ALTERNATIVE ASSESSMENT
IN MATHEMATICS EDUCATION

A case study in St. Vincent and the Grenadines

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ABSTRACT

Following changes in mathematics in recent years and the way it is advocated that it be taught in schools, research in mathematics education has begun considering changes in the way student mathematical learning is assessed. Over the years, many teachers and educators have equated assessment with written tests, often using short answer questions and multiple choice items. This has led to ongoing debates about the place of tests in assessment. Some researchers have argued that written tests only assess a sample of the mathematics felt to be important. They have indicated that there is an increasing mismatch between the status of school mathematics and current assessment practices. This has resulted in the move towards the use of alternative assessments for formative purposes, such as self-assessments, interviews and journals. While these alternatives are positive developments, there is need for more research in the area of assessment of mathematics. For example, little is yet known about teachers' views of assessments, whether they would be receptive to alternative forms, whether they could implement them, and what effects such implementation might have on teachers' teaching and students' learning.

The present research was designed to investigate the above issues in a Caribbean secondary school context. Three local teachers were investigated to determine whether they could use suggested alternative assessment strategies, as intended, with (13 to 15-year-old) students of three third form classes in the context of Number and Number Theory. Eighty-two students from one secondary school in St. Vincent and the Grenadines in the West Indies took part in this research. The main data were collected over a 12 week period in 1996 during which the researcher was a participant-observer—she was one of the three teachers. The study was qualitative and involved interviewing and observing (i) the students *before, during* and *after* instruction (instruction designed to include the students as active thinkers in the instructional and assessment processes), and (ii) the two fellow-teachers. Data were collected by means of interviews, field notes of classroom observations, teachers'

and students' journal entries, and from an analysis of the St. Vincent and the Grenadines third form mathematics curriculum. Additional data regarding teachers' views about assessment were collected, by means of a questionnaire, from 20 teachers in 15 secondary schools on St. Vincent.

In this research, conducted within a constructivist perspective, four alternative assessment approaches were tried by the teachers following introductory workshop sessions. One teacher trialed self-assessment, while the remaining two teachers both trialed journals and interviews as alternatives for formative assessment in the mathematics classroom. Although observation was not formally selected to be researched, it was a complementary aspect of the three teachers' assessment processes.

The questionnaire data suggest that, rather than being resistant to change in traditional manner of assessment, many teachers who responded already seemed to be exploring alternative forms. The findings also suggest that teachers will need strong support systems to assist them in implementing alternative forms of assessment.

The findings from the main data indicate that mostly positive changes were experienced by the students and teachers who took part in the study. Specifically, the data showed that:

(a) Student self-assessment required students to determine their strengths and their weaknesses on a given mathematical task, set up their own criteria for good work, grade their weekly tests and compare self-grades with the teacher's grade, all with the aim at improving learning. The data revealed that students struggled with this at first, but with feedback from the teacher, researcher and peers, they were able to reflect on and monitor their own learning. The findings indicate that students need support and opportunities to evaluate and reflect on their own mathematical understanding and performance. Student-teacher discourse helped facilitate improvement of student performances.

(b) Although observation of students is part of teachers' daily practice, it was surprising to note that six of the twenty secondary school mathematics teachers surveyed indicated that this approach was not applicable for assessment purposes. Nevertheless, the main data revealed that the observation of students can help teachers to (i) understand students, (ii) learn from what they see, and (iii) help students move to another level of thinking or performance. Further, the data indicated that observation operates as an informal, spontaneous assessment activity that can reveal patterns of errors. It was also noted that immediate feedback should be given to students. Two concerns that were voiced were that caution was needed when interpreting observations and that informal observation needed to be structured.

(c) Analysis of the data collected on the use of journals revealed that when asked initially about writing in mathematics, students did not recognise word problems and story telling as aspects of writing to solve mathematics; hence they could not at that stage link writing, particularly journals, to mathematics. Initially, students were hesitant about the role of journals in mathematics. They objected at first to having their journals assessed. These concerns diminished as the trial progressed. 'Postie notes' in conjunction with student journals evolved as a means of vital communication between teacher and students to discuss student thinking. The two teachers involved in trying out student journals used the data collected to inform their teaching. Their experience indicated that journal entries need to be read frequently if they are to have value.

(d) With respect to student interviews, at the end of the trial only two of the 54 students who experienced this means of assessment retained some concerns about it. The rest were positive. For their part, the teachers learned to listen to their students thinking aloud as they explained how they solved problems. They also learned to acknowledge their students' ideas and to hold back rather than immediately tell students the answers. The third form mathematics syllabus, lack of time, external examinations and traditional teaching and learning practices were viewed by both teachers as deterrents to successful implementation of the interview approach.

(e) As students became active partners in the learning process, most believed that they gained a fuller picture of their own achievements and progress and a better sense of themselves as writers and thinkers in mathematics. The findings give further support to the constructivist view of learning, as the use of the four alternative assessment approaches influenced student learning by getting them to be more active constructors in the learning and assessment processes.

The teaching practices of teachers were affected in different ways, and this seemed to be related to their beliefs about mathematics learning and teaching, and hence

assessment. While one teacher was able to implement self-assessment successfully, another was concerned about the pressure of time and other commitments. Students also were concerned that this intervention would detract from the time needed to cover the mathematics syllabus.

This research, highlights the importance of secondary teachers' perceptions to successful implementation of alternative methods. The data revealed that while it was not possible to have the alternatives implemented entirely as intended, teachers and students nevertheless benefited from their use.

This thesis is dedicated to

My husband and daughter
Carlton and Cheruice Trotman

My parents
Eileen and Cleve Herbert

My Aunt
Albertina Herbert

My sisters
Beverly, Sharon, Chesla, Patricia, Karen and Kathian

My brother
David

My many relatives, in-laws and friends

Thanks for providing that nourishment
for the soul
without which all thought falters.

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I command you – be strong and courageous! Do not be afraid or discouraged. For the Lord your God is with you wherever you go.

(Joshua. 1: 9 NLT Bible)

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CHAPTER 1

INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

In recent years, assessment has attracted increased attention from the international mathematics education community. There are numerous reasons for this. One reason may be attributed to changes in society. As society shifts from an industrial age, in which an individual could get by with basic reading and arithmetic skills, to an information age, which requires the ability to access, interpret, analyse, and use information for making decisions, so the skills and competencies needed to succeed in today's workplace are changing. This shift has raised questions about the link between students' learning of mathematics, classroom instruction and the assessment procedures used to determine students' mathematical knowledge (Berenson & Carter, 1995; Beyer, 1993; Broadfoot, 1996; Grouws & Meier, 1992; Joffe, 1990, 1992; National Council of Teachers of Mathematics, 1989; Niss, 1993a, 1993b; Stephens & Izard, 1992; Webb, 1993).

A second reason is that, whereas there has been considerable development over the last decade of mathematics education *goals, ideals, theory and practice*, and of views about mathematics itself, the development of *assessment concepts and practices* has lagged behind (Niss, 1993a, p. 4). The consequence is *an increasing mismatch between the state of mathematics education and current assessment practices* (Niss, 1993a, p. 4).

Galbraith (1993) explains that the mismatch stems from assessment operating from a different theoretical base to that of instruction and learning. Contrary to our understanding that students tend to learn in a constructivist way, many assessments – particularly traditional multiple choice and true or false assessment – are behaviourally based and test facts and skills in isolation. Such assessments seldom require students to apply what they know and can do in real-life situations. Moreover, standardised tests do not match the emerging content standards, and over-reliance on this type of assessment often leads to instruction that stresses narrow basic knowledge and skills.

This contrasts with changes in instruction toward engaged learning that will prepare students for the 21st century.

> Current tests reflect the ideas and technology of a different era and world view. They cannot assess how students think or reflect on tasks, nor can they measure interrelationships of ideas ... Only when new instruments are developed will we no longer be bound by old assessment procedures rooted in traditions of the Industrial Age (Romberg, Zarinnia & Collis, 1990, p. 23).

Although standardised tests have their place in education, they are often over-emphasised. This concern was expressed by Ginsburg, Jacobs and Lopez (1993, p. 237).

> At present, assessment is still dominated by standard tests that are inadequate to the task of revealing what the teacher most needs to understand in order to plan instruction: the students' thinking processes and strategies, and their learning potential.

To arrive at a closer match between teaching, learning and assessment, educators and policymakers have called for a rethinking of assessment and its role in supporting educational reform. One suggestion offered by Bazzini (1993) is the development of new assessment approaches. He suggested that, rather than looking at test scores and correct responses only, the *role of the individual's own activity in the teaching/learning process* (p. 99) should be examined. Bazzini (1993) further indicated that there is a growing acceptance of the view that a prerequisite for meaningful learning of mathematics is recognition of (i) the need for learners' personal involvement and reflection, (ii) their working processes, and (iii) teaching and learning as a long term process of interaction.

Given this emphasis on the need for changing assessment practices, one might expect the literature to report studies of teachers' changing assessment practices, but this is not the case. Although there is an abundance of opinion about why alternative assessments should be used and how teachers might incorporate these assessment approaches into their classrooms, there seems to be relatively little research conducted on the effectiveness with which teachers use various assessment approaches. Further, the views of those most crucially affected by the changes, the students, are seldom sought and seldom heard, certainly in St. Vincent and the Grenadines. Secondary mathematics teachers in St. Vincent and the Grenadines have also expressed concern that a single examination result should not determine a student's future or career. These teachers called for more teacher control of the assessment of student learning, and the use of a combination of assessment approaches. Given these factors, it seemed important to undertake some research into the issues and alternative possibilities.

This study investigates assessment practices in mathematics at the junior secondary level in St. Vincent, and explores the use of four alternative assessment approaches. The primary focus is on formative assessment as carried out by three teachers in their classrooms. This chapter introduces the problem, its setting, background and significance. The remainder of this chapter reports on:

1.2 Historical Background of St. Vincent and the Grenadines

1.3 Assessment in St. Vincent and the Grenadines

1.4 Aim of the Study

1.5 Research Questions

1.6 Researcher's Background

1.7 The Thesis Structure.

1.2 HISTORICAL BACKGROUND OF ST. VINCENT AND THE GRENADINES

Education occurs within a socio-cultural and political setting and as a result cannot be understood apart from, or should not be examined in isolation from, that setting (D' Ambrosio, 1990). Thomas (1992) argued that mathematics education is political because it is concerned with access to power and privilege. Like Thomas (1992), Watson (1982) described the politics of mathematics education as having two dimensions: the socio-cultural context and government policies and practices. These dimensions have an impact on present and future directions of mathematics education and the feasibility of expanding or changing our assessment practices. In this section, I provide a brief background on the social context and government policies and practices in St. Vincent and the Grenadines.

The Social Context

1. Population

St. Vincent and the Grenadines has a population of approximately 119 000 and an area of 388 square kilometres. This population consists of approximately 6000 Garifuna, 1000 of British descent, 110 000 blacks of African and South and East Indian descent, and the remainder a mixture of Asians, Americans and French (Jinkins & Bobrow, 1997). Formerly a British colony, St. Vincent and the Grenadines gained full independence within the Commonwealth in 1979. Its history of British colonisation (including a period of slavery associated with plantation labour in the 1900's) not only fashioned the institutions but also defined its social mores. According to Brock (1982) and Said (1993), indigenous cognitive, social and political behaviours were steadily destroyed during colonisation and replaced with other Western values. This European dominance brought with it concepts such as "natives, minority, civilised, third world" (D' Ambrosio, 1990), and more recently, in terms of language, 'dialect, Creole or non-standard' English (Sam, 1992).

2. Language and Colonialism

Creole or non-standard English is a legacy of colonialism. Since there was no formal education during slavery, slaves had only a rudimentary acquisition of whatever elements of English that were considered necessary (Arnove & Arnove, 1997; Brock, 1982; Watson, 1982). This led to a variety of vernaculars that contained a combination of English, French, Carib and African.

With emancipation came formal education structures. During this period at issue were questions of *who shall be educated, what knowledge is most valuable and what shall be the language of instruction* (Arnove & Arnove, 1997, p. 87). English then became the measure of intelligence and ability in the sciences and all other aspects of learning, and was recognised by many people as an education filter serving an elitist group (Arnove & Arnove, 1997; Arnove & Graff, 1992; Freire, 1985; Said, 1993). Thus, the introduction of English as the official language led to education becoming extremely elitist and selective.

In the post colonial period, struggles continue over the language and content of instruction. In St. Vincent and the Grenadines, the focus on standard English persists (Lamming, 1994). It is further rooted in the assumption by many Vincentians that 'foreign is best', and promoted by a curriculum that emphasises standard English. An examination of texts used for literature studies, for example, shows that books promoting indigenous literature are seldom used. Strong adherence to inherited concepts of worthwhile knowledge was strengthened by teachers who were graduates of universities in the United Kingdom, Canada and the United States, and by some elites responsible for educational policy (Fergus, 1991; Harding, 1993).

The focus on English, a second language for many students, has implications for assessment of mathematical understanding. Ellerton and Clements (1996), in their report of research on language factors in mathematics in Australia, pointed to the fact that mathematics is one form of communication and that what takes place in mathematics classrooms is influenced by culture and modes of communication. If standard English is the only means of communication, then this might seriously hinder students from learning mathematics and demonstrating their true mathematical understanding. It seems clear that the use of standard English in the classroom will tend to marginalise the majority of working class children in St. Vincent and the Grenadines (Lamming, 1994); although they may be able to express their ideas accurately and imaginatively using Creole dialect, they tend not to be able to do so in standard English.

The effect is that many students are penalised rather than credited for using their vernacular. The use of standard English as the medium of teaching and assessment can inhibit students' ability to develop and express their mathematical thinking. It makes it difficult for them to actively participate in the construction of their knowledge as they engage in classroom discourse, or as they are assessed orally.

Culture and language are therefore important aspects of learning. Although not the focus of the research in the present study, they were nevertheless recognised as factors relevant to interpretation of results.

Government Policies and Practices

According to Clements and Thomas (1996), every decision and action relating to mathematics education might be regarded as having political overtones. This is possible since decisions by policy makers in turn affect educational practices, research funding, curriculum and texts, and the education community. As D. J. Clarke (1996) pointed out, fair assessment of mathematics begins with a recognition of what performance is valued by the particular society, and is dependent upon the country's ability to provide equal access to all to engage in these performances. Ideally, there should be an alignment of the society's demands, the vision and goals of the curriculum and the use of assessment approaches that adequately reflect these goals. The use of alternative assessment approaches for formative purposes must be considered in light of these.

1. Government Policies

A major objective of educational policy at the start of the 1960s was to provide schooling for all primary students (W. King, 1991). By the mid 1980s, considerable progress had also been made to provide secondary education for the majority of primary graduates. Science, Mathematics and English are compulsory subjects throughout secondary schooling. It was felt by the government that developing students' knowledge and skills in these areas would help reduce poverty and promote sustainable developments (United Nations Development Programmes, 1994). However, limited funding for education meant the continuance of the 11^+ Common Entrance Examination as the entry requirement to secondary schools. In this way the government provides placement at secondary schools for at least seventy percent of the candidates taking the examination. The country's ability to achieve its stated educational objectives is linked to the policies of multinational and regional donors such as United Nations Educational, Scientific and Cultural Organisation, Overseas Development Administration, and the World Bank.

Under St. Vincent and the Grenadines' constitution, formal education remains solely under the control of the government. The government's education innovations have been driven by a range of motives including a desire to:

- improve the national economy by strengthening a connection between schooling, productivity and employment; and
- retain control of policy development and decision-making (Bray & Packer, 1993).

In the context of education there was a movement away from social welfare strategies towards an economic growth policy (Buchert, 1995). This is evident by the government's emphasis on education for all, human resource development and a market driven focus. This shift was associated with a focus on (i) higher education, and science and mathematics as subjects, to promote sustainable industrial and economic development, (ii) self-helping communities, and (iii) a reduction in poverty.

In keeping with this shift is the concept of partnership in education—a process of involving everyone with an interest or stake in education (Buchert, 1995). In St. Vincent and the Grenadines, partnership in education brought together government, donors, non-governmental organisations, community organisations, churches, parents, students, teachers and schools. This involves decentralisation or redistribution of power in the educational process, particularly at the grass-root level (Buchert, 1995; Ministry of Education, 1996; United Nations Development Programme, 1994). Evidence of the high regard that is given by the government of St. Vincent and the Grenadines to partnership in education is seen in the self-help programmes conducted by schools and communities. The concept of partnership in education may be transferred to partnership in the learning and assessment processes, and as such is a key element for the introduction of alternative assessment approaches.

Evidence suggests that overall plans for the development of education are yet to be realised. K. King (1990) suggested that the inability of most small state governments to improve education may be closely connected to their endeavours to control, centralise and expand educational opportunities. One aspect of this is a hierarchical, authority-driven decision-making system. Bray and Packer (1993) argued that it is difficult for small states to effectively undergo major systemic changes because of their heavy dependence on external funding aid and foreign technical expertise.

2. Economic Dependency

One of the lasting effects of colonialism is seen in neo-colonialism, the continued domination of small, developing states by the developed countries, although the former are officially independent (Watson, 1982; Bray & Packer, 1993). In educational terms, this control may take place through foreign aid programmes, financial aid for building, technical assistance training, curricula, and examinations. Additionally, in many cases, donor countries stipulate how and where the aid should be utilised.

In various forms, colonialism and dependency have been dominant forces in Vincentians' education, and continue to be so. They provided the socio-cultural and political contexts within which our education had to develop. Looking briefly to the future, developing countries such as St. Vincent and the Grenadines will continue to be affected by their smallness and dependency on the developed countries. While education by itself cannot cure "underdevelopment", it must recognise the importance of the socio-cultural and political dimensions in the country and work in unison with them. Hence, attempts at effecting changes in the education system must be considered in light of our cultural experiences. The Caribbean Examinations Council, established by Caribbean people to meet the educational and economic needs of the people of this region, is a good example of how this can be done.

1.3 ASSESSMENT IN ST. VINCENT AND THE GRENADINES

Formal assessment of students' academic mathematics progress in St. Vincent and the Grenadines has always involved paper-and-pencil testing. As Watson (1982) and Bishop (1989) described, testing, for summative purposes, was used to select a minority to be educated and to maintain that minority as an elite. Scholarships were won by urban primary students who were more likely to be British descendants or children of affluent landowners. One criticism of using this method of assessment, when applied to student learning, is that it tends not to reveal the students' thought processes that led to their responses. In fact, this method is often used *to gather and reward only the correct product of a thinking process and not the quality of the process itself* (Butler and Beasley, 1987, p. 237). The assumption has been that *correct answers mean mastery; wrong answers mean learning deficiencies* (Greenwood, 1993, p. 144). This focus on right answers is inadequate if it is important to understand the student's comprehension of mathematical ideas and processes.

An examination of present assessment trends in St. Vincent reveals the presence of both summative and formative assessment. However, formative assessment approaches seem to be used only informally by teachers in their daily interactions with students. In this section a brief description is given of the main features of current (summative and formative assessments) assessment structures and practices in St. Vincent and in the Caribbean.

Current Summative Assessment Practices

Students at both primary and secondary schools are not assessed on practical activities or discussion exercises in mathematics although, at the secondary level, some subjects offered by the Caribbean Examination Council carry a school-based assessment project and others an oral examination. The rationale behind the adoption of school-based assessment by the Caribbean Examination Council (1985) is summarised as:

(i) to assess those objectives which do not lend themselves to assessment by a written examination; and

(ii) to provide students with several opportunities to display their abilities under conditions that are familiar.

The present system of classroom assessment is designed to serve some specific goals related to the promotion and classification of students. In particular, assessment in secondary schools is used to:

- support criteria for the promotion of students throughout the grades;
- establish criteria for the selection of qualified minorities; and
- justify decisions about students' classification based on their intellectual development, for example, placing students in streams.

The assessment regime has the following features:

- There is a rigid pattern of timing, since the assessment is centred on written tests and terminal examinations. Some weeks are set aside exclusively for testing.
- The explicit aim of testing is to give a course mark for the term. This is mainly for reporting purposes.
- The marks given to students represent an aggregate of different aspects and information obtained. The complexity of the learning achieved by students is masked by the assessment.
- The level of an acceptable command of knowledge is indicated by an arbitrary line, the pass level, which in most cases tends to be fifty percent correct responses.
- Terminal and mid-term examinations are of two kinds, multiple choice and long paper examinations, thereby mirroring the examination format used by the Caribbean Examination Council.

An examination of current assessment practices reveals a dominant focus on summative, individual and competitive work, which suggests that assessment is lagging behind theories of instruction.

1. Development of Regional Assessment

The emergence of the Caribbean Examination Council in 1972 may be partly attributed to an awareness of the serious shortcomings in the foreign examinations and the perceived need for some form of regionalisation of secondary school examinations and educational systems (Broomes & Halliday, 1993). It was also due to the increasing need of many English-speaking Caribbean territories for self-governance following the move towards political independence.

The Caribbean Examination Council examination results give more information to Caribbean candidates about their performance than do foreign examination systems. GCE examination results are restricted to grades such as A, B, C, D and E, while the Caribbean Examination Council examination results in mathematics provide information in terms of levels of thinking within three categories: reasoning, comprehension and computation (as shown in Figure 1a). The levels of thinking range from A to D.

Caribbean Examinations Council Preliminary Results Slip

Name School Registration Number Date Sex

SUBJECT	PROFICIENCY	GRADE	PROFILES
Mathematics	General	One	Computation (**A**) Comprehension (**A**) Reasoning (**A**)

Figure 1a. An Example of a Student's Mathematical Assessment by the Caribbean Examination Council

The Caribbean Examination Council provides opportunities for students to attempt to write any subject that it offers at one of two levels of proficiency—Basic or General. The Basic proficiency is tailored to meet the demands of the world of work, while the General proficiency is seen as a basis for advanced study. Examples of each level of proficiency are given in Appendix A. This provision may be linked to Cockcroft's (1982) view that the purpose of classroom assessment is to find out what students know and can do. The general level allows more advanced students to demonstrate their understanding, while the basic level does not intimidate the less advanced students. The Caribbean Examination Council examinations are accepted internationally with the general proficiency grades one and two being recognised as British General Certificate Examination equivalents in the region and also by institutions in Canada, the United Kingdom and the United States (Bray & Packer, 1993; Broomes & Halliday, 1993).

Current Formative Assessment Practices

The restructuring of the primary mathematics curriculum in 1991 led to the establishment of several principles that suggest a shift towards formative assessment. These principles include (i) students should be encouraged to [gradually] assume responsibility for what they are expected to learn and master, and (ii) mathematics should be assessed formatively and summatively using a variety of assessment approaches (Broomes & Cumberbatch, 1991).

