychometric soundness (Kabelo, 2013).

6.5.2.7 HOTS' characteristics

Development of sustainable Higher Order Thinking Skills (HOTS) is the other important aspect that SIC envisages to foster in numeracy students. Courses offered at tertiary level have placed increasingly more curricular focus on HOTS. In the context of mathematical literacy, development of HOTS is linked to such skills' applications in all authentic quantitative contexts, which in turn lead to skills associated with quantitatively sound decision-making processes. Development of HOTS has the short-term effect of students' becoming adept in appropriately taking quantitative decisions, while the long-term goal is to help such skills evolve into a higher level cognitive ability that cuts across disciplinary boundaries and professional fields. HOTS, therefore, once attained and then nurtured, yield intellectual profits by way of sound numeracy practices that the student becomes competent to undertake.

SIC has inherent HOTS-related aspects that consistently place the emphasis on attainment of basic skills as a precondition for the advancement of various numeracy competencies. As a concurrently developed faculty, HOTS remain strengthened by the purposeful instructional and assessment emphasis placed on such skills by SIC.

HOTS as an aspect of 21 st century competences, is also worth mentioning here. Joke & Natalie (2012), while investigating the implications of integrating such competences in curricula noted that curricular efforts geared towards such a goal are fundamentally different. The researchers recorded the diverse nature of HOTS integration as suggested by various authors; for instance, added to the existing curriculum, integrated as cross-curricular competencies, and taught as part of a new curriculum (p.310). The fact that proper mechanisms of assessing these competences are still in the developmental stage is also interesting: such mechanisms have to form an integral part of the HOTS-based curriculum itself (p.314).

6.5.2.8 Sustainability characteristics

SIC as a sustainable curricular alternative depends mainly on whether or not the effect it produces is sustainable. Numeracy competencies once attained, however, are sustained in successive fields of activity in which the students become involved. HOTS also have similar sustainable effects by way of deeply entrenched numeracy-related HOTS-based practices. The very question of sustainability of HOTS is technically answered reflexively, in that skills of that nature affect the mathematical thinking and the mathematical approach positively; both of which are habits of mind, as opposed to temporarily achieved skills or competencies. Higher Order Thinking Skills, being habits of mind, once reinforced through the practice of the Semi-Integrated Curriculum, should guide the students in their pursuit of skills and knowledge in all spheres of their careers.

Within the context of this research, sustainability of SIC in general, and its influence on HOTS, were explored through participants' responses. While skills and concepts consolidated through SIC were sustained significantly as demonstrated in the responses, the effect of HOTS were only established within the scope of particular test items in which the respondents performed just satisfactorily. The reason for such mediocre levels of performance was explored in detail in the answer formulated for the particular research question referring to HOTS.

6.5.2.9 Concluding remarks on characteristics

The characteristics mentioned above are conceptualized by this researcher based on the understanding of SIC that evolved prior to and during the research period. Such traits are supported by ideas drawn from literature and data collected. The researcher's experience of teaching the module, and the influence the classroom experience had on the conceptualization of SIC as a curriculum alternative, cannot be overemphasized. "Analytic memo writing" used extensively in this research also contributed to this conceptualization (Gregory, 2014). The researcher's interaction with the student cohorts of many semesters had long-lasting effects on this researcher's perceptions as to how best the students' numeracy-based competencies could be fostered. SIC, by virtue of its roots in such perceptions, transcends a set of characteristics mentioned above. There are thus other characteristics that could be considered significant, yet are excluded from the above list. Such sub-characteristics could, however, be subsumed under a single characteristic, or multiple main characteristics mentioned above.

6.5.3 Question 2.3: What influence does a Semi-Integrated Curriculum introduced for the mathematical-literacy module have on students' Higher Order Thinking Skills (HOTS)?

The answer to this question was drawn from the responses to the SIC pre-test, post-test, and the post-test on HOTS. At the very outset, this research could not claim that major differences in HOTS were attained purely as a result of exposure to SIC. Arguments in support or defence of this claim had to be drawn specifically from the post-test on general competencies and the post-test on HOTS. Other sources of data, namely, the contact session scripts and interactions were also used, in a limited way, to support the arguments presented here.

An emphasis on HOTS was maintained throughout the contact-session period. This purposeful emphasis resulted in a particular pedagogical approach, which was to some extent unforeseen by the researcher. This particular approach deviated greatly from the approaches with which the participants and the researcher were familiar. The focus of the contact sessions was never on fluency in procedures or on the correct use of algorithms. Rather, classroom discussions were purposefully geared towards the facilitation or the nurturing of HOTS, without the participants being aware of such intentions on the part of the researcher. While procedures were not sidelined altogether, participants were forcefully drawn into deeper levels of thinking and mathematical contemplation. Not being forced to learn for a particular assessment, the participants ventured into mathematical explorations with a mind open to learning. The most striking aspect of the contact sessions, the open-minded approach to learning, may have hugely impacted on the outcome of this research. The positive development with regard to learning in general, and HOTS in particular, could thus be to some extent attributed to the incredibly stress-free atmosphere in which the participants conducted their mathematical activities.

From the perspective of analytical conclusions reached in this thesis, the influence that SIC produced on HOTS was significant. Almost all participants demonstrated changes in their overall understanding and hence the attainment of HOTS by way of correctly used concepts and skills.

While this positive development cannot be entirely attributed to the intervention, the effect that was actually produced by SIC on HOTS can also not be underestimated. It is also to be noted that the effects of a focussed instructional intervention on intellectual behaviour is generally far-fetched, and hence cannot be measured accurately by the use of an instrument. An instrument, however, may be used to measure certain aspects of the effect of HOTS, especially those related to the recently acquired conceptual knowledge and skills. Hence it is unlikely that such an instrument can accurately predict how the participants would respond if given an alternative set of HOTS-based questions.

A reference to Bloom's taxonomy which is a "well established framework for categorising a set of assessment items into six levels according to the thinking pattern required" can place the above argument in proper perspective (Jamie, Mark, Steven, & Tyler, 2014). According to these authors, within Bloom's taxonomy, *remember* and *understand* are considered to belong to lower-order cognitive skills (p.308). The third level of the taxonomy which is *apply* belongs to the intermediate cognitive skills and the three higher levels of the taxonomy which are *analyse*, *evaluate* and *create* require higher-order cognitive skills. According to those authors, the taxonomy was designed to be a "cumulative hierarchy where mastery of the lower levels of the taxonomy were prerequisite for performance on higher levels meaning that a question written at the analyse level of the taxonomy would require mastery of the basic content in order to perform the analysis required by the question" (p.309). This, in so many ways, justifies the SIC-based proposition that a set of ESCs are prerequisites to context-based problems and hence to HOTS. A related interesting idea from the same authors is that "to perform at higher levels of Bloom's taxonomy, students must have mastered the lower levels" (p.311). The students' expectation of possible higher-order questions in the test would force them to master the essential skills so as to apply them in the problems involving *analysis* and *evaluation.* Thus, those authors argue, an emphasis on HOTS inadvertently leads to the consolidation of essential skills, as well as to retention (p.311).

Recent research has reinforced the popular perception among practitioners that purposeful development of HOTS through specific intervention strategies do help students solve complicated problems that are typical of the "contemporary knowledge based society" (Oleg & Jamal, 2015, p. 225). According to those authors, interestingly, the most appropriate method of fostering HOTS is by the use of Problem Based Learning (PBL). However, the difficulties associated with the PBL model are the students' inability to learn on their own, lack of motivation to voluntarily develop HOTS, and the added workload for the lecturer (p.225). These hurdles may be overcome, according to Oleg & Jamal (2015), by the adaptation of the PBL environment which is "HOTS-centered, student-centered, student adaptive, assessment centered and computer supported" (p.225). The authors also classify HOTS into two general categories, i.e. analytical thinking skills, and creative thinking skills. While *ordering, comparing, contrasting, evaluating*, and *selecting,* belong to the first category, *efficiency* (producing many ideas), *flexibility* (producing a broad range of ideas), *originality* (producing uncommon ideas), and *elaboration* (developing ideas) belong to the second category (p.227). It is interesting to see how an increased awareness on HOTS in the tertiary education sector is gaining momentum internationally with curricular and pedagogic innovations such the PBL model. SIC may be considered in this context to have similar objectives capable of producing similar influences on the development of HOTS, but with different operational characteristics.

In conclusion, the point to be made here is that there is certainly an effect on HOTS that may be attained by a focussed curricular intervention such as SIC. HOTS cannot be considered a set of intellectual felicities that may be created overnight through short-circuited curricular efforts. HOTS are rather a state of mind that is allowed to evolve as a result of consistent pedagogical efforts purposely aimed at fostering a particular inquisitive state of mind that instinctively unearths the meanings behind mathematical statements, ideas, and propositions. Such a way of developing mathematical-literacy-related behaviours and hence the associated HOTS, is what is envisaged in SIC.

6.5.4 Question 2.4: To what extent are Higher-Order Thinking Skills, attained in a mathematical literacy course, sustained in the subsequent semester of study?

The answer to this question was primarily drawn from participants' responses to the post-test after the SIC intervention, the post-test on HOTS, and relevant literature. The post-test on HOTS was administered to the same participants in the second semester of the data-collection year. The post-test on HOTS was administered purposely after a brief academic time had elapsed, with a view to emphasizing the sustainability over time of skills attained as a result of SIC. The test was administered without the presumption that a certain degree of attainment of HOTS had taken place.

Rather, the objective was to measure the degree to which the participants may or may not have achieved HOTS in any measure. However, the post-test on HOTS maintained the aspects of content that were initially used in the post-test, so as to make sure that the SIC pre-test and post-test, and the post-test on HOTS, did not differ significantly in terms of the concepts and skills involved. This assisted the researcher maintain the three aspects of the research instrument aligned for the purpose of reaching logical conclusions.

The post-test on HOTS yielded significant insights into the critical aspects of student learning that takes place under controlled conditions and under purposeful instructional guidelines. For instance, the responses showed remarkable differences in the approach the participants adopted for conducting problem solving. Differences were also noticed in the general use of skills, procedures, and concepts for arriving at solutions. The question of sustainability is therefore linked inextricably to the attainment of a variety of attitudinal changes the participants went through, rather than what could be observed in the responses to a test administered in controlled time and conditions. The argument here, therefore, is that, while participants demonstrated considerable levels of attainment of HOTS, in the post-test for HOTS such levels could not be taken with absolute certainty as dependable measures of progression. This is not to undervalue the attainment the respondents might have actually acquired as a result of the purposeful exposure to SIC. Indeed, actual attainments of that nature were noticeable in the overall performance of the participants.

Another salient point is that participants in this research were drawn from a variety of non-mathematics major disciplines. It is unlikely that such students will in future be faced with exactly similar contexts they encountered in the post-test. This means that skills and concepts demonstrated in a particular context might not be demonstrated with the same level of mastery when problems from another context are encountered, even though the same skills and concepts are involved in the contexts in question. Once again this is not to understate the level of attainment the participants demonstrated in the post-test and HOTS test. The purpose of this argument was only to highlight the complexity of measurement of skills in a context-driven curriculum such as mathematical literacy.

Higher Order Thinking Skills, by their very nature, are fundamentally transferable across disciplines. Such skills attained in a mathematical literacy context are therefore not confined to one particular area of study. Also, HOTS in general, and problem solving skills in particular, involve instances whereby "students deepen their understanding of mathematical concepts by analysing and synthesizing their knowledge" (Ayhan & Serkan, 2012). The researchers also found that problem-solving strategies and HOTS, once attained, remained consistently contributing to higher academic success levels (p.99). There is ample evidence in literature that HOTS are not context dependent, rather, they incorporate advanced mathematical and scientific thought. Critical thinking skills and HOTS are considered the most important outcomes of undergraduate education by many universities (Barry & Ada, 2011). One important observation these authors made is that "solving real-world problems using basic mathematical calculations is an essential critical thinking skill" (p.45). These authors listed "Evaluating information, Creative thinking, Learning and problem solving and Communication as the most important critical thinking skills" that should be fostered by purposeful curricular interventions (p.45). It is also interesting to see that an assessment instrument called Critical Thinking and Assessment Test (CAT) was used by the above authors. The instrument relied basically on "short essay responses to assess critical thinking unlike many standardised test that rely on multiple choice questions" (p.47). This point is noteworthy, in that appropriate instruments to be used in research for measuring the attainment of critical thinking skills and HOTS, could produce a fairly accurate picture of such skills' development and sustainability.

HOTS, and the ways in which students demonstrate their attainment or lack thereof, are, however, too complex to be observed in one episode of students' intellectual behaviour, as seen in this research. Broadly speaking, "no strategy, behaviour or characteristic should be expected to always be productive for every problem" (Ayhan & Serkan, 2012, p.101). In other words, while it is important that students have a variety of HOTS at their disposal, they should be able to use their intellectual discretion and meta-cognitive skills to determine when and where such skills should be put to use. While this researcher witnessed the development of HOTS in its very limited sense and context among the participants, such skills' long-lasting effects across disciplines over an extended period of time, including the professional fields in which the participants might find such skills useful, are to be the topics of further research.

There is ample evidence in literature that endorses the view that for students to "learn critical thinking, instructors need explicitly to teach it through focussed instruction" (Linda & Richard, 2010, p. 38). However, the sustainability of such focussed instructions as SIC should be considered within certain limitations, according to those authors. The argument here is that the attainment and sustaining of HOTS are heavily dependent on various faculties within an institution collectively fostering such skills in their subjects. It is also "unreasonable to expect students to learn critical thinking at any substantial level through one or a few semesters of instructions" (p.38). In spite of significant effects being produced only in long-term-focussed instructions, it is a fact that such skills can be attained with certainty. Therefore it is imperative that such skills in general be reinforced across the curriculum, while some other competencies are best taught in a more structured way; the purpose in both instances being the "transformation of classrooms into communities of thinkers" (p.38). Reinforcement and sustaining of HOTS through a curricular intervention such as SIC must be seen within this context. While developing HOTS is "central to the mission of all educational institutions", the way in which that centrality may be translated at curricular level is the pertinent question (p.39). However, it remains a fact that HOTS help "internalise important concept within a discipline and interrelate those concepts with other important concepts both within and among disciplines" (p.39). This point supports the notion that the interdisciplinary nature of the curriculum stays well aligned with the consolidation, reinforcement and sustaining of HOTS through a curricular intervention such as SIC.