An examination of present classroom assessment practices shows that there is a shift towards formative assessment by both individual teachers and schools. Individual teachers have taken the initiative to implement assessment approaches for formative purposes (see Section 6.5). Most secondary schools' report cards now have both formative and summative dimensions. In the former, teachers are asked to give descriptive accounts of student learning. Regionally, with the exception of mathematics, most subjects offered by the Caribbean Examination Council are assessed by several different assessment approaches such as orals, practicals, projects or continuous school-based assessments. These assess students' processes as well as their products.

As Chapters Two and Three indicate, emphasising one mode of assessment over others can result in a quite narrow mathematical experience for students and teachers. It is apparent that there is a need for a variety of assessment approaches that are well matched to the full range of goals held for student performance. As our goals for students change and the demand for educational improvement intensifies, assessment practices must also change. The time therefore seemed appropriate to explore in depth the potential of alternative assessment approaches for formative purposes, particularly if these would promote the teaching and learning of mathematics.

1.4 AIM OF THIS STUDY

This study responded to the call for assessment reform in the Caribbean (Caribbean Examination Council, 1990), and elsewhere (Baird and Mitchell, 1986; National Council of Teachers of Mathematics, 1989, 1993), calls that have engendered a search for better ways to assess student learning. The main aim of this study was to investigate whether three local teachers could use suggested alternative assessment strategies, as intended, with Form 3 students (13 to 15-year-olds) in the context of Number and Number Theory at one high school in St. Vincent, and how the implementation of such strategies might affect the students' learning in mathematics.

Prior to the main investigation, it was considered desirable to obtain teachers' views of assessment practices and whether they felt a need to reconsider such practices. This would extend research efforts that have concentrated mainly on teachers' perceptions and beliefs about the nature of mathematics and mathematics teaching. Additionally, whereas the literature includes numerous examples of primary teachers using alternative assessments for formative purposes, examples of secondary teachers doing so are scarce. Further, since much of the research on assessment practices in mathematics education has been conducted in developed countries, it seemed desirable to investigate the issue in a developing country and thus add to the data base. It also seemed useful to determine, whether findings in developed countries parallel those in developing countries such as St. Vincent and the Grenadines.

1.5 RESEARCH QUESTIONS

The investigation addressed the following questions:

1. What are typical Vincentian secondary school mathematics teachers views of assessment?
2. How did the three teachers implement their chosen assessment strategies?
3. What effect did the use of these strategies have on the teachers' teaching?
4. What effect did the use of these strategies have on the students' learning of mathematics?

It was anticipated that data from the study would provide some information about the (i) the feasibility of reconsidering mathematics assessment practices in St. Vincent and the Grenadines, and (ii) the possibility of using alternative assessment approaches for formative purposes. Such formative assessment in turn could inform summative assessment, although the main aim would be to use the information collected to enhance student learning. Such information could be of value to teachers, educators and curriculum developers.

1.6 RESEARCHER'S BACKGROUND

The present research grew out of my personal experiences, and feelings of perceived needs. It involved collaboration and interaction between the teachers being researched and myself. Hence, there is a need to identify what I brought to the study. Such information can help place the study in greater context and provide a perspective to its formulation and findings.

On the basis of experience, observation and extensive reading of the literature, I began this research with the following ideas:

- The education system in St. Vincent and the Grenadines operates in a traditional way. However, it is presently undergoing several major changes that may bring it into line with emerging international trends.
- Although teachers in St. Vincent and the Grenadines are changing their instructional methods, their assessment methods are not yet congruent with these new perspectives.
- There is no one right way to assess students' mathematical strategies and thought processes. Assessment should include evaluation of both products and processes. A combination of assessment approaches is likely to provide rich insights into student learning.
- There is need to promote formative assessment in mathematics.
- Students construct their own knowledge of mathematics by reorganising their ideas in the course of social interaction with others.

- While the normal content strands of mathematics are important, processes such as problem solving, modelling, reasoning, communicating, making connections, and using tools are also of importance.
- Increasing use of computers in mathematics will require teachers and educators to focus on conceptual understanding rather than on the use of algorithms.
- The role of a teacher is facilitating learning, not transmitting knowledge.
- The ultimate responsibility for learning rests with the learner, not the teacher.
- Social interaction during learning is important and, in tutorial and large group lectures, time needs to be provided for small group discussions.
- Students only become autonomous learners with help through approaches such as individual and group project work, and the development of their reflective skills which are helped by using learning logs and portfolio assessment.

In terms of learning theory, I position myself as a social constructivist. This theoretical position is described fully in Chapter Two. As part of my work in learning, I am interested in the influence of gender and culture in the educational development process (including equity issues in mathematics), alternative assessment approaches, and in student/learner autonomy and responsibility.

Prior to studying at the University of Waikato, I worked as a senior mathematics teacher at a girls-only secondary school in St. Vincent and the Grenadines and I attended the University of the West Indies. While there I participated in several regional and local conferences and workshops on mathematics and conducted research on (a) the use of clinical interviewing to assess Form 1 and Form 5 students' misconceptions in mathematics, and (b) the effects of a problem solving approach in developing computational problem-solving skills among Junior 4 pupils.

The insights gained from these activities have to some extent impacted on the present research. For instance, they convinced me that to investigate the feasibility and potential of alternative assessments, it would be more beneficial to carry out a few in-depth studies than to attempt a 'broad-brush' approach.

1.7 THE THESIS STRUCTURE

This thesis is presented as follows: Chapter One introduces the project, Chapters Two to Four includes the theoretical framework and literature review, Chapter Five gives the research design and description. Chapters Six to Ten describe the research findings. The findings from the three classroom interventions are presented as four individual case studies, each one concentrating on one assessment approach. The final chapter, Chapter Eleven, summarises the limitations, conclusions and suggests implications for future research in this area. An overview of the structure is given in Figure 1b on the following page.

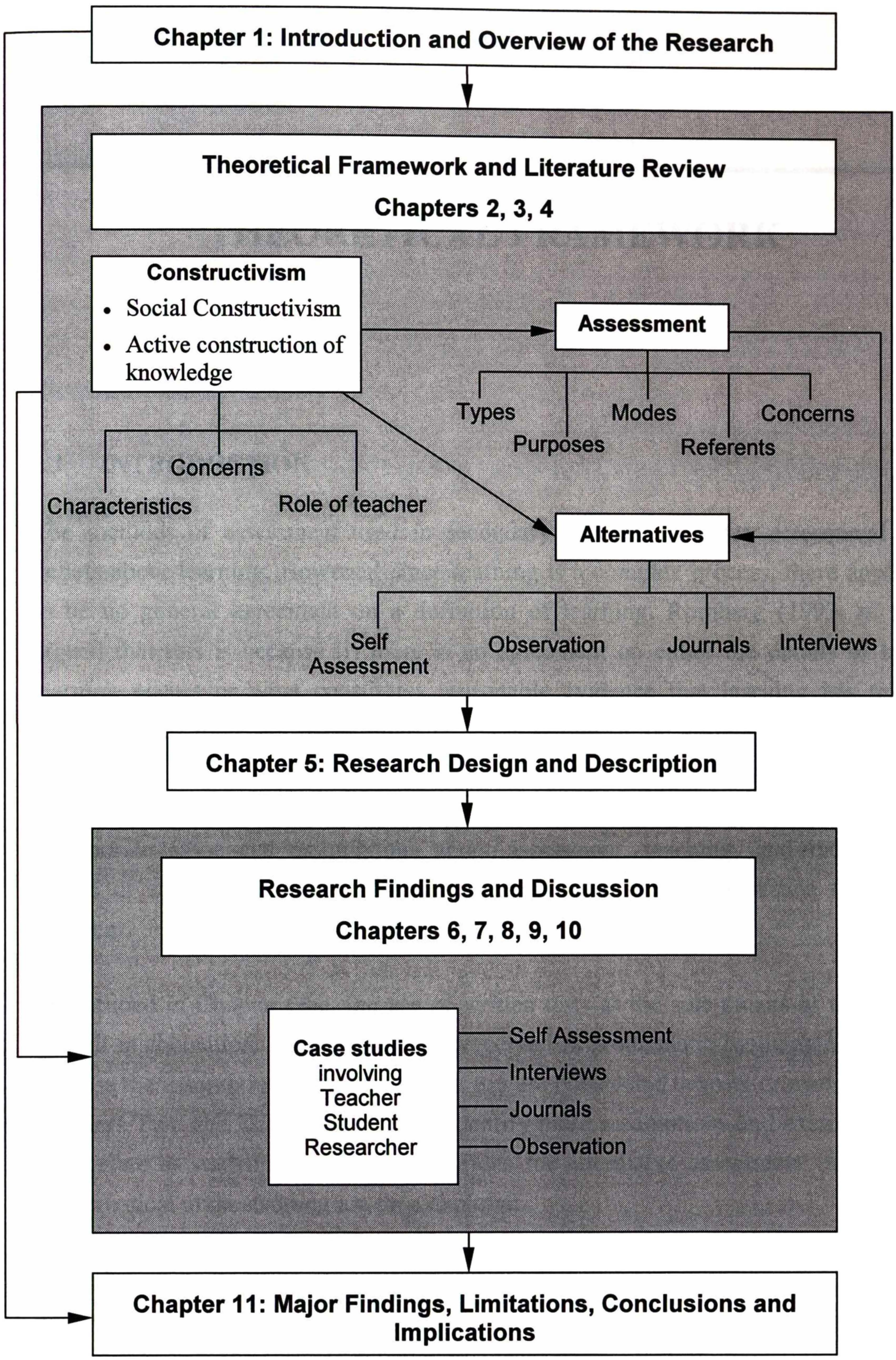


Figure 1b. An Overview of the Thesis Structure

CHAPTER 2

THEORETICAL FRAMEWORK

2.1 INTRODUCTION

The methods of assessment used in secondary schools are often determined by beliefs about learning. However, since learning is a complex process, there appears to be no general agreement on a definition of learning. Romberg (1993, p. 98) argued that this is because (i) there is no agreement on either the details of how learning occurs or what constitutes reasonable evidence that learning has taken place, and (ii) there are many kinds of learning due to the variety of things to be learned.This results in different theories of learning; hence different models of mathematics teaching incorporate different assumptions about learning. They also incorporate associated assumptions about assessment, teaching, and indeed the nature of mathematics itself. These different views in turn influence teachers' practices.

As outlined in Chapter One, the use of written tests as the sole means of assessing student mathematical understanding is perceived as problematic by many educators because the assumptions underlying their use are considered suspect or even invalid. Chapters Two and Three of this thesis identify these assumptions and examine how they relate to student learning; implications for alternative assessment of student mathematical understanding are then explored.

This chapter argues that students are not passive learners, and learning is not a transmissive process. Rather, students are active 'cognising' subjects involved in the construction of their own knowledge. This view requires many teachers to reconsider and/or change their assessment practices if they wish to improve their students' mathematical knowledge. This chapter focuses on an emerging conceptualisation of mathematical learning based on an alternative epistemology in which the role of the traditional, behaviourist view of learning is minimised. This view suggests a movement to understanding *learning* and *doing* mathematics as a social construction process. This perspective was used as the guiding theoretical framework for the present study.

In the following sections two theoretical models of learning, the behaviourist and constructivist, together with their implications for assessment, are discussed. It is important to note that a focus on two theories does not indicate a paucity of other theories; rather, this focus (i) highlights the fact that mathematics learning and assessment can be embedded in entirely different paradigms, and (ii) represents on the one hand the long dominant theory and, on the other, the main emerging theory in St. Vincent and the Grenadines. The remainder of this chapter is presented as follows:

2.2 Behaviourism and Assessment Practice

2.3 Constructivism and Assessment Practice

2.4 Summary.

2.2 BEHAVIOURISM AND ASSESSMENT PRACTICE

Behaviourism

Behaviourist learning theories was based on a traditional philosophical perspectives regarding epistemology. The generally held view, often implicit, was that what we know is what we can justifiably demonstrate to be true; our knowledge was considered to be the sum total of what we know (Hergenhahn, 1988). Learning was defined as acquiring new behaviours (Joyce & Weil, 1992). Behaviourism, the predominant learning theory for much of this century in the English speaking world, is firmly rooted in the positivist, objectivist tradition of the past. Its tenets stem from science and suggest that *knowledge is hard, objective and tangible* (Cohen & Manion, 1994, p. 6). Hence behaviourism is referred to as the 'science of human behaviour' (Joyce & Weil, 1992). This philosophical orientation emphasises the importance of the environment in shaping desired behaviours. It holds that learning is evidenced by a change of behaviour; therefore if one can control the behaviour of the learner, then the individual's acquisition of knowledge can also be controlled (Jonassen, 1991). Models of learning and instruction that followed a behavioural approach may be linked to the work of Pavlov's classical conditioning, Skinner's operant conditioning, Thorndike's associationism, and Watson's (founder of behaviourism) study of behaviour and how it varies with experience (Joyce & Weil, 1992). Watson believed that all organisms adjust to their environment through their behavioural responses (Hergenhahn, 1988; Joyce & Weil, 1992).

Major Concepts of Behaviourism

Writers such as Joyce & Weil (1992), Leder and Forgasz (1992), Resnick and Ford (1981), and Romberg (1993) perceive the major concepts in behaviour theory (as it relates to the learning of mathematics) as summarised in Table 2.1.

Table 2.1. Major Concepts in Behaviour Theory and their Characteristics

Learning Activity	Characteristics
• responding to stimuli	• learning results from the pairing of responses with stimuli • predict responses and identify stimuli • reinforced stimulus-response pattern led to conditioned response
• making bonds or connections (Edward Thorndike, founder of Associationism)	• knowledge is built on making connections that develop between a stimuli and responses, while learning consists of establishing and reinforcing the needed connections • an individual had a number of possible responses, how that individual responded to the situation was dependent on the strength of the connection between the situation and the specific action
• drill and practice • automaticity, speed and accuracy (Edward Thorndike)	• learning requires practice and rewards that lead to increases in speed and accuracy • practice on a large number of mathematical problems of the same type from texts and/or worksheets until response is accurate and automatic
• programmed learning (Skinner's Operant conditioning theory) • direct teaching (A derivative of Skinner's operant conditioning)	• learners work or practice at individual pace • carefully sequenced problems (stimuli), answers (responses) frames that exposed individual to subject in gradual steps to achieve stated objectives • show-do-tell model of teaching • assessing took the form of seatwork practice on a set of graded exercises solved under the teacher's direction

Contd. on next page

Table 2.1. contd.

Learning Activity	Characteristics
• learning hierarchy (Robert Gagne, 1967)	• behavioural objectives were sequenced based on highly structured curricula • the subject matter divided into broadly defined topics • courses emphasise the hierarchical development of basic knowledge, skills, concepts and principles • transfer of learning considered dependent on previously encountered similar situations

Thus, from the behavioural perspective, the aim is to break up the content into small units and to maximise the effectiveness of the reinforcements. Learning amounts to stimuli-response pairings, and mastery of a task involves the development of a chain or repertoire of such connections. Rewarding the repeated practice (e.g., praising, giving good grades) would enable the bonds to strengthen resulting in improved performance.

Criticisms of Behaviourism

The main criticisms of behaviourism are briefly discussed below.

Criticism 1: Learning involves more than passive activity

Behaviourist believe that learning occurs passively but rationally, by reflecting on stimuli from the environment (Joyce & Weil, 1992; Resnick & Ford, 1981). Within this premise, students are regarded as having a 'tabula rasa' mind where it is believed that mathematical knowledge will be lodged if it is presented in a clear, sequential and interesting way by an individual who is 'well versed' (Jonassen, 1991). Education research (e.g., Dickson, Brown & Gibson, 1984; Grouws, 1992; Joyce & Weil, 1992) over the last two decades has made it clear that far from being 'blank slates' waiting to accumulate pieces of information, learners actively construct their own knowledge in very different ways depending on (i) what they already know or understand to be true, (ii) their prior experiences, and (iii) their perceptions and interpretations of new information. Von Glasersfeld (1990) argued that reinforcement only fosters the repetition of what gets reinforced regardless of individual student understanding. Additionally, the role of experience in shaping an individual's behaviour is considered important in attempts at changing that behaviour. Consequently, Darling-Hammond (1993) contended that there is need for teachers to move beyond merely covering the curriculum, to enable different learners to construct their own knowledge and to develop their mental abilities in effective and powerful ways. This research and this criticism have implications for assessment practices.

Criticism 2: Learning is fragmented

Another criticism levelled at behaviourism is that it takes a fragmented rather than a holistic approach to learning. According to Kroll (1989, p. 201), stimuli-response learning led to *the segmentation of the subject into many disjoint parts.* One example, is seen in the use of this approach for teaching computations. This requires the teacher to break down algorithms into steps and present these steps to students in some appropriate sequence. Emphasis is placed on teaching the algorithm rather than on conceptual understanding. What emerges is a standard algorithm for doing computation. When students have mastered the algorithm, word problems are then administered (Dickson et al, 1984). These researchers suggested that this analytical approach involves a series of rules to be learnt or memorised which students may or may not be able to relate to reality or to concrete situations. Further, most students are unaware that there is any other choice of method or strategy open to them. This approach is said to encourage cognitive passivity; everything is furnished (Blais, 1988). Consequently, students are unlikely to consider why and how a set of procedures worked. In addition, misunderstanding due to this approach has led to the emergence of a wide range of errors, for example, errors due to place value and the use of zero as a place holder (Dickson et al, 1984); or a *computational set* where students have the tendency to compute the given numbers in a word problem without thought to what is actually going on (Blais, 1988).

Criticism 3: Focus on students' performance/ability to recall

Entwistle (1990) argued that, from a behaviourist perspective, *doing* mathematics meant following rules laid down by the teacher while *knowing* mathematics implied remembering and applying the correct rule when the teacher asks a question. As a result, this learning theory tends to focus attention on the students' performance rather than on the thinking or reasoning involved in students' responses. Consequently, McIntosh (1979) argued that simply obtaining answers problems by mere mechanical routine without knowing why a particular rule was used cannot be considered as understanding mathematics or as being well versed in mathematics. Many teachers teach for the lowest common denominator so that the skills prescribed in the curriculum and the skills they know will be tested are taught to all students, irrespective of whether the mathematics being presented is cognitively appropriate for the students (Darling-Hammond, 1993; Drummond, 1993; Shepard, 1989; Stiggins, 1988). Such an approach inevitably produces a majority of school leavers who feel they cannot do mathematics and/or have developed the attitude that what is tested is what is valued most (Drummond, 1993; Gipps, 1994; Harlen, 1995), or that mathematics involves discovering truths that are beyond their ability (Leder & Forgasz, 1992). For example, a good mathematical knowledge becomes equated with the quantity of information the learner can recall when questioned. The mathematical truth is determined when the answer is validated by the teacher (Entwistle, 1990).

Criticism 4: Teacher-centred learning

One important implication of the stimuli-response learning is that the process of teaching is of utmost importance as it is by this that the learning process succeeds or fails (Jonassen, 1991; Joyce & Weil, 1992). This makes the teacher the source of all knowledge in the learning situation. Educators have argued against behaviourism on the basis of this issue of control (Joyce & Weil, 1992). They contend that this knowledge is dispensed in a didactic manner where the emphasis is placed upon the need for students to learn basic mathematics skills and to make correctly sequenced verbal and written statements (Ellerton, Clements & Skehan, 1989). Teaching therefore involves transmitting the selection of knowledge, while learning involves receiving and absorbing it (Biddulph, Bell & Carr, 1989). In this perspective, the role of the teacher is characterised by "chalk and talk", and teachers assume that all students will take the same intended meaning from the learning experience. Thus, the entire learning process is controlled by the teacher and knowledge is transmitted during instruction directly into the student's mind. Hence, instruction is often one-way rather than interactive, and the role of students that of listeners and followers (Wheatley, Clements & Battista, 1990). Such a role could contribute to students becoming dependent on teachers, and may further reduce the need for students to think for themselves.

Criticism 5: Learning as an observable behaviour

Behaviourists were concerned with trying to explain learning without referring to mental processes. Skinner (1953) argued that any emphasis on mental processes or structures was misplaced since learning could only be defined in terms of an individual's observable behaviour.

The advent of a cognitive revolution during the period 1956–1960 led to a decrease in the dominance of behaviourism as a learning theory. Behaviourism, according to researchers such as Blais (1988) and Resnick and Ford (1981), has been criticised on the grounds that it does not account for all kinds of learning (it disregards mental activities for instance), or explain some learning (such as the recognition of new language patterns by young children for which there is no reinforcement mechanism). Additionally, critics of the behaviourist movement have alleged that behaviourism oversimplifies human behaviour and sees the individual as an automaton instead of a creature of will and purpose (Schoenfeld, 1993).

Despite over-reliance upon drill and practice methods of instruction, an awareness that behaviourism has run its course, and the historically recognised need for the development of conceptual understanding, behaviourism has not become extinct. Behaviourism has exerted, and continues to exert, a strong influence on education principles and practices, including in the field of learning mathematics. According to Connell and Peck (1993), such emphasis has led to the creation of strongly held inappropriate views by students of their role in learning mathematics. Although other emerging theories have gained some ground, evidence that behaviourism continues to influence educational practices in many countries today can be found in (i) the use of behavioural objectives, (ii) lists of graded exercises in mathematics texts, (iii) curricula practices such as the hierarchical development of basic knowledge, skills, concepts and principles (Romberg, 1993; Schoenfeld, 1993), and I believe (iv) assessment practices. Given the limitations of behaviourism, Connell and Peck (1993) argued for an alternative view of learning that recognises the importance of mental processes in learning. Such an alternative carries with it the need for new roles for teachers.

Behaviourism and the Role of the Teacher

Teachers who follow a behaviourist perspective believe that:

- Students need grades, stars, and other incentives as motivation to learn.
- Students should be graded according to uniform standards of achievement that the teacher sets for the class.
- The curriculum should be organised along subject matter lines that are carefully sequenced.

- Objectives should be clearly stated in behavioural terms.
- Student behaviour is a response to their past and present environment and that all behaviour is learned.