The concept of "21^{st} century skills and the new learning paradigm" are also relevant in this context (Kivunja, 2015, p. 9). Broadly considered belonging to Career and Life Skills' domain, these skills are unfortunately not included in higher education curricula even though, because of the demands of the information age and the need for multi-tasking, versatility, and speed, they are considered key components of the new learning paradigm (p.9). Those skills are broadly and thematically grouped into categories such as: flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility. While the particular competences constituting each category are still to be explored, Kivunja (2015) also advocates for the inclusion of skills associated with these categories in the higher education curricula for the students to be "competitive in the 21^{st} century digital economy" (p.10). It is clear from the above formulation that the notion of 21^{st} century skills is a formal extension of HOTS to a wider domain of essential competencies to include broad dimensions of themes such as those mentioned above.

The purpose of the above argument is that the scope of HOTS and the notion of 21 st century skills to which HOTS belong are philosophically positioned in the wider fast-changing terrain of what constitutes the 21st century university graduate's skills and competencies. While SIC may be considered to have helped sustain HOTS to some small measure, however insignificant, the need for large-scale curricular undertakings with similar intentions cannot be disputed (p.10).

Such a large-scale curricular enterprise was undertaken at the University of Canterbury, New Zealand. The aim of the course was to teach critical thinking skills to a cohort of 1000 students at first-year level, drawn from non-statistics major courses through the teaching of statistical literacy (Irene & Jennifer, 2012). The concepts of HOTS and *critical thinking skills* were used to define the statistical-literacy learning outcomes of the course (p.1059). Provided to students in fully online format, the course structure had so many characteristics that could be a model for improvement of a SIC-based instructional framework proposed for the University of Zululand, South Africa.

In short, the answer to the question to what extent the HOTS attained are sustained in the subsequent semester may be summarized thus:

- Post-test responses indicated no major improvements in HOTS, yet significant positive changes towards development of HOTS were noticed;
- It was found that HOTS may be sustained if appropriate measures at curricular, instructional and assessment levels are taken;
- Development of HOTS is dependent on the collective effort by the faculty. SIC should be part of the collective effort; and
- If the development of HOTS is made a common characteristic across curricula, their sustainability may be ensured.

6.5.5 Question 2.5: Is the introduction of a Semi-Integrated Curriculum worth being undertaken for the mathematical literacy module of a Bachelor of Education course? Why?

The educational worth of a research-based curricular intervention as "an institutionally constrained social practice" is determined by a multitude of factors such as ease of implementation, level of acceptability among recipients, lecturers' ease of practice, overall gains for lecturers, students, and the institution, and the positive educational changes the curriculum is able to effect on students (Robin & Bob, 2012). The last of these, however, subsumes the rest, in that the educational worth is predominantly determined by the educational changes the curricular innovation makes on students.

Within the context of this research the question of whether or not it is worth undertaking the introduction of SIC encompasses almost all the aspects covered in this research, and is hence answered using multiple sources of data. The pre-test and the pre-SIC interviews indicated the dire need for a curricular strategy to fill conceptual and skills-related gaps in ways that suit a mathematical literacy module. The practice-related modalities of such an innovation incorporated conventional and progressive curricular ideas so as to address primarily the conceptual and skills-related deficits. SIC, therefore, was specifically conceptualized to suit these needs. The worth of HOTS may hence be measured in terms of the extent to which it achieved the overarching goal of filling the conceptual and skills-related gaps. An indication of such an achievement or lack thereof, as shown by the responses to the post-tests administered, was that no large-scale improvements could be noticed. However, changes in approach, conceptual understanding, and attainment of skills, were significantly noticeable. This was clearly shown in the responses to post-test questions and post-tests on HOTS.

Responses to post-test questions deserve more elucidation here. As noted earlier, no major improvement in participants' understanding or skills-related fluency could be distinctly noticed in the post-test responses. A change in approach to the learning in general, and a more logical approach to mathematical problem-solving in contexts in particular, may be the most significant gain the participants demonstrated as an influence of SIC. No curricular intervention carried out for a short period of time with a highly focussed purpose can be expected to produce dramatic improvements in student performance. However, SIC's influence was witnessed more on the overall changes in learning approaches that the participants adopted, than on any major difference in achievement, as indicated by a test score. A multi-purpose instrument that can accurately indicate the educational attainment of a curricular intervention such as SIC could be used to assess the overall changes which transcend the mere improvement in scores for tests designed in the conventional format. This is because SIC was originally conceptualized for the purpose of advancement of mathematical-literacy-related competencies which could be demonstrated in a conventional test, the post-test being significantly limited. A mediocre level of achievement noted in the post-test results was therefore to be taken in its entirety, including what it represents and what it does not, so that a comprehensive understanding of the effect of SIC may be generated.

The effect of curricular interventions similar to that of SIC from a cognitive neuroscientific perspective is also worth exploring in this context. Recent research in cognitive neuroscience has revealed that failure to be competent in essential skills such as manipulation and working with fractions is a serious educational problem. Teaching of such skills must be acknowledged "as critically important and improved before an increase in student achievement in algebra can be expected" (Robert, Lisa, Drew, & Xinlin, 2013, p. 14). These authors also refer to misconceptions emanating from students' view of fractions exclusively in terms of part/whole relations. One such misconception, for instance, was that "while $\frac{3}{4}$ had a mathematical meaning $\frac{4}{3}$ did not have any meaning at all" (p.14). Students' argument in defence was that "you cannot have four parts of an object that is divided into three parts". These authors attributed this misconception to emphasizing one single interpretation for fractions in terms of [21]part/whole relationships (P.14). Mastery of conceptual and procedural knowledge related to ESCs such as fractions also influences mastery of algebra attained later and also, more interestingly, it influences working memory, attention and IQ (p.16). (The relevance of SIC in emphasizing essential skills is therefore significant).

In the context of higher education, the worth of the mathematical literacy curriculum may be determined in terms of the degree to which it helps students "achieve their full potential" through the mastery of "both functional and more academic mathematical skills which underpin achievement in many undergraduate programmes" especially social sciences (Vicki, Pamela, Sian, Yvon, & Lynne, 2013). Those authors also noted that programmes in many disciplines in South Africa and around the world were becoming increasingly quantitative; while many students were unable to meet the mathematical literacy demands of those disciplines (p.1144). This point was considered and was integrated with the conceptualization of an alternative curriculum that led to the formulation of SIC. The conceptualization of SIC in this context may be further compared with

[21] Interestingly, in East Asian languages fractions are named by stating the denominator first and numerator second as opposed to the other way around in English. For instance, one third would translate as "of three parts one". Hence the East Asian languages seem to have a better way of conveying the part-whole relation and the bond between numerator and denominator (Robert, Lisa, Drew, & Xinlin, 2013, p. 16).

a similar curricular innovation called QuIRK (Quantitative Inquiry, Reasoning and Knowledge) undertaken at Carleton College (US). Perhaps the most striking similarity between SIC and QuIRK is that "it (QuIRK) aims to cultivate numeracy in students by fostering the use, analysis and communication of quantitative evidence" (Louis, Scott, Nathan, & Susan, 2015, p. 14). QuIRK's integrative and interdisciplinary characteristics are also similar to that of SIC. At Carleton College, faculties collaborated on the formulation of a set of learning outcomes and appropriate rubrics for assessing quantitative literacy. Students take three courses (as opposed to two at the University of Zululand) named QRE (Quantitative Reasoning Encounter). The underlying philosophy of QuIRK, just as in SIC, is that students will not learn to "become numerically proficient unless it (numeracy) is modelled and reinforced throughout the curriculum" (p.14). As a result of the integrative nature, students reflected on, as seen in the above institution, how and why they should learn numeracy, as well as how they might apply numeracy in new contexts (p.14). The integrative nature of QuIRK was demonstrated in the way the "quantitative reasoning curriculum remained diffused" across disciplines, resulting in the creation of powerful integrative learning experiences for the students (p.15). Interestingly, those authors also admitted to the fact that every curricular initiative is fundamentally experimental. This is because "not every interdisciplinary project succeeds and that faculty should be willing to see some failures as the price of trying new pedagogies and charting new curricular terrain" (p.15). The worth of SIC as a curricular alternative cannot be more explicitly expressed than in the succinct and veracious way articulated by those authors.

The worth of the curriculum, in conclusion, may therefore be summarized in two dimensions. One is the immediate changes in levels of conceptual, procedural, and problem-solving competencies. The other is the far-reaching positive influence of differences in learning approaches and solution strategies employed in problem-solving contexts. The former was less evident in this research, while the latter was demonstrated at a satisfactory level. The changes in conceptual and procedural competencies effected over time by the influence of SIC can be well explained by a system of five levels of reasoning in mathematical literacy (Ann, 2014). The five levels are: illiteracy (ignorance of basic concepts), nominal literacy (may understand a concept by name, but limited in its application, has misconceptions), functional literacy (use vocabulary and methods but cannot transfer them), conceptual or procedural literacy (can make generalizations), and multidimensional literacy (uses mathematics in social issues). The question of whether the introduction of SIC is worth the effort was answered by the levels of performance the participants demonstrated in terms of the five levels mentioned above. While it cannot be claimed that all participants passed through all five stages successfully, a mediocre level of improvement that can very well be called 'achievement of functional literacy' could be associated with the overall performance of the participants.

6.6 Answer to Question 1: How can a Semi-Integrated Curriculum be designed and developed for a mathematical literacy first-year module for a Bachelor of Education programme?

The answer to this research question is formulated around ideas generated from the answers formulated for all of the five research sub-questions. This question, as the overarching exploratory framework on which the research was based, is now answered, drawing interpretations from the answers to all the other research sub-questions (Susan, 2013). This is simply because the design and development of SIC was explored at multiple levels of its various functionalities as an alternative curricular entity. Such functionalities and features are now considered collectively to present a set of arguments to serve as guidelines for the design and development of a Semi-Integrated Curriculum for a Mathematical Literacy module.

6.6.1 Identification and incorporation of those ESCs

The most significant design feature of SIC should be that of its purpose. SIC is purely purpose-driven in that the fundamental purpose of the development of mathematical-literacy-related competencies remains the cornerstone of the whole curricular structure. Various aspects of this dominant purpose filter right down to every secondary aspect, such as classroom practice, assessment, and the management of teaching and learning in general. While the purpose is strictly built around the fostering and consolidation of competencies, how such a purpose may be achieved depends heavily on the extent to which the integrative nature of SIC materializes. SIC envisaged that certain essential skills and concepts (ESCs) are fundamental to the build-up of competencies. Identification and incorporation of those ESCs are therefore primary to the design of SIC.

6.6.2 Integration with contexts and themes

The alignment of ESCs, contexts, and the general content is crucial in SIC, especially at the classroom instructional level. Appropriate contexts identified to carry the mathematical content chosen are also critical aspects of SIC. Since "numeracy practices are conceived as literacy practices involving numerate text and numeracy is considered a sub-set of literacy practice" the importance of literacy in the comprehension of contexts cannot be overemphasized (Hesham, 2013). While SIC content is to be thematically structured around broad authentic themes, the mathematical content and hence the set of ESCs that should be carried by those contexts are critical aspects not to be sidelined by the predominance of any other component of the curriculum. Of the three components, namely, the ESCs, content, and the context, the question of what precedes what else is also important. According to SIC's conceptualization, ESCs precede the context-based problems built around particular mathematical content; while all three are skilfully integrated within the theme chosen. As mentioned earlier in this thesis, the word 'integration', and hence the term 'semi-integration', are given significantly different meanings from those which such terms are conventionally associated. In literature, integrated curriculum refers to particular types of curricular integration, where curricular content is integrated within or across disciplines or subject areas where contexts and content are drawn from multidisciplinary, interdisciplinary or cross-disciplinary contexts. SIC differs significantly from other types of integrative techniques in that integration in SIC is envisaged among three curricular components which are: ESCs, content, and context. The most important aspect of every learning experience in mathematical literacy is considered, according to SIC, to have the three components integrated within themselves. Alternatively stated, every thematic unit in SIC is considered an integrated unit of the three components. The prefix 'semi' is used to indicate the independent existence of the three entities while remaining integrated within themselves, as opposed to a 'fully' integrated framework in which none of the three components might have an individual existence. The 'theme' that dominates in such 'fully' integrative techniques encompasses the ESCs, content, and context, where none of the three could be explicitly demarcated or indicated. In summary, the difference may be that, while SIC comes with the three components distinct and separable, a fully integrated system would present themes without any clear distinction among its constituent components.