According to Thorndike (1922, p. 52), the teacher's role is to arrange for students to receive *the right type of drill and practice on each of the right bonds for the right amount of time*. The focus of lesson planning is on what the teacher will do. The role of the teacher includes (i) identifying the bonds that make up the specific topic to be learnt, (ii) organising the bonds in sequential order, that is, easier ones first, and (iii) providing the proper amount of drill and practice to facilitate learning. According to researchers (Blais, 1988; Joyce & Weil, 1992; Resnick & Ford, 1981), an instructional session may be structured as follows:

- Present stimuli or explain the concept to the entire class.
- Observe or model a response—the teacher works out examples, presenting the information in clear and easy steps for students to follow.
- Provide practice in responding—individual seatwork practice is given to students.
- Reinforce appropriate responses immediately—positive and negative reinforcement are often utilised by teachers to reward or punish student behaviours.

The behavioural characteristics required are described in clearly stated behavioural objectives that focus students' attention on key points of the topic rather than considering the information as a whole.

Behaviourism and Assessment

Assessment from a behaviourist perspective is concerned with measuring students' observable behaviour. The primary focus is on the recall of memorised information through rote learning (Black, 1993; Crooks, 1988; Joyce & Showers, 1988; Leder & Forgasz, 1992); teachers focus on students' retention of selected knowledge or 'right' answers, and 'correct' methods (Biddulph et al, 1989, p. 4). Assessments that follow a behaviourist model of learning tend to test specific objectives and defined skills and, in so doing, promote the reproduction of content (Burton, 1992; Murphy & Torrance, 1988). This focus is narrow since seldom is any effort made to find out what students understand or what they have learned; rather, assessment involves a high rate of speed and accuracy of responses. Since teaching usually assumes linear and certain paths, assessment has always assumed this relationship between stimuli and response (Leder & Forgasz, 1992). As a result, the emphasis has been on assessment as a final judgement rather than as a continuous feedback system. The purposes of such assessment are for certification, selection and/or promotion, the mode of assessment being formal and consisting of pen-and-paper tests and examinations.

Cockcroft (1982) argued that an X is of little significance to students unless it is followed by (i) an indication of where the mistake occurred and (ii) some explanation of what is wrong, or a request for teacher-student dialogue. Norm-referenced and criterion-referenced tests are associated with behaviourism in that the underlying assumption of such tests is that the student knows what other students know or that the student knows isolated pieces of knowledge (Romberg, 1993). Thus, such learning leads towards kinds of tests and examinations that focus on content and skills and their reproducibility (Burton, 1992, p. 5). Further, the format of assessments is of closed-type questions and multiple choice with the focus on assessing the end product rather than assessing both processes and products to understand student mathematical thinking (Begg, 1993b; Leder & Forgasz, 1992).

The use of graded exercises and formal tests as postulated by Thorndike were considered to have several benefits. Teachers could quickly ascertain whether students' lack of knowledge was due to carelessness, the tests were suitable for all ability levels, and the tests taught care and efficiency (Thorndike, 1922). However, critics have argued that mechanistic and prescriptive approaches to mathematics curriculum development, often accompanied by tightly centralised assessment, do not work. Further, there is ample evidence indicating that learners construct their knowledge in a much more holistic fashion than is assumed by the sequenced packages, worksheets and texts of the traditional behavioural approach to teaching and learning (Darling-Hammond, 1993, p. 754). Hence, mathematics educators and researchers around the world are calling for a shift in how learning is perceived. They are calling for mathematics programmes that present mathematics as a socially constructed body of knowledge (National Council of Teachers of Mathematics, 1989; 1993).

In sum, behaviourism then is a theory of learning that focuses on students' observable behaviour to determine their mathematical knowledge. Teaching and learning are teacher controlled and subject dominated with emphasis on rote learning, repeated drill and practice, making associations and uniformity of results. Behavioural objectives give sequence to curricula, programmes, instruction and textbooks. The theory has been criticised on the grounds that (i) it leads to mechanistic and prescriptive approaches to teaching and assessment, (ii) behaviourists have failed to attend to mental processes, and (iii) students are regarded as passively absorbing information given by the teacher. Dissatisfaction with a behaviourist theory of learning has led to the emergence of other theories of learning.

2.3 CONSTRUCTIVISM AND ASSESSMENT PRACTICE

Constructivism

Constructivism (as it is perceived today) arose from a need to explain the inconsistencies embedded in the theories of knowledge in traditional western philosophy that assume knowledge exists separately and independently of the knower (Benaim, 1995). As Benaim (1995, p. 4) suggested, constructivism breaks away from this philosophical tradition by:

> cutting a nice path between the main ideas that have influenced how math has been taught: the concept of math as facts to be transmitted, the view that only some people are mathematically endowed, where the task is to assess how 'bright' students are and provide them with the right tasks.

However, constructivism is more than a theory for mathematics; it covers all aspects of learning. Constructivism emphasises a concept of knowledge based upon experience in the real world of things. It focuses our attention on how students learn, what is knowledge, and where it comes from (Benaim, 1995; von Glasersfeld, 1990). The constructivist view of learning has its more recent roots in the work of Jean Piaget. He viewed knowledge as a human construction that is developmental (Cobb, Yackel & Wood, 1992; Wheatley, 1991).

Constructivism is described as having several forms. According to Ernest (1994), in its most powerful form, constructivism may be viewed as both a theory of learning and a theory of knowledge. Thus, constructivism incorporates two strands of thinking, namely a psychology of learning, and a philosophy of knowledge (Ernest, 1994; Novak & Gowin, 1984). It is the latter strand that focuses on the nature of human knowledge, the methods used to learn it, and the limitations of human knowledge that most educators have accepted (Atwater, 1996).

One form of constructivism that has gained acceptance by some mathematics educators in explaining learning is radical constructivism. According to von Glasersfeld (1990), the main tenets of radical constructivism are:

1. Knowledge is not passively received either through the senses or by way of communication but is actively built up by the cognising subject.
2. The function of cognition is adaptive and helps the learner to organise the world that is experienced, not to discover objective truth/reality.

Lerman (1989) suggests that the first of these two principles is becoming generally accepted by mathematics educators. It is considered *a useful and productive hypothesis when thinking and listening to students and their mathematical learning* (p. 211).

The main strength of radical constructivism in mathematics education seems to be its implication of ownership of learning (Ellerton, Cowan & Clements, 1992); that is, the power to create knowledge rests with the student. This ownership is central to both students and their teachers and is also applicable to this research, since it involves teachers as researchers in their classrooms. Further, since the power to create knowledge is viewed as personal, it follows that mathematical knowledge cannot be given pre-packaged to students. Rather, it must be constructed by the student from prior knowledge and from acting in the social milieu of the world.

Wheatley et al (1990) have highlighted the social dimension of constructivism. This dimension is of interest because of *its role in promoting and restricting learning* (Clarke, 1992, p.153).

Clarke (1992) indicated that social constructivism recognises that learning involves being introduced to a symbolic world by a process of socially shared mediation.

Wheatley et al (1990) suggested that:

(i) Learning is a social process in which children grow into a community.

(ii) Mathematical ideas are co-operatively established by the members of the community.

(iii) Opportunities for learning occur during social interaction involving collaborative dialogue, explanation and justification, and negotiation of meanings.

This social dimension to the learning of mathematics implies that teachers need to be cognisant of the fact that although students construct their own knowledge, it is done through interactions with others, and not in isolation. In so doing, students develop explanations that are meaningful to others, and are able to see others' points of view (National Council of Teachers of Mathematics, 1996; Wheatley et al, 1990; Yackel, Cobb, Wood, Wheatley & Merkel, 1990; Vygotsky, 1978). The relationship of this form of constructivism and formative assessment is described in Chapter Three.

The characteristics of constructivism as it relates to the learning of mathematics are that learning is:

- an interactive activity
- collaborative
- a constructive activity
- developmental.

Learning is an interactive activity. The individual thinks and learns within a social framework. Activities are always conducted in relation to others, although individuals may have differing perspectives (Vygotsky, 1978). Through discussion or dialogic argumentation with peers and the teacher, the individual negotiates new positions that lead to development of shared meanings. Such negotiation is not bargaining, since this social interaction may produce varying patterns of conflict, influence and collaboration (Cobb & Wood, 1990; Davis, Maher & Noddings, 1990; National Council of Teachers of Mathematics, 1996; Yackel, Cobb & Wood, 1992; Mousley, Lean & Zevenbergen, 1993).

This results in helping individuals change, confirm or anchor their ideas through making an effort to listen to and understand other perspectives. Consequently, some researchers concluded that the dynamic interplay between individual meaning-making and the collaborative process of group communication creates learning as an interpretive, recursive, active, developmental process as students interact with their social and physical environment (Cobb, 1994; Yackel et al, 1992).

Collaborative learning. A growing body of research on collaborative or cooperative learning has demonstrated the benefits of group work (Gooding & Stacey, 1993a, 1993b; A. King, 1989; 1990; Johnson & Johnson, 1991). These researchers have suggested that when children collaborate, they share the process of constructing their ideas, instead of simply labouring individually. The advantages of this collective effort are that children (i) are able to reflect on and elaborate not just their own ideas but those of their peers as well, and (ii) become interactive learners developing leadership and social skills necessary for life (Webb, 1992). Further, the individual may develop ideas while working purposefully with concrete objects (Mousley et al, 1993; Yackel et al, 1992).

Webb (1992), in trying to understand the mechanisms that can make cooperative learning more successful, examined student-student interactions in small group settings. She found that students who give explanations learn more than those who do not, even after student ability was controlled. She concluded that learning therefore occurs as a result of students (i) giving explanations which require the reorganisation of the material to be learned, and (ii) making unconscious thoughts explicit.

Learning is a constructive activity. The foundational premise is that individuals actively construct their knowledge. Rather than simply absorbing ideas spoken at them by teachers, or somehow internalising them through drill or rote practices, individuals participate in choosing and shaping the milieu within which they work. Constructivism posits that individuals actually invent their ideas. In the process of constructing and understanding new ideas, students choose or decide on the skills required for the task and the processes involved in obtaining a solution(s). They modify their understanding in light of new data as they make connections between old and new ideas (Cobb, 1994; Cobb, Yackel & Wood, 1992; Wheatley et al, 1990). Thus, reflection is an essential part of this constructive activity (Confrey, 1990). The ability to reflect on one's learning is critical in the constructivist approach because it allows individuals to understand the strategies they employ.

Beyond this reflection on the process, the learner must be allowed to reflect on the new cognitive structure. As suggested by Driscoll and Cuevas (1993, p. 15), this process makes the learner aware of the meaning of new structures, allowing the learner to *invent and explore new structures or new interpretive contexts.*

Learning is developmental. Researchers and educators are concerned with the constant interplay between the levels of cognitive development as the learner searches for meaning (Mousley, Clements and Ellerton, 1992). At any given time, learners may be actively engaged in modifying, constructing or reconstructing meanings or mathematical ideas (Wheatley et al, 1990). It follows that the teacher's standards or expectations of learners' performance should be related to the learners' level of development. In this respect, the 'zone of proximal development' idea espoused by Vygotsky (1978) can play a significant role in matching task difficulty and learning. The 'zone of proximal development' is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under the teacher's guidance or in collaboration with peers (Vygotsky, 1978). The actual development level characterises mental development retrospectively, while the *zone of proximal development characterises mental development prospectively* (Vygotsky, 1978, p. 86). As suggested by Vygotsky, the 'zone of proximal development' may be exploited to design a range of appropriate teacher or peer assisted activities during which students can be provided with appropriate support for optimal learning. This idea reinforced the need for learning to be developmental and incremental rather than pre-packaged.

Grennon Brooks and Brooks (1993) support the view of learning as developmental. They looked at learning as a journey rather than a destination. Further, each level of cognitive development may be viewed as a temporary intellectual stop along the path of ever-increasing knowledge. Thus, discovery may be seen as part of this developmental process; with it develops not only new meanings but also self-confidence for the individual learner. Although many teachers would accept these three points, all too often the rhetoric of mathematics teachers and the realities of what occurs in their classrooms do not match (Desforges, 1989). Notwithstanding certain tensions between theory and practice, lack of clarity in the definition are among the criticisms levelled at constructivism by some educators.

Criticisms of Constructivism

Bell and Gilbert (1996, p. 51), from a science education focus, have discussed in detail criticisms that relate to:

> loosely defined terms, ontological issues of relativism and realism, making sense, theory adjudication, science curricula, progression in the curriculum, the capabilities and learning styles of students, the search for the grand theory, the social dimension to the practice of science and the learning of science, the role of the teacher, the scope of the utility of constructivism, the status of constructivism with teachers, the impact of teacher development ...

Those criticisms of relevance to this study are: loosely defined terms, lack of instructional design, making sense, the socio-cultural dimension, lack of concern for certifying students' level of competency, and the role of the teacher.

Criticism 1: Loosely defined terms

Two terms that are believed by Bell and Gilbert (1996) to have been loosely defined in the constructivist vision of learning are learning as an *active, constructive* process. However, if one reflects on the process of learning, it is clear that it is a constantly evolving process as new information is perceived, evaluated, and integrated into the learner's cognition. Learning requires some kind of change in individuals, and change can only be brought about by what the learners do, that is, what they attend to and what activities they engage in. Bell and Gilbert (1996) allude to the fact that answers to questions relating to knowledge being socially *constructed* would address some of the perceived looseness.

Criticism 2: Lack of instructional design

Wilson, Teslow and Osman-Jouchoux (1995), in critiquing the claim that constructivism is a hot (faddish) topic, pointed out the lack of instructional design models as one of the weaknesses of constructivism. That is, the literature on constructivism is filled with theoretical dialogue but contains few design models or concrete suggestions for practice. In response to this criticism, Begg (1995) draws attention to the fact that constructivism does not provide explanations on everything about education; rather it postulates a way of explaining how people learn. It is a philosophy of thinking about learning and not a specific approach to teaching. Additionally, ardent supporters may be reluctant to address such issues because there are no simple answers to instructional design—no end-all, be-all model (Wilson et al, 1995).

Criticism 3: Making sense

When constructivism is applied to teaching, one cannot assume understanding will occur just by passing the information on to the learner (Confrey, 1990). However, when presented with information in the classroom that contradicts their existing ideas, learners may try to adapt both interpretations, rather than change deeply held beliefs (Classroom Compass, 1995).

Criticism 4: Socio-cultural dimension

Critics have claimed that radical constructivism does not account for all learning situations, for example, socio-cultural phenomena in learning. That is, it fails to recognise that students come from different social and cultural groups and that the way different groups construct meaning will differ from culture to culture (Ellerton et al, 1992; Zevenbergen, 1991). While constructivism stresses the importance of prior knowledge, it is seen as failing to address the issue of who defines what is socially accepted knowledge (Begg, 1995). Critics suggest that failure to take into account the role of students' culture in the learning process may result in some students being disadvantaged in a school system. This criticism was countered by Ernest (1994, p.11), who claimed that radical constructivism is evolving *to better describe the broad range of phenomena involved.* Recent incorporation of the role of social interactions in constructivism is a response to these views.

Criticism 5: Lack of concern for certifying students' level of competency

A constructivist view of learning is sometimes critiqued for its lack of *concern for certifying the competency level of individual students* (Dick, 1991, p. 44). This is linked to the fact that constructivists are more concerned with assessing learning *gain* than the mastering of pre-specified objectives, and the processes of learning more than the product. Under constructivism, both the learning situation and the criteria for assessing students become redefined. An analysis of the assumptions of constructivism would reveal that they actually run contrary to popularly held beliefs and deeply cherished educational traditions (Jonassen, 1991). For example, competency testing, grading structure and the learning of mathematics as transmissive or passive process are all called into question.

Jonassen (1991, p.141) argued for a less radical view when considering assessment. He suggested that if one believes, as radical constructivists do, *that no objective reality is uniformly interpretable by all learners, then assessing the acquisition of such a reality is not possible.* In Jonassen's view, a milder perspective is needed, namely one that suggests that learners' interpretations will differ. From this it follows that a broader range of assessment strategies than traditionally used is needed to accommodate a wider variety of responses.

However, all this does not mean that constructivism is not useful for guiding research. On the contrary, the critiques have enabled constructivism to be strengthened as a theory by refining and reformulating its postulates. Its insistence on learning as a constructive, interactive and developmental activity that is socially mediated, and the influence of prior experience on learning are elements which traditional Western philosophy have neglected. Consequently, this learning theory will have implications for assessing student mathematical understanding. These are addressed in Chapter Eleven.

Constructivism and the Role of the Teacher

Although constructivism as a theory of learning does not prescribe certain teaching practices, there is widespread agreement that theories of teaching and assessment should be consistent with a theory of learning (Wilson, 1994). Galbraith (1993, p. 78) questioned whether it is *consistent to embrace a constructivist approach to teaching but then support assessment programs which deny the constructivist stance.* The need for consistency between teaching, learning and assessment is further discussed in Chapter Three. The emerging view of the learner as an active participant means a changing role for the teacher. Wilson (1994, p.7) described the teacher's new role as becoming a *cognitive researcher, employing primarily qualitative means of collecting and analysing data about students.* This places new demands on teachers to (i) plan instructional activities that will engage all students regardless of the background knowledge and experience they bring to the learning situation, (ii) develop activities that encourage students to express their thinking verbally as well as in writing, (iii) use multiple assessment approaches that will provide information about how students are learning as well as information about what they know and can do, and (iv) use assessment information to plan further learning activities that build on students' strengths and meet their needs for further growth (Wilson, 1994).

Cobb, Wood and Yackel (1990) described a case study of the changing role of an elementary school mathematics teacher. The classroom environment was established to encourage and support the theme of students and teachers as collaborators. The teacher was no longer seen as *the authority and sole source of knowledge whose role* *was to transmit information, but instead was actively involved with students' learning by negotiating meaning with them* (Cobb, Wood & Yackel, 1990, p. 130). Thus, the pedagogical task is to create an effective environment that promotes and encourages individuals' construction of knowledge (Benaim, 1995; Cobb, Wood & Yackel, 1990).

Consequently, a 'constructivist' teacher, rather than taking the role of 'sage on stage', is required to act as a guide on the side, that is, as a facilitator, negotiator and initiator providing students with opportunities to (i) be active, reflective thinkers, (ii) mentally engage in forming relationships, making connections and integrating concepts and procedures, and (iii) assess the adequacy of their current understandings (SEDLetter, 1996; Steffe & D' Ambrosio, 1995; Van de Walle, 1995). Further, when one considers the notion that learning is based on prior knowledge, then teachers are required to identify that knowledge and provide learning environments that exploit inconsistencies between what individuals know and can do and the new experiences before them. Given this situation, it becomes evident that teachers are required to *organise information around conceptual clusters of problems, questions and discrepant situations in order to engage students' interest* (Hanley, 1994, p. 3).

Rather than focussing on the individual, constructivism embraces a holistic view of learning. One aspect of this perspective is the need for social negotiation. Through interactions with other students it is believed that synergism results, benefiting the entire group (Johnson & Johnson, 1991). The emphasis in the classroom would be on communication, including dialogic argumentation, conjecturing, clarifying and questioning (Cobb, 1994; Wilson, 1994). Further, the notion of students as active participants in the learning process would necessitate that they are provided with opportunities to (i) pose problems, (ii) carry out their own experiments or investigations, (iii) make analogies and arrive at conclusions, and (iv) engage in social discourse or mathematical 'talk'. As a consequence, 'constructivist' teachers are encouraged to:

- be sensitive to students' prior experiences and to establish 'cognitive conflict' via multiple representations of concepts (Dengate & Lerman, 1995);
- seek and value students' views because they are windows to their reasoning and provide opportunities to facilitate learning;

- empower students by allowing them to develop self-confidence in their own epistemic process (Grennon Brooks & Brooks, 1993; Cobb & Wood, 1990); and
- realise that there are cases when there will be more than one solution to a problem and that students' problem-solving strategies may differ (Cobb, 1990; von Glasersfeld, 1990).

Clearly the performance required for this new role is far more complex than traditional classroom teaching/learning and assessment practices. The teacher needs to foster considerable activity among students and with students, and during such activity actively gain insights into how they are constructing mathematical knowledge. To do the latter the teacher must develop observational, listening and probing techniques. These represent radical changes in the role of some teachers and have implications for how assessment is viewed.

The perceived role of the teacher in classrooms, based on a constructivist view of learning, has been criticised, especially the idea that 'the teacher is the novice and the student the expert'. According to the 'expert/novice' claim, teachers stand back at all times but Bell and Gilbert (1996) point out that this is not the case. Teaching from a constructivist perspective is more student-focussed, but teachers still play an active role. Cobb (1990) has argued that the learning and assessment processes are taken to be shared between teachers and students. The teacher's role in the assessment is to come to understand and value what the student has learnt (Confrey, 1990).

If the teacher's role with respect to assessment is essentially to identify student mathematical knowledge and use that information to inform teaching practices then the central role of the student may be seen as communicating understanding of the mathematical ideas. Instead of regurgitating the knowledge transmitted by the teacher, the student is now required to help the teacher create a true picture of the student's own mathematical construction. The student, in short, is an active participant in the leaning and assessment processes. The involvement may take several forms such as elucidating mathematical ideas with the teacher or peers, establishing assessment criteria, selecting assessment tasks, self-assessment or communicating through writing or the creation of products (Boud, 1995a, 1995c; Stix, 1994; Wilson, 1994). As Harris and Bell (1990) argued, rather than assessment being something that is done to the students, assessment in a 'constructivist' classroom entails the redistribution of power in the form of a partnership between students and teachers.

Implications of Constructivism for Assessment

Constructivism provides one explanatory framework for mathematics education, and make suggestions regarding the assessment of mathematics understanding before, during and after learning of concepts. A constructivist approach to assessment seeks to identify how children learn and what strategies they use during the learning process (Meltzer, 1994). When applied to the assessment of mathematics it has five consequences. The first four are implied in the work of von Glasersfeld (1990) on constructivism. Assessment should:

- probe understanding rather than test rote learning (Begg, 1995; Dengate & Lerman, 1995; Ginsburg, Jacobs & Lopez, 1993; Huinker, 1993);
- direct more attention to the learner's thought processes than written performance (Dengate & Lerman, 1995; Ginsburg et al, 1993; Huinker, 1993; Wheatley, 1991);
- examine how effectively learners can communicate as a means of constructing their own knowledge and sharing their ideas with others (Grennon Brooks & Brooks, 1993; Huinker, 1993; Yackel et al, 1990);
- recognise the risk-taking involved in learning (Huinker, 1993; Lerman, 1989);
- make use of interviews to explore learners' concepts and strategies (Huinker, 1993); and
- employ approaches that foster growth and cooperation (Pateman & Johnson, 1990).

Constructivism also implies that using a single approach to assess students' varying mathematical achievements is inappropriate. The influences of constructivism have led to an emerging extension of assessment approaches (Meltzer, 1994) to determine what students know and how they represent their knowledge.