The above exposition was followed and practised in this research to the effect that significant observations could be made of the way in which students responded to purposeful and focussed curricular interventions. The insights gained in this research could be used in the fine-tuning of the theoretical elements (such as the theory of collaborative learning underpinned by constructivism) to better suit SIC; as well as in the practical aspects (such as classroom discourse and pedagogy) underpinning SIC. These two aspects, if strengthened, could make the concept of SIC well aligned with the modern progressive curricular ideology laying heavy emphasis on "21st century skills" (Joke & Natalie, 2012). The insight gained in this research further underlined the fact that essential skills and concepts are fundamental to the learning of mathematical literacy. Lack of ESCs, as noticed among the participants in this research, has far-reaching consequences, leading even to a complete aversion towards the study of mathematical literacy as a subject. This could clearly be seen in contrast with the major differences noticed in responses after the introduction of SIC, not in terms of the level of accuracy of responses, but in terms of the positive differences in the approach to the learning of mathematical literacy. This is because, as noted earlier, major differences in levels of understanding could not be claimed in the post-SIC responses. Rather, significant progressive changes in responses indicating overall improvements in concept and skill development could be noticed. These findings are especially noteworthy in the context of design and development of the curriculum, in that students' development of mathematical knowledge and skills is influenced by numerous factors. The fact that the introduction of SIC could not make a substantial difference to student learning may be attributed to a variety of reasons, such as prior knowledge, personal interest, and the level of willingness to adhere to a particular instructional strategy. Taking those factors into consideration, a prolonged intervention period would have produced, this researcher believes, a different set of results. Also, instruments specifically designed to measure changes in a variety of learning behaviours, approaches, and attitudes, could also have yielded much more detailed analytical conclusions. Added to this is the fact that a variety of competences such as procedural (algorithmic), concept, problem-solving, and mathematical communication, and the measurement of such competences' attainment should have been considered using appropriate instruments. This could have yielded much more accurate descriptions of attainment of mathematical-literacy-related [22]competencies that could result from a purpose-driven intervention such as SIC. Design and development of SIC is to take this factor into consideration for future alterations to its the original conceptualization.

Incorporation of HOTS is also a critical aspect of SIC that must be consistently emphasized in its framework. Literature has ample evidence that HOTS are integral components of 21st century skills that must be fostered at curricular level by the use of higher-order assessments, leading to a deep understanding of the material which supports *analysis* and *evaluation* as well as retention (Jamie, Mark, Steven, & Tyler, 2014, p. 319). Also, assessments emphasizing HOTS eventually lead to deep conceptual understanding, a proposition that underpins SIC in general (p.320). From a mathematical literacy perspective reinforcement of HOTS is a necessary condition to the accomplishing of the progressive curricular objectives that SIC envisages. Therefore, every thematic unit that appears in SIC is preconceived to contain such skills integrated within the content framework. Noticeable changes in the development of HOTS as the result of a purposeful intervention such as SIC have been seen in the participants' responses to HOTS-related activities. Within the limitations of this research in terms of duration, resources, and scope, the overall changes noticed across units of analysis in terms of the changes in attainment of HOTS-related competencies have been significant. Despite a lack of changes in intellectual behaviours indicating dramatic improvements in HOTS, the exposure to SIC-based instruction did manage to achieve certain changes in problem-solving patterns, as demonstrated by participants. A consistent and prolonged effort of a similar nature could have produced far more discernible evidence to that effect. A potential improvement of SIC, therefore, based on such an extended contact-based research would serve this purpose. Design and development of SIC with a strong emphasis on HOTS is a strategic curricular enterprise aimed at the long-term goal of skilled and competent citizenry, as well as the short-term goals of ability to analyse, interpret, and synthesize quantitative information.

6.6.3 The sustainability of SIC

[22] The words competence and competency are considered having slightly different meanings in this thesis. While the former means ability of a person to do something successfully, the latter refers to the level at which it is done. Competencies are the set of skills and abilities required for a certain level of performance

The sustainability of SIC as a viable curricular alternative is also worthy of exploration at this stage. Whether or not SIC may be sustained is a question related to how successful it is in meeting its own objectives. It is also related to the question of whether or not SIC could continue to develop mathematical literacy skills as well as Higher Order Thinking Skills in the students, to an increasingly discernible measure and explicit rate than first observed in this research. Can SIC be adopted for a first-year university course with the assumption that it will meet the set objectives? What are the implications therein? From what was observed in this research, especially in terms of the qualitative nature of participants' responses prior to and after the SIC-based intervention, as well as responses during contact sessions, it may be concluded that SIC could produce the desired results. This would be achieved provided the scope of the intervention is widened to a full-scale undertaking of the SIC-based design and development, leading to a subsequent fully-fledged implementation.

It conclusion, the overall worth of SIC may be measured in terms of the empirical evidence produced by this research; and also in terms of what SIC is capable of producing. In spite of this research exposing “the wealth of contradiction” by way of confirming and disconfirming data, the potential role of SIC in raising the numeracy level of students in an ideal situation would be significant (Simon, 2013). The ideal situation in this case will be constituted by longer duration of contact time supplemented by tutorial-based support mechanisms and smaller class sizes that facilitate more interactive teaching and learning. This is because the underlying assumption in SIC is that the choice of ESCs is based primarily on conceptual and skills deficits that the students carry which can only be exposed in a relatively high interactive atmosphere. A classroom discourse based on “positive deliberative interaction” thus contributes to the identification of such deficits (Deonarain & Sarah, 2012). If the deficits remain obscured by misgivings, a wrong set of ESCs might be selected leading to a section of the students being sidelined. A reference to the conceptual framework which underpinned this research is also relevant in this context (Whiffin, Ellis, & Jarret, 2014). One of the significant propositions of the framework was that the identification and consolidation of ESCs, if correctly achieved, would preclude the academic marginalization of those students who are otherwise underprepared to take on the mathematical demands of the post-secondary curricula in general. This proposition, which helped this researcher with “what to consider data”, was further analytically explored and confirmed. This exploration and confirmation was to the extent that, under the necessary conditions of prolonged and focused interventions of this nature, prior consolidation of ESCs will lead to increased levels of numeracy-related competencies (Maria & Maribel, 2013). However, Irwin (2013) warns that researchers should be reflexive and critical, challenging taken-for-granted theories and assumptions "to generate new questions" (Sarah, 2013, p. 303). This research, in that context, opens new avenues to further this research with extended scope and rigour.

One critical argument in this context that runs counter to the core proposition in this thesis is that "mathematical tasks which embed sufficient practice of important techniques while at the same time provoke rich mathematical thinking" are also possible (Colin, 2013, p. 767). Colin (2013) further argues that, while routine exercises promote procedural fluency, open-ended tasks promote exploration and creativity and "a well-constructed mathematical etude[23] might succeed in doing both simultaneously" (p.767). The reasoning here is that "rather than keeping some learners away from rich higher-level-thinking tasks until they have mastered prior procedures to the teachers' satisfaction", tasks such as those Colin (2013) advocated for dignify all learners with opportunities to think mathematically (p.768). Colin (2013) further argues this point strongly stating that "the twin aims of practice for mathematical fluency and exploratory investigation of mathematical contexts are not mutually exclusive" and that combining them in a mathematical etude has advantages not claimed by either routine mathematical exercises or problem solving tasks, considered separately (p.772). The conceptualization of SIC, however, took a different position: that consolidation of ESCs must precede context-based open-ended problems. There is difference also, in the sense that Colin (2013) argued in the context of pure mathematical learning in general, while SIC's proposition was purely based on a mathematical-literacy context. However, Colin (2013)'s argument provides an interesting dichotomy of two fundamentally different curricular propositions.