Meltzer perceived that these assessment approaches should have some or all of the following features:

- be holistic, dynamic and multi-dimensional in scope;
- account for the complex interactions between development and curriculum;
- address metacognitive processes and strategic learning;
- be continuous with teaching and learning.

Assessment, when designed with constructivism in mind, becomes redefined in an instructional approach that encourages dialogic argumentation (Meltzer, 1994; Yackel et al, 1992). The very nature of the activities involved in a constructivist view of mathematical learning makes them considerably different from those used in other approaches to learning. Other approaches (such as behaviourism) have failed to recognise learners as actively engaged in constructing or reconstructing their own knowledge in a social environment (Jaworski, 1988; Meltzer, 1994; Yackel et al, 1992). Therefore, a constructivist view of mathematical learning requires teachers *to consider what type of feedback they and their students need* (Begg, 1991, p. 4). This information may be collected from assessment that occurs at three stages (Begg, 1991) and involves numerous components (Begg, 1991; Grouws & Meier, 1992):

Before teaching – namely

- the prior ideas, conceptions and/or misconceptions students bring to the learning environment;
- what students are interested in; and
- learning activities that are suitable to help students develop a sense of responsibility for their learning.

During learning – namely

- opportunities that promote collaborative work, discussions of students' actual questions and learning-to-learn skills;
- what and how students are thinking (to gain clearer insights into their understandings);
- students' procedural and conceptual knowledge; and

- how often students receive feedback and the quality of such feedback.

After the teaching – namely

- the degree to which students are encouraged to reflect on their development in learning mathematics; and
- what is reported and recorded for students' documentation.

From this it is clear that the making of meaning is crucial to learning and therefore assessment tasks need to be embedded in contexts that are relevant to learning so that students can construct something that makes sense to them. Perhaps, as was suggested by Masters and Doig (1992), insights into students' learning or sense-making are more likely to result from programmes that attempt to provide contexts that the student can appreciate.

2.4 SHIFTING MENTAL MODELS OF LEARNING AND THE ROLE OF ASSESSMENT

Changes in teachers' views about teaching and learning require changes in their assessment practices. The changing view in mathematics education that learning is neither fixed nor linear, but rather the result of students' active construction of their mathematical understanding as they interact with their environment and build on their prior knowledge (Costa & Kallick, 1995; Dengate & Lerman, 1995; Stephens & Izard, 1992; Wood, Cobb & Yackel, 1992), requires most teachers to make a major shift in their thinking about teaching and learning, and indeed what constitutes mathematical knowledge. This shift is summarised in Figure 2a (overleaf). The differences shown on the left and right sides in Figure 2a are by no means exhaustive, but they reflect some of the major differences between behaviourist and constructivist learning.

The focus on teachers' views of assessment in mathematics is different because what teachers do grows out of their understanding of how learning takes place (Baroody, 1987; Fairbrother, Dillon & Gill, 1995; Siemon, 1989; Torrance & Pryor, 1995). An understanding of teachers' assessment ideas also provides a basis for gauging their likely acceptance of alternative assessment strategies. Several writers (Cobb, Wood & Yackel, 1990; Ernest, 1989; Fullan, 1993; Prawat, 1992) have suggested that it is only when teachers have reconsidered what they thought they knew that they can have an initial awareness of other possibilities, and reason and motivation to trial new ideas or assessment approaches. Additionally, Ernest (1989) argued that it is only as those beliefs held by teachers are confronted and examined that there can be any change in their practices.

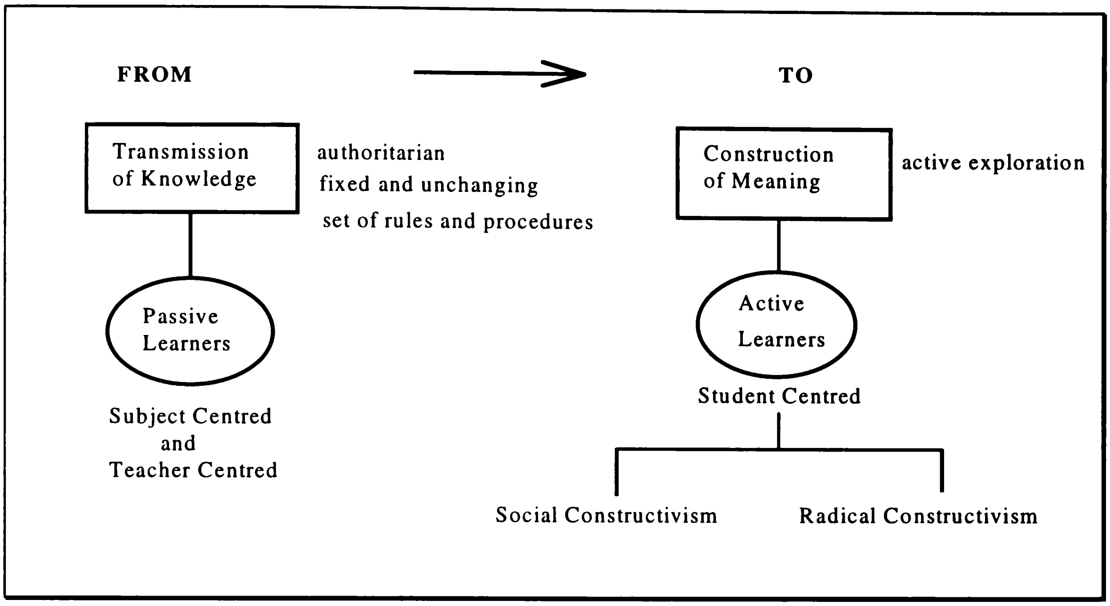


Figure 2a. Overview of a Major Change in Theories of Mathematics Learning
(Adapted from Dengate & Lerman's, 1995, model of Learning Theory)

The Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics, 1989, p.191) offered the following recommendations in Table 2.2 for changing assessment practices.

Table 2.2. Recommendations for Changing Assessment Practices

Increased Attention	Decreased Attention
• Assessing what students know and how they think	• Assessing what students do not know about mathematics
• Having assessment as an integral part of teaching	• Having assessment as simply counting correct answers on a test for the sole purpose of assigning grades
• Focusing on a broad range of mathematical tasks and taking a holistic view of mathematics	• Focusing on a large number of specific and isolated skills
• Developing problem situations that require the application of a number of mathematical ideas	• Using exercises or word problems requiring only one or two skills
• Using multiple assessment techniques	• Using written tests only

These standards advocated mathematics teaching through activities that encourage students to explore mathematics, gather evidence and make conjectures, reason and communicate mathematically. In order to adopt the above vision, teachers and educators need to shift their views of learning, of the mathematics curriculum, and of assessment practices. For example, as views of learning change from behaviourism to elements of a constructivism, teachers will need to (i) view content as a means for developing more complex and higher order skills, flexibility and metacognition, (ii) place less emphasis on parts and increase the emphasis on making connections, (iii) reduce the emphasis on summative assessment while ensuring that there is an increase in the use of assessments for formative purposes, and (iv) make conscious efforts to be non-judgmental and encourage differing viewpoints without imposing their views or steering students towards preconceived solutions (Costa & Kallick, 1995; Romberg, 1993; Wheatley, 1991).

Thompson (1985), having observed and interviewed three junior high school mathematics teachers over a four week period, noted that there was a relationship between their beliefs of mathematics and teaching practices. Namely, when one teacher viewed mathematics as a dynamic discipline undergoing continuous change, the approach to the teaching of mathematics was student-centred with an emphasis on students explaining their mathematical reasoning. However, when mathematics was seen by the other two teachers as a static body of knowledge, the focus was on teacher control and the transmission of knowledge. Thompson further reported that on no occasion did the latter two teachers respond to students' unexpected remarks, or shift the focus of their lesson to clarify difficulties encountered by some students. As argued in this Chapter, attentiveness to student cognitive thinking is one of the defining elements of constructivist learning and hence teaching and assessing.

An examination of teaching and assessment practices should also be considered in the context of the reality of teachers' classrooms.

2.5 THE REALITY OF THE CLASSROOM

Any desired shift in teachers' views of learning and assessment is likely to be influenced by the realities of the classrooms in which they teach. Researchers have argued that the reality of every day mathematics classroom settings makes it difficult for teachers to implement and maintain changes in their teaching practices. For example, some looked at the difficulty of allowing students to construct mathematical learning (Desforges, 1989; Mousley et al, 1992); others looked at the tension between theory and classroom practices (Mason, 1991; Mousley et al, 1992; Nolder, 1991). According to the latter researchers, while theoretically teachers may want to create an environment that is supportive of the innovation, this may not be possible given the rigid expectations of parents, students, and other teachers, as well as government policies and school procedures such as standard assessment practices.

Nolder (1991) presented three case studies of teachers involved with innovations designed to shift the traditional focus of assessment towards the trialing of investigations and practical work. The contexts in which those teachers worked, along with their personal and professional backgrounds, varied. In each case, the issues that arose were related to the teachers' pre-existing beliefs about mathematics and learning. Examination of one secondary mathematics teacher's teaching practice revealed that although he trialed the alternative assessments with the second and third year students, he kept the traditional method of assessing with the examination classes because of external pressures. The idea of changing from a *syllabus-dominated to an activity based curriculum* was not well received by the principal who was more concerned with parent's expectations (Nolder, 1991, p. 157). Undeterred, the teacher encouraged others in the department to contribute towards achieving the desired change, then at a parents-teachers' workshop the teacher outlined the rationale and aims of the new curriculum for the next academic year. The parents' positive reception of the changes led to acceptance and involvement by the principal.

Another example looked at the issue of student autonomy. Nolder (1991) described one teacher's attempt at moving from a traditional mathematics teaching approach towards an approach in which the learner was given more autonomy over the learning process. The teacher, a middle school mathematics teacher, appeared to be a willing candidate for trialing a constructivist approach. The school mathematics syllabus was changed from its traditional form to a commercial mathematics where the emphasis was on shifting from whole class 'chalk and talk' lessons towards more individual and collaborative work (Nolder, 1991, p. 159). The teacher initially refused to participate in the innovation but after seeing the success gained by other teachers and students she decided to become involved. Her main mode of instruction was transmission of knowledge. She believed that the most efficient way of learning mathematics was through teacher explanations, a belief that was at odds with the view of the nature of mathematics and learning underpinning the innovation. With the help of the advisor, this teacher implemented changes in her class practices but, according to Nolder, the lack of congruence between belief and practice made continuity unlikely once the advisor left.

Jaworski (1988) argued that one of the dangers of a rigid syllabus-oriented curriculum and system of testing is that teachers may be constrained by such a structure and find it difficult to shift their assessment practices or exploit other approaches. Consequently, they retain the traditional role that requires them to transmit knowledge and often feel powerless, hopeless and clueless in coping with new demands on their time, expertise and professionalism. However, Jaworski concluded that, if the teacher is confident about using an alternative approach, then working to a rigid syllabus-dominated curriculum will not deter the teacher from successfully implementing change and promoting greater student independence and autonomy in learning.

Another example of responding to change in classroom practices is discussed by Cobb, Wood and Yackel (1990). These researchers described one second grade mathematics teacher's approach to change in teaching practice. They claimed that the teacher appeared to be cognisant, before the intervention, of conflicts between her prior traditional instructional practice and the shift in mental thinking required. For example, she found her desire to challenge student mathematical thinking conflicting with her need to maintain control of the events in her mathematics lesson. Attempts made at resolving such conflicts during the intervention led to opportunities for her to learn. The teacher encountered problems in transcending the tension between the traditional and changed emphasis; for example, she noted the tension felt between offering solutions to mathematical problems and guiding students towards deducing mathematical strategies and responses.

These cases illustrate the complex interaction that exists between theory and practice. Becoming a 'constructivist' teacher may prove a difficult transformation since most teachers have been trained in the traditional, behavioural manner. It requires a mental shift and the willing abandonment of strongly held previous beliefs (Brooks & Grennon Brooks, 1993; Lovitt, Stephens, Clarke & Romberg, 1990). Engaging in a change in learning theory, for most individuals, may imply risk-taking (Fullan, 1985, 1993). People who are set in their present ways of thinking and doing things may find it difficult to give up the tried and known for the unknown.

2.6 SUMMARY

This chapter argues that, since constructivist learning theory provides a more useful foundation than behaviourism for promoting mathematics learning, any investigation of assessment in the field of mathematics education ought to be grounded in constructivism. The present study therefore used constructivism as its theoretical framework. In line with the shift in mental models depicted in Figure 2a (page 38) and the recommendations listed in Table 2.2 (page 39), assessment practice will need to shift from one that reflects a transmission of knowledge approach, to one in which learners are guided towards constructing and elaborating on their own knowledge from prior and new experiences. A behaviourist approach would appear to hinder the development of mental processes as the use of behavioural objectives tend to fragment knowledge rather than bring it together as a whole. Learning in an environment based on constructivist principles would have a greater potential in preparing students to meet the demands of a technological information era than a behaviourist environment. Therefore, if our vision of education is to provide opportunities for students to construct knowledge rather than reproduce it, then it is necessary that teachers should explore ways in which to assess higher order thinking skills rather than the recitation of content.

Literature and research which provide insights into (i) the need for linking teaching, learning and assessment, (ii) purposes of assessment, (iii) the difference between formative and summative assessments, and (iv) the potential of four alternative assessment approaches are analysed and discussed in Chapters Three and Four.

CHAPTER 3

AN OVERVIEW OF ASSESSMENT

3.1 INTRODUCTION

As discussed in Chapter Two, assessment based on a constructivist perspective represents a departure from traditional assessment approaches in that such assessment focuses on the need to consider learners' understanding and their own ideas about their understanding. At the same time, the dominant mode of assessment in St. Vincent and the Grenadines is summative assessment. So, Chapter Three reviews the literature on formative and summative assessment, but with an emphasis on the former as it is more closely linked to a social constructivist theory of learning and the main focus of this study. The remainder of the chapter is divided as follows:

3.2 Definitions

3.3 The Purposes of Assessment

3.4 Formative and Summative Assessment

3.5 Assessment and its Relationship to Teaching and Learning

3.6 Implementation Concerns of Formative Assessment

3.7 Summary.

3.2 DEFINITIONS

There appear to be disparate views on the assessment of students' progress in education. Examination of the literature revealed that the differing views may be due to lack of an agreed definition of the term 'assessment'. Currently, several terms are used to define assessment practices—including evaluation, testing and measurement (Meyer, 1992).

Assessment

The word *assessment* originated from the Latin word *assidere* which means *to sit beside*, while the word *education* can be traced back to the word *educare* which means *to bring out* (Hancock, 1992). A combination of these two words can be taken to mean *the sitting beside and bringing out*. From an educational perspective, this implies the need for teachers to work alongside their students creating opportunities for students to demonstrate what they know, feel and can do (Connor, 1991; Harlen, 1995; Rowntree, 1987).

Assessment may be defined as the process of obtaining evidence of and interpreting or describing students' achievement or competence (Ministry of Education, 1994). It is viewed as a 'continuous and dynamic' process aimed at understanding and improving student learning, rather than a static 'closed' procedure (Angelo, 1995). This process requires teachers to (i) systematically gather, analyse and interpret evidence of students' learning, and (ii) use the information to document, explain and improve learning.

In this research, assessment is defined as the process of finding out what learning is taking place including what students know, feel and can do. It also refers to the gathering and use of data about students' progress toward a set of goals in order to enhance students' learning of mathematics.

Tests and Examinations

Tests are defined as tasks or situations planned specifically for assessment of student achievement (Ministry of Education, 1994). They can include exercises set by the teacher for classroom use on a single occasion or internal and external examinations. However, they exclude all exercises used by the teacher for drill and practice purposes. Testing and examinations are one of many methods that can be used in the assessment process that provide sources of evidence of students' performance and attainment (Crooks, 1988; Gipps, 1994; Horton, 1990). Thus, tests and examinations are merely tools in the assessment process (Chittenden, 1991).

Alternative Assessment

Alternative assessment, as used in the United States of America, is defined as any assessment that is different to class-administered written tests consisting of multiple choice questions or forced-choice questions (National Council of Teachers of Mathematics, 1989). It includes any assessment that requires students to *perform or create a response* to a question rather than *chose a response* from a given list. Other characteristics which are often common to all alternative assessment approaches are that they (i) use tasks that represent meaningful instructional activities, (ii) invoke real-life applications, (iii) are scored by people, using human judgement, not machines, (iv) require teachers to re-think their instructional and assessment practices, and (v) stress the importance of assessing both products and processes of students' learning (Herman, Aschbacher & Winters, 1992). Some examples of alternative assessment are written or oral responses, portfolios, projects, investigations and journals (see Appendix B—"Assessment approaches to enhance learning: A teachers' guide"—for more detail).

3.3 THE PURPOSES OF ASSESSMENT

Assessment of student performance serves many purposes depending on the learning perspective adopted. For the student, assessment informs and aids learning and indicates mathematical progress. For the teacher, it provides information relating to learning and teaching, thus serving formative purposes. In addition, assessment may be concerned with accountability to parents and to the education community. When assessment is used for reporting, certification, selection and accountability purposes, it is summative in nature. These two modes of assessment are part of Vincentian mathematics teachers' assessment practices, as claimed by the secondary teachers in Chapter Six, and appear in the Caribbean Primary Mathematics Guidelines (Broomes & Cumberbatch, 1991). A summary of the purposes of classroom assessment, as drawn from the guidelines and other literature, follows. It provides

- feedback to enhance student learning;
- feedback to inform teaching;
- students with the motivation to learn; and
- information for certification and selection to the education community and future employers.

Providing Feedback to Enhance Student Learning

Through feedback and continuous dialogue, information from assessment should help students to take *optimal advantage of the educational resources around them* (Burton, 1992, p. 3). This information is obtained as a result of diagnosing and monitoring students' strengths, weaknesses and progress in response to the question What is there to see? (Drummond, 1993). It is believed that in doing this teachers have continuous information from which to (i) build up a portrait of the learner's level of performance, and learning needs, (ii) inform and advise students, and (iii) enable students to change what they are doing and improve their learning (Broomes & Cumberbatch, 1991; Burton, 1992; Crooks, 1988; Faire & Yates, 1994; Niss, 1993a).

Providing Feedback to Inform Teaching

The second purpose relates to teachers using the assessment information collected about student learning to make adjustments in instruction (Denvir, 1988; Webb & Briars, 1990). As well as acting on such information, such adjustments may be achieved through teachers' self-assessment which involves teachers monitoring their own strengths and weaknesses, reflecting on, and making desirable changes to their instructional practices that will serve to enhance student learning (Niss, 1993a). The view that teachers can use information collected about student learning to inform their teaching is endorsed by the Caribbean Primary Mathematics Guidelines (Broomes & Cumberbatch, 1991). They suggested that teachers may use assessment information to guide and influence their decisions about what changes to make in the organisation and delivery of their teaching in order to cater for the needs of individual and groups of learners. In this respect, the purpose of assessment is to improve both teaching and learning, so it is formative rather than summative assessment (Harlen, 1995).

Providing Students with the Motivation to Learn

Some students may need to be extrinsically motivated. While the use of extrinsic motivation might be counter-productive where the focus is on ability rather than on student efforts (Black & Wiliam, 1998), feedback given to students, whether from tests or alternative approaches, should strike a balance between assignment tasks that students find intrinsically motivating and those that motivate them through extrinsic means (Blaxter & Tight, 1993). The instructional process therefore needs to incorporate mathematical tasks that are interesting and challenging to all students (Begg, 1998).

Reporting to the Education Community and Future Employers

Two purposes of assessment that have dominated, and still dominate, the educational scene in developing countries are the certification/selection and the accountability purposes. Selection and certification are tied to securing future education and employment and have led to a highly competitive element in education in St. Vincent and the Grenadines (Broomes & Cumberbatch, 1991). These purposes, however, seem to have given high status to certain terminal examinations (e.g., the 11^{+} Common Entrance Examinations, the Caribbean Examination Council examinations and General Certificate of Education Ordinary and Advanced levels) and provided summative assessment with undue influence (Gipps, 1990). What happens in practice is that judgements are concentrated solely on data collected for making comparisons or ranking students, rather than on data collected to identify how students are thinking (Gipps, 1990; Niss, 1993a). This situation, Niss (1993a) argued, will remain as long as competence in mathematics is associated with selection, promotions, and admission to further schooling and/or securing certain jobs. Although the focus of this present research is on formative assessment, this right of parents and the community to summative data cannot be overlooked.

In brief, the above purposes are accomplished successfully when (i) accurate and thorough records of students' progress are maintained in order to improve classroom instruction, (ii) teachers communicate clearly to students which activities and learning outcomes are valued (e.g., focussing on thinking and reasoning processes rather than on memorised information and speedy answers), (iii) recognition and value are given to all learning experiences, (iv) students' reflective and self-assessment skills are monitored, and (v) more emphasis is placed on criterion referencing than on norm-referencing (Clarke, Clarke & Lovitt, 1990; Faire & Yates, 1994; National Council of Teachers of Mathematics, 1989, 1995; Webb & Briars, 1990).

3.4 FORMATIVE AND SUMMATIVE ASSESSMENT

Classroom assessment may be classified as formative/diagnostic and summative. These forms of assessment relate to the use to which the information yielded by the assessment is put (Black, 1995; Black & Wiliam, 1998; Wiliam, 1992). In this research, diagnostic assessment which aims at diagnosing students' weaknesses and misunderstandings is included in formative assessment. A similar view was taken by the Task Group for Assessment and Testing (Horton, 1990); that is, any assessment designed for a formative purpose should give information regarding students' strengths and weaknesses. Thus, formative assessment is the process of assessing students' mathematical understanding and progress before and during instruction. It is primarily concerned with informing learning as it is occuring. In contrast, assessment that occurs after instruction, and is primarily concerned with making a final judgement of a student's level of achievement in relation to the initial subject objectives, is defined as summative assessment. These two modes of assessment are now described in more detail.

Formative Assessment

Formative assessment, as defined in this research, is a process that requires teachers and their students' active participation. It represents a mode of assessment that can be used in the mathematics classroom to enhance student learning. It involves teachers and students in (i) eliciting, (ii) interpreting, and (iii) acting on information in order to contribute to the improvement of student learning (Bell & Cowie, 1997; Black & Wiliam, 1998). The assessment process is viewed as cyclic with the three aspects interacting and being interdependent (Bell & Cowie, 1997).

1. Eliciting Information

According to Johnson and Johnson (1991), teacher-student discourse or communication is a key element in the instructional and assessment processes. Through dialogue teachers collect information about their students' progress in order to enhance their learning. This information may be elicited through the use of multiple assessment approaches such as interviews, observation and self-assessment (Fairbrother, Black & Gill, 1995; Sutton, 1995). The use of such approaches would require students to elaborate, clarify, and evaluate their own learning. An important element that should be present in classrooms to facilitate the eliciting of information is establishing a classroom subculture where students feel free to express their thinking publicly (Yackel et al, 1992). This element is necessary when learning is viewed as an interactive, constructive, developmental activity (see Section 2.3).

2. Interpreting the Information Collected

The second phase in the assessment process, interpreting the information collected, involves using some criteria to assess students' understanding and/or progress. Black and Wiliam (1998) and Harlen (1995) suggested the use of a combination of criterion and self-referencing as the most effective means of providing teachers with the necessary information. These are discussed in greater detail in the latter part of this section.

3. Acting on the Information Collected

Having elicited and interpreted the assessment information, the third phase is to act on the information collected to inform teaching and enhance student learning. Both teachers and their students are the actors. The teacher acts in terms of using the information to inform teaching practices and provide students with appropriate stimuli to improve their learning. Students can act on the descriptive feedback received from their teachers, but their actions are often more evident in the use of self-assessment (Boud, 1995b, 1995c; Falchikov, 1995). That is, having perceived gaps in their understanding or skills, students may act to close the gap in order to attain the desired outcomes (Sadler, 1989). The teacher's actions during instruction may be planned as well as spontaneous. The teacher draws on the interpretations of students' mathematical processes and products while interacting with the students and can plan to include other activities. Thus, assessment becomes an integral part of teaching and learning.

The Relationship between Formative Assessment and Social Constructivism

Claims about the role of formative assessment in the instructional process derive from a variety of arguments. As discussed in Chapter Two, traditional teacher assessment practice was summative and has focused on *finding out whether students know a predetermined thing* in a linear or at least pre-planned unit of work. It is characterised mainly by right or wrong responses, tick items and closed or *pseudo-open questioning* and tasks (Pryor & Torrance, 1995, p. 2). Formative assessment from a social constructivist perspective *goes beyond the provision of test results and the provision of additional instruction* (Torrance, 1993; p. 336) to include learning with understanding and active student participation, especially regarding establishing explicit criteria and monitoring their own progress (Gipps, 1994; Harlen, 1995). From this perspective, formative assessment is more likely to begin with an attempt to discover what the student knows and can do by identifying their conceptions and procedures for operating. Information about student learning may be collected at three different points: *before* teaching, *during* learning and *after* teaching (see Section 2.3). By its very nature – emphasis on the role of teacher-student interactions in the learning process – formative assessment represents a shift away from the more traditional summative assessment characterised by test scores (Torrance, 1993; Pryor & Torrance, 1995). Table 3.1 summarises the main features of formative assessment.

Table 3.1. Summary of Formative Assessment Features

Main Features of Formative Assessment
• Embodies teacher-student interactions as part of the assessment process (Angelo & Cross, 1993; Bell & Cowie, 1997; Torrance, 1993)
• Is concerned with the totality of students' knowledge (Harlen, 1995; Murphy, 1990)
• Involves eliciting, interpreting and acting on [the] assessment information (Bell & Cowie, 1997)
• Includes understanding what students know, and how their knowledge is integrated and accessed (Gipps, 1994)
• Involves active student self-assessment, observation and questioning (Black, 1993, 1995; Black & Wiliam, 1998; Sadler, 1995)
• Depends on judgements which are student-referenced rather than criterion-referenced (Bell & Cowie, 1997; Harlen, 1995; Pryor & Torrance, 1995)

Formative assessment is characterised by less detailed planning, open forms of recording, scaffolding, and analysis of student interactions with the task or problem, all within a student-centred approach (Harlen, 1995; Pryor & Torrance, 1995). Thus, formative assessment may be seen as a collaborative effort between teacher and students (Bell & Cowie, 1997; Torrance, 1993; Pryor & Torrance, 1995).

The Role of Teacher and Students

Viewing formative assessment from a social constructivist perspective implies different roles for teachers and students than in the traditional practices (see Section 2.3).

Teachers can sharpen their teaching and assessment focus by continually asking themselves:

- What is there to see?
- How best can we understand what we see? Or more specifically,
- What do students know within this topic?
- What are they likely to learn next?
- What helps or hinders students learning in this area?
- What activities should be provided to foster this learning?
- How can we put our understanding to good use? (Drummond, 1993).

Social constructivism also implies students having an active role in the assessment process (Harlen, 1995; Torrance, 1993; Torrance & Pryor, 1995; Pryor & Torrance, 1995). According to Black & Wiliam (1998), students are involved in two actions, namely, perceiving gaps in their learning and attempting to close the gaps (see p. 50).

Formative assessment depends upon teachers' and students' mutual engagement. Without this mutual engagement, the assessment would (i) be a one-way view of student performance, and (ii) lack opportunities for students to clarify, defend and pose problems. Lack of mutual engagement usually results in assessment information that is of minimal value to the improvement or enhancement of student learning (Bell & Cowie, 1997; Pryor & Torrance, 1995; Sadler, 1989). According to several researchers, teachers have noted that including students in the assessment process resulted in enhanced student-learning, because students became more focused, motivated and aware of their own capabilities and potential (Fairbrother, Black & Gill, 1995; Harlen, 1995; S. Clarke, 1995). That is, by cooperating in assessment students may reinforce their grasp of the course content and strengthen their own skills at self-assessment. Their motivation is also increased when they realise that teachers are interested and have an investment in their success as learners (Angelo & Cross, 1993). All this is accomplished through classroom instructional and assessment practices that support interactive dialogue between teacher and student.

The preceding discussion indicates that the role of formative assessment or assessment conducted during the instruction process plays a vital role by (i) informing teaching and learning, and (ii) providing students with feedback to monitor the strengths and weaknesses of their performances which may eventually lead to them becoming more competent learners. Although it has been stated that the use of formative assessments by some teachers may place heavy demands on them, it is also acknowledged that in terms of the usefulness for learning and instruction, formative assessment will invariably provide teachers with far greater insights into students' thinking than other modes of assessment (Bell & Cowie, 1997; Crooks, 1988; Denvir, 1988; Sutton, 1995). Moreover, formative assessment provides opportunities for teachers to continually become more skilled in understanding how learning proceeds, and in analysing what skills and understanding are implicit in any given task. Thus, the use of formative assessment may enhance student learning by helping teachers become more effective teachers and assessors (Denvir, 1988).

Summative Assessment

Summative assessment plays an important supplementary role to formative assessment (Harlen, 1995). From time to time (e.g., end of term, mid-year, end of year), teachers are required to sum up students' progress in a particular area and/or aspect of learning. This may take the form of summarising evidence already used for formative purposes, testing or using a specific task (Harlen, 1995). This mode of assessment, known as summative assessment, focuses on what students have learnt and may require a single overall result.

The practice of adding quite disparate data (e.g., practical and theory) to arrive at a single grade or mark is questionable since this tends to be done in arbitrary ways. Torrance (1993, p. 340) argued that summative assessment takes only *snapshots of where the children have got to, rather than where they might be going next*. Further, when the emphasis is on summative assessment teachers are more often forced (directly and indirectly) to prepare students for the test, whether or not they have grasped the underlying concepts. As a result, rules and procedures can assume importance at the expense of understanding (Denvir, 1988). The primary purpose of summative assessment is to report students' performance to parents, teachers, students, and schools. As Masters and Doig (1992, p. 253) aptly explained, summative assessment is concerned with describing *the levels and kinds of understandings students have achieved at any given point in their learning*. Using a constructivist approach to learning where students are seen as actively constructing their own knowledge, summative assessment will provide a resume of what is firmly established 'robust' knowledge (Denvir, 1988).

Written Tests and Examinations

Summative assessment, as currently practised, is formal and is embodied in many timed, written tests and examinations. Written tests comprise of a set of written items based on specified objectives (Ministry of Education, 1994). These objectives are usually behavioural, and outline specific classroom expectations. Students respond to the questions posed, or provide information stipulated by, the instruction. Tests are either constructed by the classroom teacher or are standardised to assign grades (Gardner, 1992). At the heart of the debate on the merits of testing is the argument that written tests tend to focus on knowledge that is easy to test and ignore other important aspects of mathematics such as process (see Section 2.2). The consequence of this lack of information on student processes is that not only wrong conclusions could be drawn about student performance but also too little information is obtained about the instructional progress (Black, 1993; Gardner, 1992).

Too much emphasis has been placed on summative assessment leading to a separation of testing from learning. The concept that testing is initiated externally from the student, separate from the learning process, and primarily aimed at determining whether inert knowledge is in students' short-term memories exercises far too much influence over the education community today (Brown, 1990b). However, in Stiggins' (1992) view, it is not a matter of making a choice between alternative and paper-and-pencil tests. What is needed is that teachers recognise and use all available assessment approaches to create a true moving picture of a student's developmental progress in mathematics.

The Relationship between Summative and Formative Assessment

According to Boud (1995a), a distinction can be made between the purposes of formative assessment (mainly to aid teaching and learning) and those of summative assessment (mainly to measure the outcomes of student learning). Table 3.2 (overleaf) briefly summarises key differences between formative and summative assessment and gives some indication of the role of the teacher and students. Each mode of assessment is described according to purpose, time of application and possible use of the information obtained.

Black (1993) and Harlen (1995) have voiced a concern that what is passed off as formative assessment in schools is, in effect, repeated or ongoing summative assessment since no action is taken to inform learning. They noted that the major sources of information about students' performance were formal tests which occurred at the end of a unit or at the end of the academic year.

According to Denvir (1988, p. 207), *the question of whether formative and summative assessment involves the same or different activities depends on the learning espoused.* For instance, in the traditional view of learning, both formative and summative assessment are identical activities which involve finding out what is known and not known—or what is right or wrong. As a consequence, where distinctions are made, they relate to the purposes to which the information collected is put rather than to the form of assessment (Black, 1995; Denvir, 1988; Torrance, 1993). Some researchers have argued that an assessment can serve both formative and summative purposes (e.g., Black, 1993; 1995). An example to illustrate this would be, consider the teacher who gives a test at the end of a unit of work, reports progress to parents, and uses the information obtained as a basis for planning for the next group of students. While the test is summative, one of the actions taken by the teacher (ie. using the data to inform future teaching) is formative. Hence, Boud's (1995a) suggestion that summative assessment may be used to serve learning may be possible when teachers review the information collected from formative assessment in order to make summative judgements.

Table 3.2. Difference between Formative and Summative Assessment

	Formative	**Summative**
Purpose	To monitor and guide a process while it is in progress	To judge the success of a process at its completion
Time	During instruction	At the end of instruction, a unit of work or the term
Use of information	Inform and improve a process during lessons	Judge the overall success of a lesson or lesson sequence; to grade, place, or promote students

Other researchers have claimed that formative and summative assessment are quite different since their purposes are incompatible (Begg, 1998; Harlen, Gipps, Broadfoot & Nuttall, 1992). Hence, the results collected from assessing for formative purposes should not generally be used for summative purposes as information gained *during instruction is not a measure of what has been learned* *after a topic is completed and the main concepts reviewed or used in further work* (Begg, 1998, p. 1).

Gipps (1994, p.72) explained that the key difference between formative and summative assessment *is not timing, but purpose* and this difference should be borne in mind, particularly since teachers tend to employ both modes. In the words of Harlen (1995, p. 16):

> If [teachers] do nothing more than recognise the difference and hold on to both, then assessment can have a positive role in the future learning and teaching in our schools.

This suggestion has implications for assessment practices in St. Vincent and the Grenadines. Heed should be taken of Harlen's (1995, p.16) caution, *if we let teacher assessment become synonymous with assessment for summative purposes then it will continue to narrow and distort that teaching.*

Frames of Reference in Assessment

An important aspect of assessment is interpreting the information collected. This involves making judgements or comparing a student's performance with some referent. Through the academic year, teachers, especially those in secondary schools tend to use some, if not all of these referents. Harlen (1994) explained that the result of teachers' assessment will clearly depend upon what the task is, and how the judgement is made in relation to what standards or criteria are set. There are three kinds of referents commonly used: criterion, normative and ipsative (Brown, 1990a; Nix & Griffin, 1991; Masters & Doig, 1992; McGaw, 1988; Mousley, 1996; Wiliam, 1992). A descriptive summary of each referent is provided in Table 3.3 (overleaf).

The shift from norm referencing towards criterion referencing coincided with the increase in emphasis on classroom assessments for formative purposes and a change in the examination structure (Gipps et al, 1995). Although few would disagree that assessment using criterion-referencing is better than norm-referencing, nevertheless problems arise in developing and using criterion-referenced assessments (Gipps, 1990). These are usually because criteria are well defined and may fail to recognise and explore the range of other learning and understandings that occur as a result of an individual's learning experience (Bell & Cowie, 1997). In fact criterion-referenced assessment in the long run relies on norm-referenced assessment to determine suitable criterion.

Table 3.3. A Comparison of the Three Referents

Normative	Criterion	Ipsative
• compares students' performance with that of peers	• relates students' performance to well-defined criteria	• assesses students' learning against their prior learning
• gives students little constructive insight into the nature of their performance	• indicates what students know, understand and can do in relation to the criteria	• finds out where students are to help them learn more effectively
• associated with grading, ranking, selecting and reporting	• points out levels achieved and may indicate where help is needed or the levels at which it is possible to perform or achieve an outcome	• allows teachers to consider students' strategies, effort and progress, and particular circumstances
• the number of students passing a test may change by altering the pass mark	• the number of students passing a test remains unchanged since there is no fixing of the pass mark	• involves students and teachers only
• may lead to sorting and labelling of students but does not indicate what students can or cannot do	• may lead to over-specification and a focus on narrow, tightly defined objectives if the criteria are stated in specific terms	• may not provide the necessary information needed to help students learn more effectively

Despite the problems, the Caribbean Examination Council adopted criterion referencing, justifying it as a better or a more fair way of assessing children (Broomes & Halliday, 1993). However, in secondary schools in St. Vincent and the Grenadines, most internal assessment practices are based on traditional testing and examining, grounded in norm referenced traditions (W. King, 1991).

Each referent has its advantages and disadvantages. Some researchers have suggested that there should be a combination of both criterion and self-referencing in formative assessment in order to better provide teachers and students with the information that is needed to improve student learning (Black, 1995; Harlen, 1995).

Where the emphasis is on improving teaching and learning, then it may be desirable for teachers to be aware of these options, to examine further their possibilities, and use them where applicable (Mousley, 1996).

3.5 ASSESSMENT AND ITS RELATIONSHIP TO TEACHING AND LEARNING

One factor contributing to the need for assessment reform involves the relationship between assessment and the processes of teaching and learning. Researchers have indicated the need for teaching, learning and assessment to be aligned. This relationship is essentially symbiotic (Broadfoot, 1990; D. M. Clarke, 1997), intertwined (Bazzini, 1993), or intimately connected (Black, 1995; Leder, 1992). It is clear that changes in any one of these areas should not be made without reference to the likely impact on the others.

The Relationship between Teaching and Learning

Smith (1987, p.11) examined the history of the terms 'teach' and 'learn' and concluded that there is some kinship between the two terms. Both words come from the same middle English word *lernen* which has its root in the Anglo-Saxon word *lore*, originally meaning 'to learn or teach'. According to Smith, the definition of 'teach' in the 1500s was to show how to do something and/or to give lessons. As time progressed the traditional definition of 'teach' has shifted slightly in focus to mean imparting or sharing knowledge or skills. In response to those who say that teaching may not logically implicate learning, Smith (1987) contended that it can be anticipated that teaching will result in learning because teaching involves not only engaging in activities but paying attention to what is going on, diagnosing and using feedback to inform instruction. However teaching is regarded, the aim includes nurturing and promoting learning (Kirk, 1990). Further, Carpenter, Fennema, Peterson, Chiang and Loef (1989) argued that changes in teachers' conceptualisation (from a behaviourist to a constructivist perspective) of how students learn could result in changes in their teaching practices. For instance they could begin to emphasise the importance of the ideas that students construct; subsequently there is likely to be an increase in student interaction and involvement. Therefore, there is a need for teaching and learning to be interwoven.

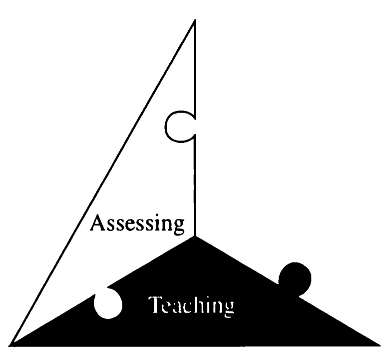
Fitting Assessment with Teaching

Closely linked to teaching is assessing. In fact, most educators have maintained that assessment is an integral part of the teaching of mathematics (Cockcroft, 1982; Grouws & Meier, 1992; Leder & Forgasz, 1992; Niss, 1993a, 1993b). The issue of assessment and teaching is related to the link between assessment and the curriculum. The curriculum is related to teaching, for it is the teachers' interpretations of the curriculum that guide their teaching. There appear to be differences in both traditional and contemporary views regarding whether assessment is the servant of curriculum or whether assessment drives the curriculum (Blane, 1992; Burton, 1992; Joffe, 1990). While this issue may be debatable, it is clear that if the position is taken that mathematics leads assessment, then changes in mathematics curricula and teaching will necessitate changes in approaches used for assessing student achievement and promoting learning.

Researchers have argued that although ideally there should be an intertwined or symbiotic relationship between teaching and assessment, present classroom assessment practices show that this relationship is not happening (Bazzini, 1993; Broadfoot, 1990; Broomes & Halliday, 1993; D. M. Clarke, 1997; Joffe, 1992). These researchers have appealed to teachers to ensure that assessment supports both teaching and learning (by matching assessment with classroom experiences), or that the assessment reflects what is being taught in the classroom (Bazzini, 1993; Broomes & Halliday, 1993; D. M. Clarke, 1997; Joffe, 1992). They further suggested that the alignment of assessment with teaching results in certain benefits to both students and teachers, as summarised in Figure 3a.

Students are more likely to learn when:

- instruction is focussed;
- they are assessed on what they were taught.



Encourages teachers to:

- focus on higher-order, integrated skills;
- communicate goals and standards;
- design avenues to help students achieve them
- make the best use of their time.

Figure 3a. Some Benefits gained when Teaching and Assessment are Aligned (Adapted from Macmillan, 1997)

The link between assessment and teaching is fostered through the use of appropriate assessment approaches that can assist in developing student understanding of mathematics (Bell & Cowie, 1997; Black & Wiliam, 1998; Costa & Kallick, 1995). For example, if students spend their time working in groups, then they should be assessed in a similar setting, such as by observing them as they interact and by using well-explained criteria that define the desired expectations. In this context, textbook-based tests will not provide information about students' contributions to a lively class discussion (Costa & Kallick, 1995). The learning resulting from different assessment approaches and situations will reflect the differences in student understanding. Therefore, teachers should identify opportunities for a variety of assessments to enable them to fully comprehend what students know, feel and can do (National Council of Teachers of Mathematics, 1989, 1995; Raymond, 1994; Shepard, 1989).

Meltzer (1994) discussed two major instructional goals that assessment practices should meet before assessment can be aligned with instruction. Briefly, these goals require that (i) areas in which instruction is needed are identified, and (ii) a starting point along with the instructional method and evaluation of the teaching and learning are determined. Meltzer perceived these goals as also relating to planning and designing the assessment to match with the teaching objectives and content—that is, to match what is taught, and what is assessed. Consequently, good assessment practices could lead to good instruction.

Fitting Assessment and Learning

As discussed in Chapter Two, theories of learning that characterise mathematical learning as memorisation of facts need to give way to a conception of mathematics learning in which learners gain understanding as they actively construct their own knowledge—a constructivist approach to learning. According to Shepard (1989, p. 5) such an approach to learning and teaching includes the need for students to *develop their own cognitive maps of the interconnections among facts and concepts.* Shepard implies that an active, constructive approach to learning should be taken since it is during the constructive process that students are to some extent making certain decisions or evaluating their work before taking the next step. Thus, from a constructivist perspective, *the idea of learning without some form of assessment of what has been learned is inconceivable* (Brown and Knight, 1994, p.36; Figure 3b overleaf). Consequently, formative assessment is central to learning.

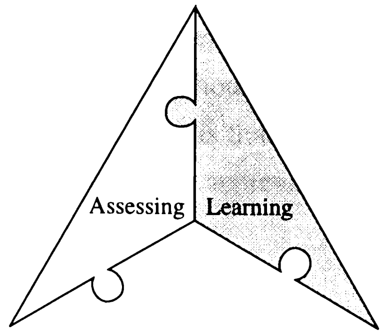


Figure 3b. Assessment is Central to Learning
(Adapted from Macmillan, 1997)

From the constructivist perspective, the importance of changing assessment practices so that they mirror the learning process is a necessary prerequisite for optimising student learning (Dirks, 1997). The need for this match becomes clearer when one considers beliefs of 'teaching to the test' and 'learning for the test' (Boud, 1995c; Dirks, 1997; Grouws & Meier, 1992). Such beliefs are central to the controversy that presently surrounds testing—as to whether these are desirable practices, and whether they can effectively enhance learning. Wiggins (1989, p. 41) claimed that teachers should teach *to the test,* but this was strongly refuted by Shepard (1989) who argued that teaching to the test *cheapens the instruction and undermines the authenticity of scores as measures of what children really know* (p. 7).

Further, there are inevitable problems. For instance, some students focus on or cram only the areas to be tested with the result that they lack ability to apply the knowledge because they have an incomplete understanding of the theory they are discussing. Another problem is that some teachers, consciously or otherwise, narrow their curriculum to improve test scores. In other words, instruction is skewed toward what is assessed (Boud, 1995c; National Council of Teachers of Mathematics, 1989). These limitations again point to the need for better assessment and for assessment tasks to be redesigned to more closely mirror real learning tasks (Shepard, 1989, p. 8). This view was later echoed by Resnick and Resnick (1991) as they stressed the need for performance-based assessment which would remove the need to teach to the test and align assessment with learning and teaching. However, Begg (1998) argued that if alignment exists then teaching 'to the test' is acceptable.

Fitting Teaching, Learning and Assessment

While summative assessment marks the end of teaching, formative assessment is an integral part of teaching that encourages and supports further learning (Bazzini, 1993; Leder, 1992). According to researchers, rather than viewing teaching, learning and assessment as separate entities they should be seen to support each other. An appropriate analogy for this point of view is that of a triangular puzzle composed of three pieces in which the solution is only achieved if the three pieces are properly aligned (see Figure 3c).