6.6.4 Aspects of SIC illustrated in the context of particular learning activities

The reader is referred to Appendix A, which includes four mathematical literacy activities designed and developed using the SIC framework. Each activity indicates the theme identified, ESCs required, mathematical content covered, aspects of HOTS envisaged and the statement of

[23] An etude is a mathematical activity designed as an exercise to improve a mathematical technique or demonstrate a certain mathematical skill

the context-based problem. The themes chosen for the illustrations are drawn from authentic real-life experiences the students come across. However, SIC envisages interdisciplinary themes of a wider scope and relevance, which largely depend on particular student cohorts that are doing particular modules at a given time. Such interdisciplinary themes are further envisaged to be of more academic relevance than those used here for illustrations.

The first activity uses the theme of 'instilling awareness of HIV related mortality' which is highly relevant in the current socio-economic conditions. The mathematical content is the calculation of percentage and ratios of particular quantities within the context of HIV-related deaths in South Africa. In this case, the concepts of percentage and ratio, together with the skills of calculating the percentage of an amount, ratio of two given quantities, and rounding off decimals, constitute the set of ESCs to be consolidated before the context-based problem is introduced. A set of purely numerical examples is then chosen for the consolidation of those skills and concepts. Once mastery is achieved in ESCs students are encouraged to take on the context-based problem. The aspect of HOTS in this activity is that of identifying and analysing a pattern discerned from the number of deaths that occurred in different years. A pattern that emerges could be further explored and related to the trends usually associated with infectious diseases in general. Analysis and interpretations undertaken further lead to a deep understanding of the content and the context. This example shows how the set of ESCs, the mathematical content, and the authentic context, are integrated in one thematic unit. This example also shows the advantage of having ESCs consolidated prior to the introduction of contexts. The other illustrated examples shown in the appendix also follow the same structural pattern in their presentations.

Lastly, for the reader to be given a brief recapitulation of the salient points dwelt upon in the above section, a summary is provided below.

6.6.5 Design and development of a Semi-Integrated Curriculum: the main guiding aspects

- Philosophically anchored in constructivism as the learning theory (i.e. knowledge is socially constructed);
- Emerges out of a need for consolidation of Essential Skills and Concepts (ESCs) separated from the main mathematical content;

- Focus on ESCs is central to the curriculum;
- Three constituent components: the set of ESCs, the mathematical concept, the context;
- Usually sequenced as in the order above, ESCs appearing before concept and context;
- Integration is between the concept, ESCs, and the context, all three taken as appearing in interdisciplinary contexts; and
- Although interdisciplinary units are integrated with ESCs and concepts, the lecturer uses his or her discretion to separate ESCs and to have them treated as such. *Semi* is hence contrasted with *fully* where the whole curriculum comes in interdisciplinary units.

The design and development of SIC is governed by the above broad principles. Details of assessments are, however, not included in the above list. This is because assessments in SIC are determined by numerous other issues. Assessing the educational outcomes for integrative curricular projects in general is difficult (Louis, Scott, Nathan, & Susan, 2015). "No one metric would completely capture the combination of reflective, applied, cross-disciplinary, creative work" and further "how and where we measure the success of" integrative efforts "remains somewhat elusive" (p.15). While an emphasis on alternative assessment methods is consistent with constructivist theory and progressive curriculum ideologies, such methods are, however, strongly compatible with the authentic nature of the contexts chosen for mathematical literacy courses. Alternative assessment methods such as projects, assignments, and investigations meant for extended periods of engagement, are highly advisable for mathematical literacy courses for their formative relevance. However, traditional assessment methods such as tests and examinations serve their own purposes, and are equally relevant, for various reasons, in a mathematical literacy curriculum. An appropriate research-based assessment methodology must be developed as a continuation of this research, especially in the context of multiple-choice questions-based examinations and tests that are currently administered to students at the University of Zululand. Investigations into an appropriate assessment methodology and the validity of multiple-choice tests and examinations in the context of a SIC-based mathematical literacy course can very well be the topic for further research. Within the context of the integrative nature of SIC, however, the distinctive practices associated with an integrated curriculum such as SIC "are not easily transferable from one institutional setting to another" (p.15). However, the underlying curricular and philosophical ideas of SIC may be used in another setting for a similar curricular enterprise.

6.6.6 Recommendations based on conclusions

The following recommendations are made based on the conclusions reached in this study.

The Mathematical Literacy curriculum currently followed at University of Zululand should be thoroughly revised.

The curriculum that is currently practiced at University of Zululand needs to be revised to incorporate certain curricular characteristics that are indispensable for a course that is expected to cater for a student population with inherited conceptual deficits. This research showed that lack of appropriate curricular mechanisms such as focussed instruction and use of constructivist pedagogy have a debilitating effect on the attainment of the very purposes for which the curriculum has been designed. A study of conceptual and skills deficits that the Education Faculty students have inherited leading to the identification of s set of such concepts and skills that should be classified under ESC's should be undertaken. The present curriculum should then be revised to an extent that the formulation of purposes is revised to incorporate the needs of the students and is followed by an extensive review of content matter that is aligned with such purposes. Purely context based thematic units of content should then be compiled to form the sequence of learning experiences that should constitute the revised curriculum.

The revised curriculum should focus on mathematical-literacy-related competencies more holistically to suit non-science-major education students' quantitative requirements.

Non-science-major students pose a distinct challenge to mathematical literacy curriculum designers. Students drawn from various disciplines in the social sciences have a unique set of quantitative requirements that need to be considered to have them correctly incorporated into the curriculum content structure. Students from the social sciences should have statistical literacy as a component integrated with the general numeracy content. This should enable them meet the statistical literacy requirements they encounter in social science modules. This should also help them attain the preliminary understanding of statistics which in turn will help them get exposed to techniques of statistical analysis of quantitative data. Financial literacy must also be given significant weighting in the curriculum. A relatively new term in this context is 'budget literacy' which if included will expose the students to the basic terminology and calculations associated with budgets. A detailed study of such requirements identified by a sample group of students could pave the way for the compilation of a comprehensive set of needs on which the new curriculum can be based. While the making of an exhaustive list of appropriate competencies and associated content matter could be a time consuming exercise for the faculty, an enterprise of that nature must be undertaken for an extended period of time for the sake of a curriculum that effectively prepares the students with the 21st century mathematical literacy skills. This research has shown that the alignment of curricular objectives with curricular content is of pivotal importance for the attainment of such objectives.

The revised curriculum should also have an appropriate emphasis on the development of Higher Order Thinking Skills (HOTS).

Higher Order Thinking Skills constitute a significant component of the 21st century skills. This research showed that HOTS can be effectively fostered by a focussed instructional sequence designed with a special emphasis on HOTS. HOTS as such is not a set of skills that need to be emphasised separately through a distinct set of learning experiences but rather, such skills should be integrated into the content structure to be reinforced and consolidated across topics. Pedagogical characteristics of the curriculum also play a role in the fostering of HOTS. In this context this research revealed that a pre-determined instructional emphasis on HOTS supported by appropriate curricular content and pedagogical preferences yield positive responses by way increased interest in HOTS based problem solving activities. A radical shift in mathematical thinking styles towards that which promotes higher order mathematical thought underpins the 21st century mathematical literacy instructional design. Non-mathematics major students' mathematical thought process should therefore be HOTS driven rather than LOTS (Lower Order Thinking Skills) driven to raise the level of such students' mathematical preparedness. Emphasis on HOTS in teacher training curricula has the added dimension of indirectly influencing the many generations of school students the teacher trainees are likely to see in their own classrooms. In other words an emphasis on HOTS should progressively become widespread to eventually get assimilated in the learning culture of both the teacher trainees as well as the students they will teach.

One option is to follow a curricular revision based on the concept of a Semi-Integrated Curriculum.

One major suggestion made in this thesis with regard to the design of a new curriculum and the associated emphasis on HOTS is based on the conceptualisation SIC. The fundamental curricular change that SIC advocates for is the consolidation of essential mathematical skills and concepts preceding the authentic context based problems. The practice of SIC based instruction should be contrasted with the conventional mathematical literacy instructional design that solely emphasises context based problems relegating the un-attained essential skills to curricular insignificance. While the conventional curricula failed at multiple levels in terms of 21st century skills purely because of the design flaws, SIC expedites the attainment of such skills through a review of essential skills. SIC also strongly emphasises the need for HOTS to be integrated into the thematic units of instruction so that such skills are fostered consistently. This pre-eminence of HOTS should be felt across the curriculum so the thematic units selected provide the necessary gravity. Contexts, concepts, skills and HOTS together then form a sequence of learning experiences ultimately leading to the formation of a culture of HOTS based learning. In other words fostering of HOTS, either through the practice of SIC or otherwise, should be a learning outcome across modules in the faculty and should enable the moulding of a learning culture that promulgates HOTS based curricular thought in the related discourse.

6.6.7 Limitations of the study

The study had certain limitations in terms of factors that were beyond the control of the researcher as well as factors that defined the scope of the research. The period of intervention was fixed for twenty hours spread over a month. The limited period proved to be a restriction that did not allow any impromptu deviation from the course of action initially planned. In other words the researcher had to stick to the plan in spite of a need felt to increase the duration of the contact sessions. This could have had an influence on the participants' development of skills.

Another limitation of the study was that the number of participants had to be restricted to ten to keep the number at a manageable level. A larger group of students or perhaps the whole cohort of students enrolled in the course, if taken as research participants, could have yielded more elaborate sets of data. The research could then have produced more convincing results in spite of the possibility that such a research project might fall beyond the scope of a PhD research enterprise. The limited number of participants also had implications with regard to the degree of representativeness of the group that was studied. A group of ten participants drawn from the cohort of four hundred students could not therefore claim significant representativity. Here again the researcher had to be content with the characteristics of qualitative research, more specifically case study research, where in-depth descriptions of individuals and events dominate.

A third limitation of the study was that the skills and concepts covered in the pre-test and hence the post-test was limited. A more detailed coverage of concepts and skills in those tests could have exposed the participants' pre-conceived mathematical notions (both correct and incorrect) more comprehensively. This would obviously have called for a prolonged intervention period leading to more convincing end results for the research as a whole.

6.6.8 Future research

The scope for future research could be thought of as a spin-off from the original research and in relation to the limitations mentioned in the section 6.6.7. A critical aspect of any future research should be the inclusion of the whole cohort of students as participants. Such a research project should use a mixed method approach that involves both qualitative and quantitative methods of data collection and analysis. A longer period of intervention should also be an important aspect of such a project coupled with the design of a pre-test and a post-test covering a broader range of concepts and skills. This will ensure a detailed study of conceptual learning difficulties associated with mathematical literacy concepts and skills leading to a comprehensive understanding of the impact a SIC based intervention can produce at a larger scale. While qualitative data from such a large group can yield more convincing results with regard to the cognitive and affective dimensions of the curriculum, the quantitative data could produce a more comprehensive picture of trends and characteristics related to the attainment of mathematical literacy competencies.

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APPENDIX A

MATHEMATICAL LITEARCY ACTIVITIES DESIGNED AND DEVELOPED USING THE SIC BASED INSTRUCTIONAL FRAMEWORK

ACTIVITY 1

THEME: Instilling Awareness of HIV-related mortality

CONTEXT: HIV-related deaths in South Africa

MATHEMATICAL CONTENT: Calculation of percentages and ratios

ESCs required

1. Understanding of the *concept* of percentage
2. Understanding of the *concept* of ratio
3. The *skill* of calculating percentage of an amount
4. The *skill* of calculating the percentage the given quantity is of the original quantity
5. The *skill* of rounding off
6. The *skill* of reducing the ratio between two quantities

Aspect of HOTS

Insight developed from an emerging pattern

CONTEXT-BASED PROBLEM:

The table below shows the approximate number of South Africans living with HIV and AIDS and the number of AIDS-related deaths from 2005 to 2009. Use the following table of information to answer the questions.

Year	SA population	South Africans living with HIV and AIDS		Total deaths in the country	AIDS related deaths	
		Number	% of population		Number	% of total deaths
2005	A	4720000	10,0	634100	298600	47,1
2006	47821700	4830000	10,1	628600	289800	46,1
2007	48431400	4940000	10,2	621600	B	45,0
2008	48653800	5060000	C	602800	257500	42,7

2009	49320500	5210000	10,6	613900	263900	43,0

1.1 Calculate the difference in percentage of AIDS-related deaths between 2005 and 2008

1.2 Calculate the following missing values:
   a. A
   b. B (rounded off to the nearest 100)
   c. C (rounded off to one decimal place)

1.3 Determine the ratio between the total South African population during 2009 and the number of South Africans living with HIV and AIDS during 2009.

1.4 What is the significance of the pattern that emerges in the last column with regard to the spread of AIDS?

ACTIVITY 2

THEME- Entrepreneurship

CONTEXT-Tender contract for the supply of disposable rubber gloves to Department of Health

MATHEMATICAL CONTENT- Percentage and ratio

ESCs required

1. The concept of percentage
2. The concept of volume of a rectangular box
3. The concept of volume in terms of ‘number of smaller boxes that fit in the larger box’
4. The concept of selling price
5. The skill of substituting for variables in a complex formula
6. The skill of following ‘order of operations’
7. The skill of calculating a certain percentage of a given quantity

ASPECT OF HOTS

Critically look at the validity of a formula that is used to make decisions related to awarding of tenders

CONTEXT-BASED PROBLEM:

The Department of Health advertised for companies to tender to supply sterile disposable rubber gloves to a local clinic. Rubber gloves come in different sizes and are generally sold in boxes containing 50 pairs of the same size. The clinic required 100 boxes of each of the following sizes of gloves: $6\frac{1}{2};\ 7; 7\frac{1}{2}\ and$ 8. High Five Co-operative, which is 100% Black owned, decided to submit a tender to the

Department of Health. It costs High Five R 98, 00 per box (excluding VAT) to manufacture the gloves, regardless of the size of the gloves. High Five first adds a profit of 25% on the price of each box and then charges a further 20% for transport and administration costs. Based on this information, answer the following questions.