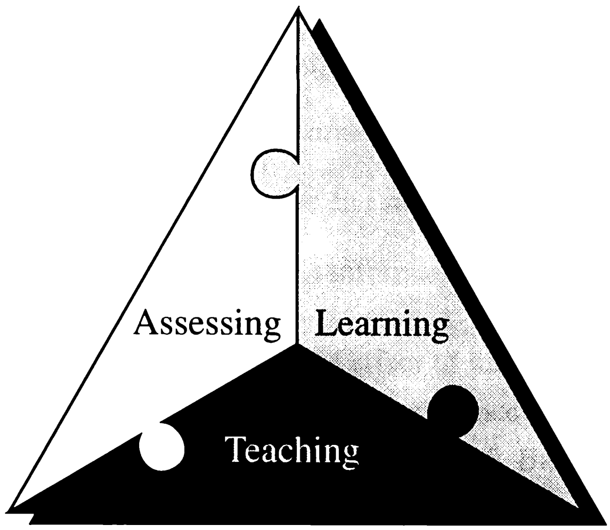


Figure 3c. Aligning Assessment, Teaching and Learning
(Adapted from Macmillan, 1997)

Realigning the trio allows them to become a whole entity which is more complete than any one piece by itself. To achieve this unity teachers must assess as they teach (D. J. Clarke, 1997; Webb, 1992). By (i) listening to and encouraging students' responses, (ii) regarding student knowledge as a social construction, and (iii) using a variety of classroom-based assessment approaches, teachers will become more successful in understanding the depth of learning as it is occurring, the misconceptions that students develop and how they resolve difficulties during the process of learning (D. J. Clarke, 1997; Cobb, Wood & Yackel, 1990; Grouws & Meier, 1992). By attending to the above, and providing students with the relevant information, teachers are better able to help increase student understanding of mathematics.

3.6 IMPLEMENTATION CONCERNS OF FORMATIVE ASSESSMENT

Calls for better forms of assessing student learning have raised questions about their relative benefits and drawbacks compared to traditional forms of assessment. Preliminary studies give some indication of the obstacles, including resource limitations, that educators and teachers can expect to face in trying to shift from traditional, behaviourist assessment practices to a constructivist approach to assessment. Even if alternative assessments are implemented in St. Vincent and the Grenadines, there will remain several substantial concerns such as the effect of alternative assessments on fairness, equity, cost and maximum use that can be made of the information collected from such assessments. According to Crooks (1993) and Shepard (1994):

- Will the assessment do any good?
- Will the assessment cause any harm?
- Will decisions be based on a true and sufficiently broad picture?
- Will decisions be based on stable information?

The first two questions refer to purposes and effect of the assessment. The third and fourth questions relate respectively to validity (relevance of assessment evidence) and reliability (consistency of assessments) (Biggs, 1995; Bachor, Anderson, Walsh & Muir, 1994; Messick, 1989; Shepard, 1993). In short, there are issues involved to do with different consequences and time, as well as the quality of assessment.

Different Stakes or Consequences

Assessment can be either high or low stake. That is, the results of assessment can have more or less serious consequences for students. Assessments designed and implemented by teachers, reflecting the curriculum, and used to inform and guide students' learning and the instructional process are typically low stake (Costa & Kallick, 1995). That is, students are not adversely affected if their performance is poor. The consequences of such attention require teachers and students to focus attention on the knowledge and skills that have not yet been learned.

The tests and examinations in the Caribbean that carry high stakes for students are those that are used for selection and/or certification and are based on a single test score (K. King, 1991). Examinations such as the Caribbean Examination Council and the General Certificate of Education examinations are high stakes assessments for students because their admission to tertiary institutions and employment prospects are affected by their scores on the examinations.

Time

Alternative assessment approaches require teachers to acquire new skills, knowledge and attitudes. Wiggins (1990) found that the use of alternative assessment may be time consuming. He felt that in comparison to other countries that have both oral and written assessment components, the USA was out performed. Wiggins (1990) stated that this resulted from time, money and training being routinely set aside in other countries to ensure that assessment continued to be of high quality. Therefore, regardless of how open or consistent an assessment is, it is not acceptable and will not be used unless it is perceived and found to be manageable. Although consideration should be given to enabling teachers to find time to plan, develop, implement, collect assessment information, and reflect on their practices, if too much time is spent in preparation and administration, the assessment will be unsuccessful. Nevertheless, Stenmark (1989) concluded that any time or cost incurred would be well spent when assessment is aligned with instruction.

3.7 SUMMARY

Assessment plays an important role in the classroom. Teachers can use assessment to help enhance student learning and their teaching practices. From a social constructivist perspective, there is a need to align teaching, learning and assessment in order to enhance student learning. This may be best accomplished through a combination of modes of assessment, which implies in St. Vincent and the Grenadines, an increased emphasis on formative assessment. Formative assessment linked to a social constructivist theory of learning focuses on students as active participants in the learning process. It is conducted during instruction when the teacher assesses what students know, feel and can do, and as such, teaching, learning and assessment are integral and inseparable parts of the same enterprise. In contrast, summative assessment is viewed as formal assessment that is linked to a behaviourist theory of learning. Such a view is manifested in many written tests and examinations where assessment is seen as (i) measuring a product only or concerned with summative grades, and (ii) being quite separate from learning.

An analysis of the reasons for assessing student understanding and the uses of the results collected reveals that different purposes require different types of evidence to be obtained. While formative assessment is considered by many researchers to be a more suitable approach to assessing student learning of mathematics, there is still a need for summative assessment as well. Further, it is suggested that when monitoring and describing student progress or performance, it is desirable to adopt a criterion and/or ipsative-referenced rather than a norm-referenced framework.

Teachers need to be aware that concerns relating to the use of alternative assessments must be considered. The concerns mentioned in this chapter relate to appropriateness and effectiveness of the assessment approaches.

This chapter and the next, Chapter Four, are complementary. Chapter Four builds on the arguments presented in this chapter for the adoption of formative assessment of student learning and the use of appropriate assessment approaches to enhance student learning and teachers teaching. It describes the four alternative assessment approaches used in this study. These approaches, when used to complement or in conjunction with other approaches, are considered to generate a fuller picture of the development of student mathematical thinking.

CHAPTER 4

ASSESSMENT APPROACHES TO ENHANCE LEARNING

4.1 INTRODUCTION

There is increasing recognition that the methods currently used by most schools for assessing student mathematical achievement are having *a substantial negative impact on meaningful learning* (Goldin, 1993, p.63). As highlighted in Chapter One, mathematical achievement has mainly been assessed on the basis of the number of correct answers on a given test or set of problems and many of the assessment items have been multiple choice and short answers. Most standardised tests and other traditional assessments items used at present in the Caribbean and the United States of America only measure lower level thinking skills and the narrowness of the test content is also a concern (Herman, Aschbacher & Winters, 1992). The criticism that is most discerning, however, relates to the mismatch between teaching, learning and assessment (Bazzini, 1993; D. M. Clarke, 1997; Herman et al, 1992; National Council of Teachers of Mathematics, 1995). Since these assessment practices have focused on assessing only student knowledge of specific facts and isolated skills (declarative knowledge), and assigning a mark or a grade to the students' written work, there is a need to broaden our assessment approach to include methods of data collection that focus on student thinking (National Council of Teachers of Mathematics, 1989).

This Chapter argues the need for educators and teachers to look beyond the 'what is tested is what gets taught' syndrome, to the need for continuous classroom assessment of a wider range of attributes regarding not only what students know and can do but also how they come to know. This chapter discusses four alternative assessment approaches by which student learning might be enhanced. While the four alternative assessment approaches – self-assessment, journal writing, observations and interviews – discussed in this chapter may be used for both formative and summative purposes, the emphasis throughout this thesis is on the formative aspect of assessment because this is consonant with current theories about how students learn. These alternatives represent only a few assessment approaches that may be used in place of or alongside testing, and they may be used separately or in combination, to create the fuller picture of the student mathematical understanding that is needed. The use of these assessment approaches may help to maintain links between teaching, learning and assessment. The remainder of this chapter is presented as follows:

4.2 Four Assessment Approaches

4.3 Students' Self-assessments

4.4 Observations

4.5 Journals

4.6 Interviews

4.7 Summary.

4.2 FOUR ASSESSMENT APPROACHES

The main purpose of assessment should be to enhance student learning (generated by good instruction practices and learning activities). To help achieve this it is necessary to broaden the ways in which students can demonstrate their mathematical achievements. Collecting data on students' thinking processes is one part of a broadened approach as it presents opportunities to both assist students' development and assess their progress (National Council of Teachers of Mathematics, 1995; Stenmark, 1989; Webb, 1993; Webb & Briars, 1990). Several alternative assessment approaches that are aligned with learning and instruction to identify student achievement and promote learning (Bazzini, 1993; Black, 1995; Kolstad, Briggs & Hughes, 1993; Linn, 1989; Raymond, 1994) may be used by teachers to provide 'a biography of students' learning' which goes beyond the traditional paper-and-pencil test. Four of these approaches are discussed in Sections 4.3 to 4.6.

Determining which assessment approach to use requires an analysis of what skills are to be assessed, the advantages and disadvantages of each approach, the methods of reporting and the accuracy of the interpretation it supports. The choice of an assessment approach must always be tied to the nature of the objectives and desired learning outcomes. This is illustrated in Table 4.1. Additionally, sound assessment practices should begin by defining the content of the assessment (e.g., the student processes or disposition to be assessed), and the purpose for the assessment. Table 4.1 summarises the type of assessment that is generally regarded as appropriate for specific types of content knowledge, process skills and personal development.

Table 4.1. Linking Assessment Approach to Object of Assessment

	Formative	**Summative**
Type and Purpose of Assessment	Window into student thinking Student motivation Planning instruction	Reporting Level or placement Recommendation
Object of Assessment	Content knowledge Process skills problem solving reasoning communication connections Skill and personal development	Content Knowledge Personal development work habits attitude social skills learn to learn metacognition Task completion Accountability

Several assessment approaches may be used to collect information about student learning for either formative or summative purposes. These include observations, journals, interviews, self-assessments, concept maps, projects, investigations, portfolios, tests and examinations. Of these assessment approaches, some tend to be used mainly in a formative way (e.g., self-assessment and journals) while others are more for summative purposes (e.g., tests and examinations). The four assessment approaches that were used in the case studies in this research were:

Students' self-assessments
Observations
Journals
Interviews

These four approaches were chosen from the eight (see "Assessment Approaches to Enhance Learning: A Teachers' Guide" in Appendix B) by the teachers who participated in the case study. A synopsis of each approach is given in Sections 4.3 to 4.6. Additional information on these forms of assessment along with details of four other assessments that were discussed can be found in the Teachers' Guide (Appendix B) where each approach is discussed in terms of what it is, its advantages, disadvantages and ways of implementing each approach.

4.3 STUDENTS' SELF-ASSESSMENTS

Brew (1995, p. 13) defined self-assessment as a *process* as well as an *activity* with a distinct identity. According to Carr (1994; p. 209), contemporary thinking about self assessment *has its roots in constructivist learning theory* which *argues for students accepting a greater responsibility for their own learning.* This view of learning recognises students' need to have an understanding of what their learning is trying to achieve (Black, 1995; Boud, 1995a, 1995b; Brew, 1995; Sadler, 1989) by assessing their own progress (Adams & King, 1995; Biddulph et al, 1989). Some possible foci for student self-assessment, according to Boud (1990), are illustrated in Figure 4a.

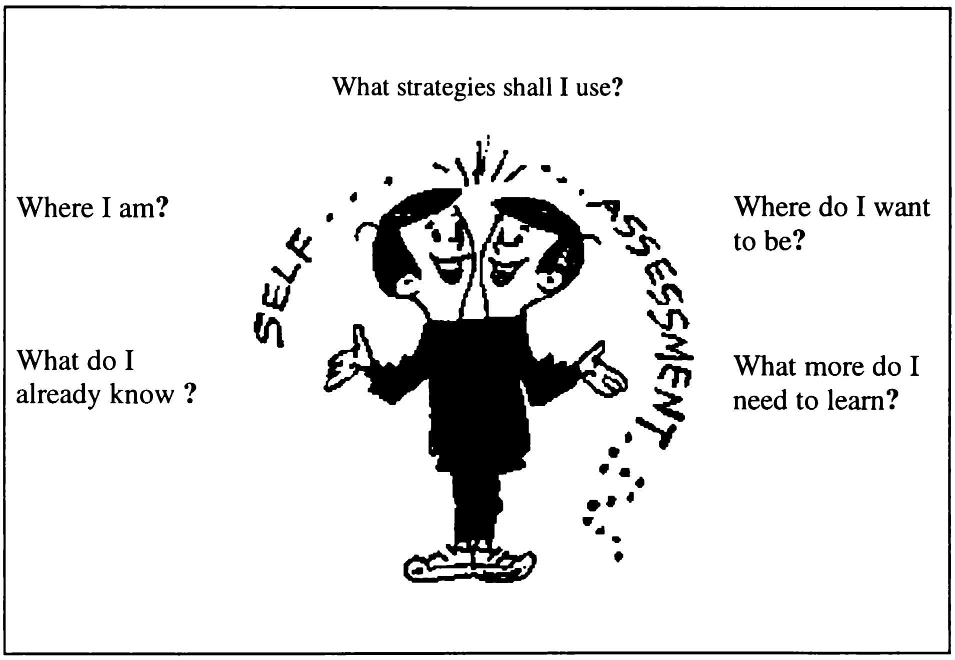


Figure 4a. Self-Assessment involves Decision Making and Action

Self-assessment involves self-awareness, self-evaluation and reflection. According to Campione, Brown and Connell (1988), self-awareness may be enhanced by encouraging students to describe their feelings as learners, in particular their mathematics anxieties. Self-evaluation involves going beyond self-awareness to critically assess one's own mathematical knowledge, processes, and disposition (Adams & King, 1995; Brew, 1995; Boud, 1990; Kenny & Silver, 1993). It is seen as an intrinsic part of reflecting on one's learning (Black & Wiliam, 1998). According to Stenmark (1991), self-awareness and self-evaluation should occur in tandem. That is, students need to examine their work, monitor their progress by reflecting or thinking about what they do well, the effectiveness of their strategies, and in what areas they still need help.

When students participate in self-evaluation and reflection, they are developing their metacognitive skills (Biggs & Moore, 1993). Metacognition refers to one's knowledge concerning control of one's own thinking (Brown, 1987; Kenny & Silver, 1993). Promoting the development of metacognitive skills would require some element of scaffolding (Collins, Brown & Newman, 1989) wherein teachers guide students in understanding the process of self-assessment during the introductory phase (Butler & Winne, 1995; Collins et al, 1989) gradually leading them towards ownership of their own learning. Such involvement leads to the 'redistribution of educational power' (Harris & Bell, 1990). Assessment becomes not just something which is done to the learners, but also something 'done with' and 'done by' learners.

The theme of gradual ownership of learning is echoed by Brew (1995) and Mousley (1996) who looked at student autonomy as a process in which learners take the initiative, without the help of others, in diagnosing their learning needs, formulating learning goals, choosing and implementing appropriate learning strategies, and evaluating learning outcomes (Brew, 1995; Boud, 1995a, 1995b, 1995c).

Innovations which may strongly promote student autonomy include problem-based learning (Boud & Feletti, 1991), and self-directed learning (Hammond & Collins, 1991). The emphasis in these approaches is on negotiation between teachers and students (Brew, 1995; Butler & Winne, 1995), whereby teachers and students describe, discuss and clarify ideas involved in the task or problem that they are engaged in. The ensuing negotiation helps to guide the learning process by giving the teacher a clearer perspective on the student level of development, while simultaneously making a useful contribution to the socialisation process (Tanner & Jones, 1994, p. 425).

As students reflect on what they have learned and on how they learn, they develop the tools to become effective learners by enhancing *their strengths and reducing their weaknesses* (Kenny & Silver, 1993, p. 231). Further, student reflections can also provide the teacher with both data upon which to make judgements and feedback for refining instruction.

The work of Boud (1989) and Masqud and Pillai (1991) served as a baseline for the selection of the self-assessment approach used in this study. Boud (1989) conducted several with undergraduate law students. Two that informed this study were (i) the use of a common set of students' established criteria to assess their own performance and that of their peers on a research project, and (ii) the use of self and peer assessment in generating a class participation grade. Fifteen students participated in the first survey and twenty-five in the latter. Each student contributed five to eight criteria, from which the top three were used. Student self-assessment involved justifying their own assessment with respect to the established criteria and submitting this with the project. The results of the first survey showed that that there was a qualitative improvement in students' performance relative to previous years (when self-assessment was not used). The main findings of the second survey revealed that (i) there was a very high level of agreement between teacher and student grades, (ii) some students rated themselves either more or less favourably than the rating received from their peers, and (iii) students actively participated especially in establishing the assessment criteria. Boud (1989, p. 23) highlighted the need for students to gain sufficient practice to formulate responses in a useful form and to *appreciate the criteria which they are using*.

These two studies give evidence of learning gains. However, the reports were brief, little description of the self-assessment process was provided, and no indication was given of the changes that occurred in the classroom environment and/or pedagogy.

One example of a qualitative study designed to include students in the assessment process is that reported by Masqud and Pillai (1991). These researchers trained a class of secondary school students in self-grading their tests. They found that the scores gained by this group were significantly higher than those of the control group. They attributed this to the lowering of students' distrust of and antagonism towards teacher feedback in relation to test results. However, Boud (1995) cautioned that although self-grading or self-testing may be useful for the development of self-assessment skills, an overemphasis on these would shift the focus away from getting students to engage in establishing and working with criteria.

4.4 OBSERVATIONS

Essentially, observation is one assessment activity that is used daily by teachers to evaluate some aspects of students' thinking, development, accomplishments, behaviour or attitudes, and to make instructional decisions based on the students' needs (Arasian, 1996; Drummond, 1993; Good & Brophy, 1994).

Ginsburg et al (1993) report one such instance. They investigated the use of observation in conjunction with interviews. With a Grade four class teacher, they developed a scheme for coding students' observed strategies. This included the recall of number facts, concrete counting involving fingers or any other easily accessible objects, mental counting procedures such as counting on, and regrouping strategies. Students were given a number problem to solve. Observation of their approaches to the problem followed up by subsequent brief interviews showed that the students approached the task differently. Some used only concrete counting while others mentally calculated the answer. This information was later used by the teacher to improve instructional planning and the development of student learning. This study reported two years of research work in a classroom about an assessment approach used by teachers to inform both teaching and learning. Basic considerations in using this approach include (i) who, and what behaviours will be observed, and (ii) for how long this will occur. Further, Ginsburg et al (1993) cautioned that while some documentation of students' processes, products and dispositions is necessary, too great an emphasis on documentation can interfere with teaching and learning.

In another study, Nicholson and Anderson (1993, p. 369) found sixteen out of twenty-one primary teachers defined observation as simply watching students, that is, looking at (i) how children work, and (ii) for relationships between children, environment, and peers. Less common themes were listening to students (4 teachers), recording anything children do (3 teachers), and asking students questions (1 teacher).

In contrast, Gipps, Brown, McCallum and Mc Alister (1995) reported that twenty-one out of thirty-two Year 2 teachers described observation as a method of looking and assessing the tasks students are doing. However, according to Hopkins (1993), observation is more than a process of just listening and noticing the important elements of a performance or behaviour. It can be purposeful, selective and systematic and may be used to increase teaching and learning effectiveness (Good & Brophy, 1994; Hopkins, 1993; Kumar, 1996).

From the literature, it is apparent that (i) research on observation has focused mainly on it as either a research tool or a means of evaluating teachers' behaviour, rather than as a way of assessing student learning (Stiggins 1988; Nicholson & Anderson, 1993), (ii) teachers are familiar and comfortable with observation as a research technique (Gipps et al, 1995), and (iii) although many teachers may act on the information collected from observing students few ever document the information. Some researchers, arguing that when the information is documented it generally lacks structure and is not systematically recorded, have sought a degree of structure to observations (Bell, 1993; Clarke, 1996; Wolf, 1993). However, there is probably less need to document data gathered, processed and used for formative purposes since the teacher is acting on the information gathered *during* instruction.

There are many situations in which observation is the most appropriate assessment approach that may be used to collect data about student disposition toward mathematics learning. For example, it is appropriate in situations where full and accurate information about students' behaviour cannot be gained through the use of interviewing, self-assessment and/or journal writing, and when studying the interaction and participation of a student in a group. Further, observation may be used to study the behaviour of students, such as time spent on task, as well as their dispositions toward mathematics. These dispositions may be observed by the manner in which they approach tasks (Nicholson & Anderson, 1993). Such interpretive procedures may be categorised as qualitative descriptions which rely heavily on memory and usually call for the teacher to evaluate, describe and comment or make notes as well. Further, observation of the manner in which students are encouraged to ask and answer questions, explain their point of view, defend their explanation, and reflect on their own thinking are just some of the information that can best be tapped through observation of students *during* instruction (Biddulph, 1993; Cross & Hynes, 1994; Hopkins 1993; National Council of Teachers of Mathematics, 1989; Nicholson & Anderson, 1993).

4.5 JOURNALS

Traditional mathematics courses have rarely required students to write or reflect on their learning, concentrating instead on textbook exercises and problems set in a lecture format. The use of writing as a tool for the teaching, learning and assessment of mathematics is a recent development, springing in part from the National Council of Teachers of Mathematics Standards on Communication. Publication of the Standards spurred a reform movement that calls for instructional practices to give more emphasis to open-ended problems, written and oral communication, making mathematical connections and active student participation and engagement in the learning process (Clarke et al, 1990; National Council of Teachers of Mathematics, 1989; Stenmark, 1989).

One approach to promote and develop communication skills is the use of journals in mathematics assessment. Holly (1987, p. 4) described a journal as being far more than a flow of impressions. It includes *descriptions of circumstances, others, the self, motives, thoughts, and feelings.* It has both factual and interpretative dimensions. The main purpose of journal assessment in mathematics education is to write, think and record mathematical ideas and processes.

Two types of journals that are usually considered are those requiring students to (i) write, with minimal direction, their feelings and/or thinking about the mathematics being taught, and their daily experiences and progress in the mathematics class – this type is sometimes referred to as a collection of free-writing comments (Countryman, 1992) – and (ii) complete a specific written task by establishing restrictions and guidelines necessary to accurately complete the task (Carter, Ogle & Royer, 1993; Clarke, Waywood & Stephens, 1993).

According to Gopen and Smith (1990), it is through written expression that an understanding of student thinking may be arrived at by both the learner and the teachers. For example, in deciding what to write, students must select and organise their essential ideas about a problem and its solution. By forcing a slow down in the thought process, writing enables the mind to clarify ideas, make connections among concepts and more fully integrate new knowledge. In the process of explaining why a particular strategy was chosen, each student becomes actively involved in reflecting on what he or she has been doing and thus has the opportunity to formulate, modify and further develop their thinking and reasoning skills, which leads to both a better understanding of the material and heightened mathematical communication skills (Countryman, 1992; Dougherty, 1996; Holly, 1987; Linn, 1987; Waywood, 1992). Thus, writing in mathematics is an integral part of learning.

Students' journal entries may be assessed both formally and informally (Carter, Ogle & Royer, 1993; Stix, 1994). Informal assessment could take the form of reviewing students' entries to assess their acquisition of a particular concept. The focus of assessment should be on the effort students put into thinking about mathematics and organising these thoughts for presentation in writing. Student journal entries will be graded when assessed formally.

The effect of the use of journals on student learning has been studied by Waywood (1992) and Clarke et al (1993). Waywood (1992) studied the link between journal writing and mathematics. He reported how journal writing can lead students to summarise and reflect on the mathematics they are learning. Clarke et al (1993) looked at the perceptions of students concerning their experience of working in the context of learning mathematics. These reports are based on the experimental use of journals in secondary mathematics classrooms in one single-sex school in Melbourne. The sample, drawn from diverse socio-economic nationalities and backgrounds, consisted of approximately five hundred students from years seven to eleven. Like Waywood (1992), these researchers probed the structure of mathematical writing. Unlike the qualitative approach taken by Waywood (the use of journal excerpts) or the quantitative approach used by other researchers, Clarke et al used a combination of both approaches. At the time of the study in 1988 journals contributed thirty percent of the assessment of mathematics. Findings from the report by Clarke et al (1993) revealed that students' perceptions of the nature of journal use related closely to the school goals. Additionally, sixty percent of the students cited the main benefit of journals as *helping them to learn* (p. 240). While fifty percent reported that the most important thing learned from the use of journals was the ability to explain their thinking.

The findings of these two studies revealed that the composition of students' journals included summaries, narrative/recount or exemplification, dialogue and application. These categories are indicative of students' mode of thinking or of their changing stance towards learning. The experience of these researchers has been that while the use of journals enhances students' mathematics learning, the processes engendered by journal use happen over years, and only occur with a conscious teaching effort. Hence, further research is needed to address the issue of the connection between journal writing and the learning of mathematics.

The acceptance of journals in mathematics may be achieved, over time, through teacher-student discourse—for example, prior to considering the question of how writing will improve learning, teachers should first find out how students perceive mathematics. If 'doing mathematics' is considered as memorising rules and formulae and success regarded as making 'good grades', then it is little wonder that students may fail to appreciate the value of writing in mathematics (LeGree, 1991; Mc Intosh, 1991; Miller, 1991, 1992). What is needed then is for teachers to get students to attend to certain things, and to stimulate student reflections by commenting positively on journal entries. Additionally, Countryman (1992) and Woodruffe (1992) suggested that it is the responsibility of teachers to ensure that students place the same value on journals as assessment tools as is given to other aspects of the assessment of mathematics. They encouraged teachers to promote the use of journals in mathematics by keeping journals of their own experiences and to find ways to integrate the use of journals into their instructional and assessment practices. However, Davison and Pearce (1990, p. 20) cautioned that teachers will need to read more than a few selected articles before implementing this assessment approach. In their opinion, what is required is teachers' belief in the effectiveness of this assessment approach and a willingness to trial it.

4.6 INTERVIEWS

Chambers (1995) argued that traditional testing practices do not allow for communication between teacher and students regarding their understanding and thinking about a concept. As a complement to self-assessment, observation and journal assessment, interviewing (sometimes referred to as conferencing or questioning) can open up a window into student mathematical thinking.

Interviewing as an assessment approach originated from the conviction that, in order to assist student learning, it was important to grasp a student's line of reasoning (Ginsburg et al, 1993; Hughes & Large, 1993; Hunting & Doig, 1991; Long & Ben-Hur, 1991). Piaget, one of the first to systematically investigate children's thinking, provided a useful approach for us to assess students' thinking processes. His clinical interview method – posing questions to a child, then following up the replies – has been modified by researchers and educators so that today we have the flexible and structured interview, organised probes, and thinking aloud techniques (Ginsburg et al, 1993). An interview may be described as a two-way conversation initiated for the specific purpose of obtaining relevant information. It involves the gathering of information through direct interaction between individuals (Cohen & Manion, 1994). This assessment approach may be conducted as a one-to-one interactive, oral communication or it may be modified to include groups of students, or whole class discussions (Hughes & Large, 1993; Long & Ben-Hur, 1991).

An important study that informs the interview approach is that conducted by Peck, Jencks and Connell (1989) of the USA. They investigated, using brief interviews, 32 sixth-grade students' conceptual understanding of numbers and any inadvertent errors. The interviews were conducted after a placement test and then every few weeks when a new topic was introduced or an old one was completed. It took about one hour to interview the class on a one-to-one basis. Regardless of the correctness of the students' responses they were asked to explain their reasoning. The findings revealed that only about eight percent of the students had sufficient conceptual understanding to interpret and use fractions for mathematical thinking and problem solving. The findings led the researchers to conclude that, had they relied on the results of the written test alone, more than half the class would have been misjudged. The researchers believed that both teachers and students benefit from a series of brief interviews where the focus is on conceptual and procedural understanding and the information obtained informs future instruction. This study provides evidence of learning gains and of the symbiotic relationship between teaching, learning and assessment.

Heath (1994) reported two cases where interviews were used as a complement to testing, to further assess students' understanding of mathematical concepts. In both cases, the students claimed to know the course material very well. One student blamed her failure to pass the written tests on anxiety. The interview approach was used to verify what the student knew. Through dialogue, the use of this assessment provided the teacher with the opportunity to not only delve into the student's thinking and reasoning but to assess her verbal ability to communicate mathematical knowledge. Continual monitoring of the student's thinking also provided the teacher with opportunities for listening to the student, seeing the problems through the eyes of the student, responding to the individual's needs, and focusing on learning rather than answers (Heath, 1994; Liedkte, 1988; Long & Ben-Hur, 1991).

The purpose of interviews is to listen to what students have to say about the mathematics they are learning and the learning process. Being given full attention can be rewarding and serves to encourage communication. Students may benefit from the use of interviews when they find it easier to communicate orally about what they have done or are doing rather than by written work. Long & Ben-Hur (1991) claimed that delving deeply into students' thinking and reasoning through dialogue contributes to their understanding of subject matter. Through questioning, students' struggle for meaning may be nurtured and encouraged. As teachers engage with students in discussion, they are better able to determine their students' understanding and at the same time give students immediate feedback and encourage them to learn mathematics (Hughes & Large, 1993; Peck, Jencks & Connell, 1989). When used in conjunction with paper-and-pencil tests, interviews yield much useful information about students' understandings of mathematical concepts (Peck et al, 1989).

Long and Ben-Hur (1991) described the interview process as having three components: *the initiation, the formulation of hypotheses about students and the students' understanding, and the testing of these hypotheses through questioning* (p.45). Interviews may also involve a fourth component—modification of students' knowledge. The formulation of hypotheses may occur at any time during and after the interview process (Ginsburg et al, 1993; Long & Ben-Hur, 1991). When hypotheses are formulated during the interview process, the teacher has the chance to change or modify questions in order to test hypotheses.

Costa and Kallick (1995) believed that teachers may help students develop the art of talking about their mathematical learning and describing their line of reasoning or thinking by consciously and deliberately introducing new ways of thinking, defining and discussing terms that relate to mathematics and students' experiences. For example, teachers may encourage the use of terms such as reflect, imagine, review, analyse, strategy, classify and plan. Teachers modelling of this would provide *a powerful and intrusive scaffold for students* (Costa & Kallick, 1995, p. 156).

Further, knowing what types of question to ask strengthens the ability to evaluate students' thinking and reasoning (Long & Ben-Hur, 1991). However, questions need to be neutral rather than leading, and in depth. It must be noted that if at any time during the interview the student appears reluctant to continue with the interview, that is, there are long silences and mono-syllabic responses, then the interview should be discontinued (Bell, 1993). Recording students' responses provides the teacher with the opportunity to later analyse both their form and content (Bell, 1993; Ginsburg et al, 1993).

The above assessment approaches are an integral part of student learning. For example, self-assessment and interviews are closely connected to instruction, they involve immediate feedback to help students improve their work in progress, and are designed to provide rich, detailed pictures of individual students' learning (Berlak, 1992; Shepard, 1989; Stenmark, 1989). Clarke (1996) cautioned that each assessment approach will require some degree of adaptation to meet the particular needs of the learner and the classroom situation.

4.7 CHARACTERISTICS OF THE FOUR APPROACHES

The four assessment approaches described in this chapter have one overarching objective, that is to provide a better understanding of the learning experienced by students in order to enhance their learning of mathematics. Several common characteristics are outlined in Table 4.2. If assessment approaches are to be consistent with current understandings of mathematical learning, then any attempts at aligning assessment with teaching and learning would require changes in classroom assessment practices.

Table 4.2. Some Common Characteristics of the Four Alternative Assessment Approaches

Common Characteristics
• They are approaches that can be carried out informally
• They may be used for assessment before, during and after learning
• They represent alternatives to the usual testing involving multiple choice questions or other tests
• They assess students' performance in terms of mathematical creation, product and processes
• They can tap higher-level thinking and problem-solving skills
• They allow teachers to recognise, value and reward appropriate multiple answers, strategies and invented processes
• They use tasks that are also meaningful instructional activities
• They require new instructional and assessment roles for teachers

These changes require that learning be perceived as a constructive process in which the teacher is constantly engaged in attempting to understand student learning by using a variety of assessment approaches, and in which the students are actively engaged in the assessment process.

4.8 SUMMARY

There are several alternative assessment approaches that teachers can use to assess students' mathematical learning. Which of these approaches – or combination of them – will most effectively enhance student learning depends on a variety of factors, such as time, purposes of assessment, teacher and student roles. Examples of four approaches served as a baseline for selection in this study. While these reported studies differ in the type of assessment approach used, sample, research design and ecology, they tend to agree in focus and emphasis. Primarily, they illuminate the need for a range of alternative assessments to be used in classrooms to (i) encourage student participation, (ii) enhance student learning, and (iii) offer teachers several possible examples of implementing changes in their classroom assessment practices.

The four assessment approaches reviewed – self-assessment, journal writing, observations and interviews – are used in the main phase of this research as they present alternative ways to testing for collecting assessment information in order to enhance student learning. Data on the use of these approaches by classroom teachers are reported in later chapters. The following chapter, Chapter Five, describes the research methodology, design and process.

CHAPTER 5

RESEARCH DESIGN AND DESCRIPTION

5.1 INTRODUCTION

This research is in keeping with the premise that knowledge is not passively received but actively created by the learner through actions and reflections. Hence, a qualitative research design was deemed appropriate to answer the research questions:

1. What are typical Vincentian secondary school mathematics teachers views of assessment?
2. How did the three teachers implement their chosen assessment strategies?
3. What effect did the use of these strategies have on the teachers' teaching?
4. What effect did the use of these strategies have on the students' learning of mathematics?

The research generated non-statistical data including the participants' own written and spoken words which were analysed by looking for emerging themes and patterns. The remainder of the chapter is presented as follows:

5.2 Research Approach

5.3 Data Collection Methods

5.4 The Research Design and Description

5.5 Data Analysis

5.6 Ethical Concerns

5.7 Summary.

5.2 RESEARCH APPROACH

This section discusses the methodological approach in which the present research is grounded, that is, a qualitative research approach. It explains the reasons for selecting and using the case study method to explore the use of the four alternative assessment approaches. Aspects of research quality such as the credibility and trustworthiness of the research process, findings and the interpretation of the findings, are also discussed.

Qualitative Research

The study is a qualitative one which means it is interpretive. In such research the researcher explores in depth ideas, concepts, feelings and thoughts related to various issues (Banister, Burman, Parker, Taylor & Tindall, 1995; Walker 1993). A strength of qualitative research is the flexibility of the research process (Burgess, 1985). The nature of the research process allowed formulation and reformulation the plan of research action and, at times, the simultaneous collection and analysis of data.

Another benefit of using a qualitative approach in the research is that it enabled both the researcher and participants, to become involved in posing questions, searching for and trying out solutions, and reflecting on their processes (Oliver, 1980). This is consistent with Cole's (1989) view that teachers need to become researchers themselves instead of merely being the subject of research. Cole believed that as teachers move into the role of teacher-as-researcher, they develop increased professional understanding.

Case Study

The approach used was case studies. Merriam (1988) suggested that *researchers use a (qualitative) case study design to gain an in-depth understanding of the situation and its meaning for those involved* (p.xii). She further commented that the case study is a suitable approach for examining critical issues and practices in education, *especially when the desired outcome of the research is to improve on practice and gain understanding* (p.10). Additionally, a case study design has more appeal because it is concerned with gaining insights through *discovery and interpretation rather than hypothesis testing* (Merriam, 1988, p.10).

Qualitative case studies are best suited when the research questions ask *how* and *what* (as in this research), and when the desired outcome of the research is a rich, thick description and interpretation of the phenomena (Merriam, 1988; Yin, 1989). The uniqueness of a single case can also be justification for its study. Studies of unique cases can demonstrate the limits of generalisations and can show that a generalisation may be invalid (Reinharz, 1992). As mentioned in Chapter One, the use of alternative assessment for formative purposes is a rare occurrence in mathematics classrooms in St. Vincent. The use of the case study approach to describe in depth, and present the findings is an approach that fits with the purpose of this research. The variety of methods used for collecting the data of the research are described in Section 5.3.

5.3 DATA COLLECTION METHODS

Throughout this research project, I kept a diary of my reflections, sifting through the data, re-reading the literature to make decisions about the next action, and participating in discussions. Further, as both the researcher (R) and one of the teachers, I had to simultaneously increase my awareness of my position in the research and the processes being utilised. In this way, some triangulation of data occurred in this research (see Table 5.1).

In this research, data were collected by means of:

- Field Notes
- Interviews
- The Teachers' Assessment Questionnaire
- Journal Entries
- Observations
- Document Analysis (of the St. Vincent and the Grenadines Third Form Mathematics Curriculum)

Table 5.1. Data gathering approaches

		Questionnaire	Interview	Field Notes	Journals	Observation	Students' written work
Teachers	**(i) Secondary (20)**	✓✓					
	(ii) Participants (2)		✓✓	✓✓	✓✓	✓✓	
	(iii) Lecturers (2)		✓✓	✓✓			
Students			✓✓	✓✓	✓✓	✓✓	✓✓
Education Personnel			✓✓	✓✓			
Researcher				✓✓	✓✓	✓✓	

The interviews, questionnaire and journal extracts are coded as shown in Table 5.2.

Table 5.2. Coding Structure for Presenting Data

Code	Description
RJ/SA/12.9.96	Researcher's journal, self-assessment, and date of the journal entry
M/T15/9.96	gender, and number assigned to the teacher, and date the questionnaire was sent.
JI/F/12.96	the teacher, interview, gender of the teacher and date of the interview
X1/J/10.96	class and student number, source data taken from (journal) and date of the journal entry
Z3/SI/12.9.96	class and student number, source data taken from (assessment interview) and date of the interview
F-UI/F/6.97	follow-up interview, gender of the teacher and date of the interview

1. Field Notes

Field notes consist of relatively concrete descriptions of social processes and their contexts (Banister et al, 1995). Researchers have argued about the value of field notes in research situations where it is often impossible or inappropriate to use other data collection methods such as audio recording (e.g., Banister et al, 1995; Bogdan and Bilken, 1982). These researchers contend that when field notes have a framework, or features on which analysis will be based, they provide rich descriptive evidence and dialogue relevant to what occurred and the meaning of these occurrences for participants. The main advantage of using field notes, however, is that it allows for a wide range of data to be collected and recorded. They are also flexible, allowing the researcher to note observations from any particular spot in the classroom, thereby allowing the researcher to move easily from place to place (Maykut & Morehouse, 1994). Such notes constitute the 'thinking out loud' process that is a main aspect of reflexive thinking, and may include notes of the researcher's feelings (Banister et al, 1995).

Field notes were used as a source of data in this research. Written by both researcher and the other two teachers involved in the classroom trials, they allowed a wide range of data to be collected and recorded. As researcher, I recorded moments of the research process such as teacher-teacher interactions and support, their doubts, suggestions and concerns. Additionally, I noted observations of student-student interactions, teacher-student interactions, students' participation in the learning and assessment processes and the work that they were doing. The flexibility of making field notes meant that I could make links between present observations and previous ones. Further, the use of field notes was valuable when moving from group to group of students and from one class to the other. The field notes recorded by the three teachers were discussed in our weekly meetings, and were helpful in revealing emerging patterns and changes. Consequently, we were able to connect past with present developments in student learning and our teaching assessment practices, and to share these developments with other teachers in the mathematics department.

2. *Interviews*

Interviews are used in education research to collect a rich source of information regarding the interviewee's thoughts, understandings and attitudes (Banister, Burman, Parker, Taylor & Tindall, 1995). Additionally, in classroom settings, the use of interviews may provide opportunities for regulating instruction to maximise students' individual growth (Banister et al, 1995; Liedkte, 1988; Ginsburg et al, 1993; Heath, 1994; Long & Ben-Hur, 1991). During interviewing the researcher listens, formulates, tests and reformulates hypotheses. The use of interviews allows researchers to reflect on their own experience and role within the research process (Banister et al, 1995). Some researchers and teachers have voiced concerns about (i) compared with mail questionnaire the interview procedure can be time consuming, and (ii) that certain biases may occur, such as the use of leading questions, hinting at desired responses, too long or in depth questions, intimidating expressions or tone of voice, and discrepancies in the interpretation of information collected.

Bell, Osborne and Tasker (1985, p. 151) highlighted the need for *a conscious value-free approach* to effectively probe student thinking. Although it may not be easy for teachers to maintain, a conscious effort is required to reduce possible effects of subjectivity. Often a brief listen to one's audio-recorded interviewing is sufficient to highlight subjective tendencies such as asking leading questions or hinting at desired responses.

The data collection method most widely used in this study was the interview. The term interview is used broadly to include all discussions with participants where information was elicited. As a result, there were formal open-ended and informal interviews with the (i) other two teachers in the study, (ii) others in the mathematics education community, and (iii) students. These are coded as JI, OI and SI respectively. Because of its interactive nature, interviewing has several advantages over other techniques for collecting qualitative data. A primary advantage is the ability to probe in depth particular knowledge domains, unexpected and revealing responses, and significant areas of respondents' insights and experiences that may result in outcomes unanticipated by the researcher (Cohen & Manion, 1994; Banister et al, 1995).

Teachers. Informal interviews included discussions or questioning without imposing any prior categorisations that may have limited the field of inquiry (Best & Khan, 1993). Such discussions occurred at our regular meetings over the twelve weeks and at unscheduled times within the group and with other staff members. The discussions developed as a result of sharing and challenging, gathering new ideas and opinions from others, reading and discussing the assessment guide, and trialing at least one of the approaches in a classroom context. To ensure that the research process was as open as possible for those being interviewed, before beginning the interviews respondents were given a copy of any formal interview questions and were reassured that all information received was confidential. They were also given the opportunity to comment on the research questions and to withdraw from the research if they desired. None chose to withdraw. Respondents were asked the same basic questions in the same order (see Appendix C). However, some degree of probing was needed for clarification purposes. An interview ranged from 30 to 40 minutes. Transcripts were given to the teachers for their comments. Using this open-ended approach allowed for comparison of respondents' answers to each question.

Other mathematics education people. Formal open-ended interviews were used when interviewing personnel from the Ministry of Education about their perceptions of learning and assessment in St. Vincent and the Ministry of Education's vision of assessment in the secondary schools mathematics curriculum. Questions used in this interview are presented in Appendix C.

Students. I carried out many informal interviews with individual students and with groups of students during and after instruction. Students were interviewed (i) while working on task, and (ii) before and after instruction. The latter occurred only when the dominant mode of assessment was self-assessment. Each interview was tape-recorded and notes were made of non-verbal responses that were used. While permission was sought from the teachers to record the interview, time was spent before the intervention interacting with students, discussing with them the importance of the recorder in the classroom, getting students to listen to tape recordings of themselves and basically establishing rapport and trust. Consequently, students accepted the presence of the tape recorder in their classroom.

Student interviews varied in length, from five to ten minutes. The questions were based upon a set of assessment activities, tasks or problems that students were either presently engaged in or had previously encountered. Some journal entries were used as interview probes. The flexibility of the interview method helped me to repeat or rephrase questions and to deeply probe participants' thinking. Throughout the interview students were encouraged to explain how they solved a particular problem and/or their reasons for assessing their performance in a particular manner. Thus, interviews provided detailed information about student thinking and understanding of numbers, number theory and mathematics, and teachers' changing views about assessment and assessment practices in St. Vincent.

3. *Questionnaire of Teachers' Views of Assessment*

Questionnaires are used to collect opinions of respondents (Best & Khan, 1993), and can be used to collect information from a large number of respondents economically and quickly. They have a certain degree of flexibility depending on the researcher's objective and offer greater anonymity than interviews (Frankfort-Nachmias & Nachmias, 1996). Questionnaires can consists of open-ended, closed or a combination of both types of questions (Best & Khan, 1993; Burns, 1994; Cohen & Manion, 1994; Frankfort-Nachmias & Nachmias, 1996). Open-ended questions are used to explore respondents perceptions, ideas and beliefs, while closed-ended questions may require the respondent to tick beside one or more items (Burns, 1994). The main disadvantages are (i) a low response rate, and (ii) there is no opportunity for probing. The present study used a combination of closed and open-ended questions. Following-up the questionnaires secured a response rate of 20 out of 28 (71 %).

The questionnaire was the most appropriate means of obtaining the data from a sample of secondary school mathematics teachers in St. Vincent and the Grenadines. It was more cost effective and easier to access respondents than interviews since the teachers were spread across the country. Additionally, a hand-delivered questionnaire for self-administration made it possible to include more schools as well as teachers from diverse locations. Furthermore, since the time in which to access the sample was limited, as the researcher was involved with the main research project at one school, the use of a questionnaire was seen as more appropriate.