2.1 The following table shows High Five's format for calculating the selling price of their gloves. Determine the values of items A, B, C, D, E, F and G

Column 1		Column 2	Column 3
	Item	Working details	Cost in rand
Cost of manufacturing the required number of boxes of gloves	A		
Profit of 25% on the cost price	B		
subtotal	C=A+B		
20% for transport and administration costs	D		
Subtotal	E=C+D		
14% VAT	F		
Total selling price (called Pt, the value of the tender under consideration)	G=E+F		

2.2 The Depart of Health uses the following formula to make decisions about which company will be granted tender: $\text{Ps} = 80\left[1 - \frac{\text{Pt}-\text{Pmin}}{\text{Pmin}}\right] + 2{,}5$ where:

Ps = Points scored for the tender

Pt = Value of the tender under consideration (in rand)

Pmin = Lowest acceptable tender value(in rand)

The lowest acceptable tender value (Pmin) for the rubber gloves is R 56 000. Use the total selling price (Pt) calculated in the last cell of the first column to calculate Ps, the number of points scored by High Five co-operative.

2.3 The total selling price tendered (Pt) by another company, L & R Enterprises, was R 66 000. The Department of Health announced that the tender that scored the highest number of points will be awarded the contract. Show with the aid of the formula given in 2.2 whether High Five or L & R Enterprises will be awarded the tender.

2.4 The dimensions of each rectangular box of rubber gloves are: 8 cm×10 cm ×20 cm. The boxes will be packed in a larger rectangular container that can hold exactly 40 boxes, which will be arranged in four identical layers.

2.4.1 Draw a diagram to show possible layout of one layer of the boxes in the large container.

2.4.2 Determine the dimensions of the larger container that can hold exactly 40 boxes.

2.4.3 Do you think the formula used to make decisions is appropriate? How would you improve it?

ACTIVITY 3

THEME – Financial Disputes

CONTEXT- Salary Negotiations

MATHEMATICAL CONTENT- Percentage and Ratio

ASPECT OF HOTS- Critically Analyse Salary Offers and Identify Pitfalls

ESCs required:

1. The concept of percentage
2. The concept of percentage increase and decrease
3. The concept of average
4. The skill of calculating a certain percentage of a given amount
5. The skill of calculating the average

CONTEXT-BASED PROBLEM:

“Union says strike action may continue, other forms of industrial action will follow until SABC respects and implements the 12,2% salary agreement. The Communication Workers Union has threatened that if its members reject the 10% offer other forms of industrial action will follow until SABC respects and implements the 12,2% salary agreement. The 10% includes an 8,5% increase to be implemented this month and 1,5% in December 2009"- City Press 2 August 2009.

Answer the following questions based on this newspaper report:

3.1 How much more (%) are the workers demanding over and above the 10% offer from their employers?

3.2 What will be the new salary of an employer currently earning R 2100 if the proposed salary increase for 2010 is 10%?

3.3 Use the table below to answer the questions that follow.

Worker	Old salary	New salary
Marais	R1500	?
Melusi	R2300	?
Sello	R8100	?
Stadhaur	R12400	?

3.3.1 What will be the new salary of each employer after the 12,2% increment?

3.3.2 Calculate the difference in salary between the highest-earning and the lowest-earning employee?

3.3.3 Sello has an investment bank account in which he manages to save 25% of his new salary for the next 10 months. How much money will he have in the account if the bank contributes 2% to his total savings?

3.3.4 Calculate the averages of the old and new salaries. Do you think there was a significant salary increase? Do you think the strike was a worthwhile exercise?

Activity 4

THEME- Planning a Holiday Trip

CONTEXT-Trip to Portuguese Island

MATHEMATICAL CONTENT- Ratio, unit conversions, volume

<u>ESCs required</u>

1. The skill of units of time conversions
2. The concepts of percentage and discount
3. The skill of calculating amount after discount
4. The skill of units of mass conversions
5. The concept of ratio
6. The skill of currency conversions
7. The concept exchange rate
8. The concept of volume
9. The skill of calculating volume

ASPECT OF HOTS: Analyse a tour Package and take Decisions on Options Provided

CONTEXT-BASED PROBLEM:

Mr and Mrs Walburg live in Johannesburg and are planning a trip to Portuguese Island. Holiday Agency Company offered them a 3-night cruise at R 3990 per person discounted at 30% to which the return fare of R 1130 can be optionally added. Answer the following questions based on this context.

4.1 It takes 240 min to drive from Johannesburg to Durban. What time will they arrive in Durban if they leave Johannesburg at 8:00 a.m.?

4.2 Calculate the amount the couple will pay for the cruise after taking 30% discount. Exclude the airfare to Durban.

4.3 The maximum luggage for the couple is restricted to 100 000 g. Determine if the couple's luggage will be allowed if it weighs 88.5 kg.

4.4 How much will the couple pay if the cost displayed is for a single person and they decide to use the return airfare ticket?

4.5 The couple received a gift of 1000 US dollars. Determine if this amount will be enough for the cruise if the exchange rate is $1 = R 8,41

4.6 If the ship is considered a huge rectangular box with length 296 ft., width 52 ft. and height 59 ft., calculate the volume of the ship in cubic metres correct to two decimal places.

4.7 Critically look at the package and see why the company offers a discount of 30%.

APPENDIX B

ETHICAL CLEARENCE CERTIFICATE

UNIVERSITY OF
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22 May 2014

Mr Anilkumar Krishnannair 206523383
School of Education
Edgewood Campus

Dear Mr Krishnannair

Protocol reference number: HSS/1200/013D
Project Title: An exploration of the design and development of a semi-integrated curriculum for a foundation mathematics module

Full Approval – Expedited

This letter serves to notify you that your application in connection with the above has now been granted **Full Approval**

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach/Methods must be reviewed and approved through an amendment /modification prior to its implementation. Please quote the above reference number for all queries relating to this study. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

Best wishes for the successful completion of your research protocol

Yours faithfully

....

Dr Shenuka Singh (Chair)
Humanities & Social Science Research Ethics Committee

/pm

cc Supervisor: Dr A Maharaj & Dr D Brijlall
cc Academic Leader: Professor Pholoho Morojele
cc School Admin: Mr Thoba Mthembu

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1 December 2015

To whom it may concern

This is to certify that I, Lydia Weight, have proofread the document titled: AN EXPLORATION OF THE DESIGN AND DEVELOPMENT OF A SEMI-INTEGRATED CURRICULUM FOR A MATHEMATICAL LITERACY FIRST YEAR COURSE OFFERED AS PART OF A BACHELOR OF EDUCATION PROGRAMME AT A SOUTH AFRICAN UNIVERSITY by Anilkumar Krishnannair. I have made all the necessary corrections. The document is therefore ready for presentation to the destined authority.

Yours faithfully

L. Weight