4. Journal Entries

Research results on the use of journals in educational situations appear to be mixed, with anecdotal evidence offering the strongest support for writing about our actions/ inactions and reasons for such decisions. According to Holly (1987) and Holly and Mcloughlin (1988), the use of journals as a professional tool provides opportunities for teachers/researchers to reflect upon their instructional and assessment practices and change or modify them as necessary. Journals may also be used to record notes during observations. Two advantages are (i) writing about the activity, and returning to it later allows the teacher/researcher to begin to differentiate situations where actions are consistent with aims (Holly, 1997), and (ii) journals may be used to help foster thinking about learning and learning-how-to-learn (Bell, 1993). Documenting the research process makes more visible the progress (Holly, 1987).

On the occasions when the teachers in this study wrote in their journals, they recorded their feelings, experiences and thoughts about (i) their practices, (ii) student learning, (iii) the nature of assessment, teaching and learning, and (iv) trialing of the alternative assessments. The primary purpose of using this tool as a data collection technique was that it provided the teachers with an opportunity to take more control of the research process. By shifting the responsibility onto the teachers, they had an opportunity (whenever they took time out to make entries) to step back from their actions, take snapshots of their practices and beliefs, and to view them in a different light, or *to change their perceptual fields* (Holly, 1987, p. 18).

5. *Observation*

Qualitative classroom observation attempts to identify patterns of behaviour inside the classroom and to look for interactions and relationships as they occur (Banister et al, 1995). Proponents of qualitative assessment such as Cohen and Manion (1994) claimed that observation as an research strategy has distinct advantages that cannot be gained through the use of other approaches. They argued that, because cognitive growth is qualitative, observation is a desirable method for assessing cognitive growth since it allows the teacher to investigate not only the products but qualitative aspects of students' mental growth. Specifically, it helps the teacher/researcher to gain insights into students' approaches to the task as well as their persistence in completing the task and non-verbal behaviours.

Some possible concerns in using this assessment approach include that (i) certain attitudes, experiences and knowledge that the teacher-observer brings to the learning/teaching situation will influence the selection of behaviours or performances to be observed, and (ii) there is representativeness of observations—that is, who or what behaviours will be observed (Cohen & Manion, 1994; Boehm & Weinberg, 1987; Frankfort-Nachmias & Nachmias, 1996; Nicholson & Anderson, 1993).

Clarke et al (1990) and Sutton (1995) suggested that these concerns may be overcome by (i) using a checklist, specifically, an annotated class list, and (ii) focus only on recording significant events such as atypical behaviour or a clear illustration of new understandings or lack of understanding. The consensus of most researchers is that the ability to observe is developed systematically and progressively with the behaviour viewed and recorded immediately. The information is then analysed or processed to make instructional decisions based on the needs of students (Arasian, 1996; Biddulph, 1993; Hopkins, 1993).

Observation was used in this research to look at and note the patterns of teacher-student interactions, student-student interactions, and other patterns of teacher and student behaviour that occurred during the instruction process. It was also used to identify indicators of learning and assessment in the classroom as I examined students and teachers at work. Other observations were made during the participants' weekly discussion sessions. In addition, I observed how each assessment approach was being used by the teachers, and students' reactions to the use of the assessment approaches. To minimise observer bias and subjective interpretations of data, the observations and interpretations were verified through informal interviews with teachers and students; this also assisted in data triangulation.

6. Document Analysis of Third Form Core Mathematics Curriculum

While researchers have stressed the importance of using primary sources of data where possible, the value of secondary sources should not be minimised (Cohen & Manion, 1994). The documentary analysis of educational materials can prove to be extremely useful in that it (i) allows the researcher to place their work in context, (ii) is unobtrusive as it removes the researcher from those being researched, and (iii) provides data for the research (Bell, 1995; Frankfort-Nachmias & Nachmias, 1996). However, gaining access to some documents may be costly, time consuming , or at times impossible.

The Curriculum Guide in Mathematics for Third Forms (Ministry of Education, 1992) was designed to convey the philosophy of mathematics teaching and learning underlying the curriculum. The activities portray mathematics as a process involving communication, reasoning, comprehension, computation, and other modes of representation. The activities are intended to develop desired mathematical knowledge, attitudes and skills. They are also intended to reflect good models of mathematics teaching which teachers can emulate. The sections on Numbers and Number Theory, described in detail in Appendix D, were used as the basis for investigating alternative assessment approaches in this research.

Research Quality

Being able to show that one's research is valid and reliable is important in establishing scholarly acceptance (Morgan, 1981). However, these terms are associated more with positivistic research than qualitative research. According to Merriam (1988), researchers gathering qualitative data should ensure that their work is believable and trustworthy. Further, the credibility of qualitative research, as discussed by Lythcott and Duschl (1990), is determined by the coherence of the relationships between (correctly applied) methods, interpretation of data, and the sources and soundness of the arguments.

Replication in qualitative research is problematic when the aim of the research is to describe and explain rather than isolate laws of human behaviour (Guba & Lincoln, 1985). However, the absence of replication does not mean that the findings are inaccurate. Rather, the descriptions of the new conceptions and categories constructed during the research would make it possible for them to be recognised by other researchers. Therefore, the researcher's assumptions and role in the research (see Section 1.6), descriptive detail of the theoretical framework of this present research (see Section 2.3), and the research process (in Section 5.3) are given so that readers can understand how and why decisions were made in arriving at the findings presented in Chapters Six to Ten.

In educational research, triangulation is a concept applied as a means of countering the selective bias of a single view (Banister et al, 1995). That is, it allows illumination from multiple viewpoints *reflecting a commitment to thoroughness, flexibility and differences of experiences* (Banister et al, 1995, p. 145). Thus, the question of attaining greater credibility and trustworthiness was addressed through a triangulation of (i) data collection methods (interview, observation, note taking, journal entries and discussions, as described in the preceding section), (ii) investigations, and (iii) data. Time and settings were other factors involved in the triangulation. The use of multiple methods and hence different vantage points provided opportunities for both *cross checking* and mapping out, or explaining more fully, the richness and complexity of the different behaviours (Cohen & Manion, 1994, p. 223).

Additionally, data were obtained by collecting accounts from different participants in New Zealand during the initial informal interviews. Insights gathered from these along with an examination of the related literature were used to compile the Teacher Assessment Guide and to plan for the intervention. During the intervention participants were allowed to refute or affirm the emerging propositions or to check whether any issues were de-emphasised. Discussions and interviews helped to clarify any (mis)conceptions. By allowing participants to examine and comment on the transcribed data, it was felt that researcher bias might be minimised. This can also be seen as an aspect of triangulation emerging from collaboration. The teachers involved in the research became investigators into their own practices, and challenged what was happening in each classroom, and frequently offered suggestions and constructive criticisms. Thus, the voices of the participants have been employed to tell the story. Many of their comments are used to support and build discussion—a vital aspect of trustworthiness.

5.4 RESEARCH DESIGN AND DESCRIPTION

The research process occurred in four phases, namely, a (i) development phase (ii) major data collection phase, (iii) follow-up data gathering phase, and (iv) the writing up phase. Table 5.3 provides an outline of the research activities conducted during each of the phases and the timing of the activities of the study. The data collected in one phase were used to inform the next phase and/or a previous phase.

Table 5.3. Outline of Research Activity Conducted in Each Phase

Phase	Activity	Time-line
PHASE 1	Development Phase • Informed pilot study, New Zealand • Development of teacher's guide • Negotiating access for Phase 2 • Development of teacher questionnaire	TERMS 1 & 2 1995 – 1996 (Sept – Apr)
PHASE 2	Main Study and Data Collection Phase • Administering of teacher questionnaire • Teacher introductory workshop • Teachers trialing alternative assessment approaches	TERM 1 1996 (Sept – Dec)
PHASE 3	Follow-up Data Collection Phase Interviews with teachers and students after 6 months	June 1997
PHASE 4	Writing Up	TERMS 1 & 2 1995 to 1998

Each phase of the research process is now described.

PHASE 1: Development

This phase involved the development of the research design, instruments and site.

1. Informed Pilot Study in New Zealand

Prior to gaining access to conduct research in the selected school in St. Vincent, it was necessary for me to examine what was happening in the area of assessment of mathematical learning. This involved reviewing the research and gaining information from teachers who had been or were involved in trialing assessment alternatives. Five such secondary school mathematics teachers from New Zealand were questioned informally about the uses, merits and limitations of alternative assessment approaches in mathematics. Questions asked included:

- Why should we assess student mathematical learning?
- What do we want to assess?
- How should we assess students?
- What assessment approaches are evident in the assessment of secondary students in New Zealand?
- What seem to work or do not work? Why or why not?
- Are there any other suggestions?

2. Development of Teachers' Guide

Data from these teachers were analysed, and together with the review of the research literature, informed the construction of the Teachers' Guide—*Assessment Approaches to enhance learning : A teachers' guide*. This guide described eight different assessment approaches, namely, concept map, interview, journal, observation, portfolio, investigation, project and students' self-assessment (see Appendix B). A draft of the guide was given to each of the five New Zealand teachers for their comments and suggestions, modifications were then made, and the completed booklet was edited.

The Teachers' Assessment Guide booklet (Appendix B) was a resource tool for the classroom teachers. Several different assessment approaches that are intended to enhance student mathematical learning are described therein. The aim of the booklet is to provide teachers with a guide to the use of several different assessment approaches. Of primary concern was the effective role these approaches can play in enhancing the quality of learning in mathematics.

There were three sections. Each section was designed to involve participants in the discussion section thereby providing data to inform the research. The data collected in Section 1 related to ideas of formative and summative assessment, and reasons for assessing student learning. Section 2 provided data on the common characteristics of some alternative assessment approaches. In the final section, teachers' discussions centred on (i) describing eight assessment approaches, (ii) looking at their advantages and disadvantages, and (iii) suggesting exemplars and ways in which these approaches may be used in the classroom. Several focus questions were given at the end of each section and of each assessment approach to encourage teachers' participation through critical reflection and discussion. This Teachers' Guide was used during Phase 2.

3. Negotiating and Gaining Access

While in St. Vincent during December in the first term of the 1995/96 academic year, I visited a school which I was familiar with and met informally with mathematics department staff. This visit was to establish the feasibility of the research in St. Vincent by informing the teachers of what I was doing in New Zealand and about my proposed area of study. The decision to chose only one secondary school was made on the basis of accessibility and the need for voluntary participation. The latter has been found to be a significant factor in the success of interventions (Fullan, 1993; Jennings, 1994; Nolder, 1992). Additionally, data were collected for this period through faxes, letters, interviews, and telephone discussions.

Before the commencement of the professional development workshop, I attended a national Professional Teachers' Workshop at the school in August 1996. This was useful in that student learning and assessment were discussed and this provided a lead into my study. The workshop gave me the opportunity to discuss with the general staff the nature of my research and possible ways in which the findings may be beneficial for future developments in all subject areas. The outcomes of this meeting were (i) gaining the support of other departments, and (ii) stimulating other teachers' interests in trialing alternative assessment approaches.

I met with the personnel from the Ministry of Education in charge of secondary school mathematics and had an informal discussion about my research and found out what they were doing in the area of assessment in mathematics. Surprisingly, I was told that a survey was being prepared to investigate the nature and state of assessment in secondary schools. Two of the highlights from my discussion with the teachers and Ministry personnel were the suggestion for more formative assessment to be done in classrooms, and the need to encourage student participation in the assessment process.

4. Development of Teacher Questionnaire

Preliminary discussions with the teachers at the selected school and the Ministry personnel suggested that a wider sample of secondary school mathematics teachers' views about assessment should be investigated. Consequently a questionnaire was constructed to probe teachers' current ideas in this area (see Appendix E). This questionnaire was designed to (i) find out teachers' views of the assessment of mathematics in secondary schools, (ii) collect background data of respondents and information relating to reasons for assessing, and (iii) whether or not there was a need for changes in present assessment practices. The background data included gender, number of years teaching experience and the school. The questionnaire was structured to include both open-ended and closed questions. It contained six questions relating to assessment practices and the need to reconsider assessment in mathematics.

A draft of the questionnaire was validated by a panel comprising of two Teachers' College mathematics lecturers and an education officer. Members of the panel were chosen because they were all considered to be competent in the area of mathematics education. Their comments and suggestions were used to modify the questionnaire.

PHASE 2: Main Study and Data Collection

The main data collection began at the start of the 1996/97 academic year, from September 1996 to the first week in December of the same year, and lasted for one term.

1. Teacher Questionnaire

The subjects for this aspect of the study consisted of twenty (n=20) secondary school mathematics teachers in St. Vincent, three female and 17 male. This sample was distributed among 15 schools throughout St. Vincent, with a maximum of two teachers in any one particular school. The questionnaires were distributed to and later collected from the sample of secondary schools by hand. Principals were informed about the nature of the research. An explanatory letter was included with each questionnaire.

2. *The Professional Development Workshop*

Five teachers from the mathematics department participated in this session. Three of the five taught third form classes. The three goals of this workshop were to:

(i) establish common ground among the participants by pooling the information, ideas and experiences that the teachers already had about assessment;

(ii) introduce new information on alternative assessments; and

(iii) involve participants in simulation assessment activities involving some of the approaches.

To achieve the first goal and help build a shared perspective, the teachers, were helped to identify their own views of learning and assessment. This strategy was suggested by Ernest (1989) who believed that real change can only be achieved when the players are up-front about the perspectives they hold. Moreover, he believed that participants should be willing to seek ways of merging these perspectives in the generation of new ways of thinking that would lead them to a more desirable future practice.

Having listened to and discussed the teachers' differing views, we then analysed a videotape on assessment, and examined the alternative assessments presented in the teachers' guide with a view to determining the practicality of using these approaches in our classroom culture. During these discussions, I acted as a source of information and facilitator linking theory and practice. That is, I offered suggestions and advice and acted as a critical friend by linking my classroom knowledge with theory to stimulate discussions and get individuals to reflect on their practices.

The video, *Mathematics Assessment: Alternative approaches* (National Council of teachers of Mathematics, 1994), is divided into six segments that each required from 8 to 15 minutes of viewing time. Dramatised characters serve as 'the voice of the audience' expressing their enthusiasms, concerns, reservations, and questions about alternative assessment practices. The drama revealed challenges that confronted the teachers as they trialed these alternatives. The teachers were provided with situations from which they could learn how to gradually manage change. Suggestions and discussions were given by the panellists, a group of teachers. At the end of each viewing segment the teacher research participants, were required to make journal entries and discuss several questions.

The outcomes of that day's proceedings served as stimuli to (i) find out the secondary mathematics teachers' views about the present status of assessing student mathematical learning (ii) generate teachers' interest and commitment to consider change, and (iii) plan ways in which changes could be implemented and monitored effectively in the classroom. Table 5.4 outlines the activities carried out during the professional development workshop. Each session lasted for about one hour.

Table 5.4. An Outline of the Professional Development Workshop

Day	Activity		
Monday	Expressing and eliciting prior understanding: beliefs and knowledge of mathematics and learning	Matching those views with traditional assessment practices	Viewing and commenting on aspects of the videotape
Tuesday	Discussing the intervention	Sharing views, fears and other possible constraints that may affect implementing the intervention	Developing a course of action for achieving goals Committing oneself to the research project
Wednesday	Selecting alternatives	Discussing teachers' reasons for selection(s)	Reflecting on experiences of using different assessments
Thursday	Trialing of several alternative assessment approaches	Discussing several simulations	
Friday	General discussion of concerns and need for staff support		

One aspect of the first day's proceeding was getting teachers to reflect on their practice. As the teachers reflected on what learning and assessment are, and what happens in the classroom, they realised that their assessment practices were based on their beliefs of mathematical learning. Consequently, if a behaviourist view of learning prevailed (as was the case with these teachers), then it was reflected in their assessment practices. However, the teachers' recent encounters with knowledge about current theories of learning such as constructivism had caused them to attempt to make changes in their instructional practices.

Although these teachers relied on traditional testing they were trying to incorporate other informal methods. However, no credit or recognition was given for the part such information could play in formative assessment. After examining their beliefs, establishing common beliefs and discussing future actions to be taken, the teachers readily participated in the intervention. Thus, the professional development sessions not only provided instances for views to be challenged but they also allowed us as a group to reflect on past actions, the need for change and to frame our teaching, learning and assessment practices to make student learning more meaningful

Professional Development Outcomes. Having accepted that our assessment practices were insufficient, we then met to discuss the need for changes. We felt that collaboration, reflection and support were vital factors that were needed for the intervention to be successful. Of importance was the need to establish convenient times for discussing progress, and for sharing and discussing findings and/or problems encountered. It was therefore agreed to meet as a group every Friday at 1:30 p.m. since the school day ended at 1:30 p.m. on Fridays, instead of 3:00 p.m. We also agreed that teachers would be interviewed individually as necessary, that is, once or twice weekly. The ongoing meetings served to establish a sense of identity and trust to encourage reflections on practice, to help clarify and evaluate ideas, and to promote the construction and acceptance of new ideas and views.

The next step was to jointly develop a course of action for achieving the desired goals. This action-plan involved reflection, giving and getting comments, discussion, sharing experiences, and on-going and on-site mutual support. Teachers were expected to re-examine or personally reflect on the implementation of the assessment approaches and attempt to make sense of them in terms of prior experiences and future directions. Although the importance of keeping a journal was stressed and it was expected that teachers would record their reflections in their journals, this was not adhered to. Only a few entries were made in their journals. The teachers commented that it was easier and less time consuming reflecting on their practices during our meetings.

An overall view of the professional development workshop may be illustrated in a matrix as outlined by Bolam (1987). This matrix illustrates the essential features of

Joyce and Showers (1980) theory of skills training. They outlined five principal training components for development programmes and distinguished between four potential levels of impact that development can have (Joyce & Showers, 1980). These components and levels of impact are illustrated in Table 5.5 where the ticks indicate the components that are required to achieve a particular level of impact.

Table 5.5. Training Components and Levels of Impact

Level of impact / Training component	General awareness of new skills	Organised knowledge of underlying concepts	Learning of new skills	Application on-the-job
Presentation/ description of new skills	✓	✓	✓	✓
Modelling the new skills		✓	✓	✓
Practice in simulated settings			✓	✓
Feedback on performance in simulated or real settings			✓	✓
Coaching/ assistance on the job				✓

(Source: Bolam, 1987, p. 42)

The use of these components are considered to be helpful in (i) promoting and strengthening the effectiveness of professional development programmes, and (ii) overcoming difficulties caused by anxiety and uncertainty over the changes required in their practice. Breakthroughs are possible when people understand the underlying concepts and rationale with respect to change (Fullan, 1985).

The outcomes from the professional development workshop have much in common with the matrix proposed by Joyce and Showers (1980) so the matrix was used to classify the outcomes of the activities that occurred during the workshop. As shown in Table 5.6, only the first four components are present.

These components overlap and are interdependent. Some of the teachers' thinking and attitude are highlighted in Table 5.6. The fifth component, coaching or assistance on-the-job was followed up during the classroom implementation of the alternative assessment approaches. The participants felt that the process of implementing the use of alternative assessments in mathematics, giving students more responsibility in the learning and assessment processes, and supporting their students were sufficiently important for the teachers to attend every workshop session and meeting.

Table 5.6. Learning New Assessment Skills

Component	Activity
Presentation/ description of new skills	viewing the alternative assessment approaches video (Day 1) discussion of eight different alternative assessment approaches contained in the Teachers' Assessment Guide (Day 3) select suitable alternatives that could be used for assessing student understanding of numbers and number theory discuss reasons for choice of selection
Modelling the new skills	trialing selected approaches in pairs (Day 4)
Practice in simulated settings	each participant reversed the role, acting as teacher and student
Feedback on performance in simulated or real settings	dispelling such feelings of anxiety and uncertainty and we became immersed in our different roles. (Day 4 & 5) Exclamations that are reflective of our feelings during this time were 'Is this what we really do to our students?', 'Gosh, I am not so sure that I would love to have you as my teacher' or 'This is great, I like being a student again' Viewing of the assessment alternatives video served to strengthen our skills and helped to allay some of the doubts and fears as we developed our plan

3. Classroom Trials of Alternative Assessment Approaches

The Sample. The main study involved three third form classes and their mathematics teachers (including myself as one teacher) from the school. The sample was selected on the basis of availability and the teachers' willingness to participate in the research. The average age of these third form students was 13.8 years. Students are grouped for instruction according to ability. The sample comprised one 'above average', one 'average' and one 'below average' third form class. The students had no previous classroom journal or self-assessment experience. Table 5.7 gives a description of the sample and the assessment approach used by the teacher.

Of the three teachers in the intervention two were females. The teaching experience of the three teachers was eight, twenty-one and thirty years respectively. The teachers voluntarily committed themselves to the implementation of this intervention.

Table 5.7. The Sample of Students and the Assessment Approach

Class	Teacher	Assessment Approach
Xn= 28	R*	Journal, Interview & Observation
Yn = 26	B	Journal, Interview & Observation
Zn = 28	J	Self-assessment, & Observation

*** R is also Researcher**

The dominant assessment approach used by these teachers prior to the intervention was testing, which was patterned on the Caribbean Examination Council Examinations (i.e. Paper A: Long and Short questions, Paper B: Multiple Choice). Other forms of assessment used were observation, questioning and quiz. Both observation and questioning were done informally for formative purposes, while the quiz tended to be formally structured, the scores being used for summative purposes.

The Intervention. The intervention began in the second week of the school term. Each teacher was responsible for informing the students about the different assessment approaches that were to be used, and for discussing with the students their roles in the instruction and assessment processes. To enable me to observe each third form, a roster was organised by the department with the principal's approval. This roster allowed me access to the other two forms for observational purposes. It also was the best solution given the constraints under which we worked. That is, having such a plan (i) gave the teachers sufficient time to cover a unit of work, (ii) allowed me to observe those teachers and their students, and (iii) prevented any of the forms included in the intervention from missing instructional sessions. An element of partnership developed wherein the researcher and the researched benefited from the process.

Further, based on the outcomes of the professional development workshop each teacher decided to trial at least one alternative assessment approach to assess student understanding of one area of the curriculum, namely Numbers and Number Theory. This curriculum area was decided by the timing of the classroom intervention. That is, these topics represent the first units in the curriculum that all third formers in St. Vincent and the Grenadines are expected to complete by the end of Term 1 (see Appendix D).

The assessment tasks designed by the teacher or modified from textbooks addressed the following:

- Integers and Rational Numbers
- Computation of Fractions, Decimals, and Percentages
- Approximation, Estimation, Calculator skills
- Decimal places, Significant figures and Scientific Notation
- Indices and Reciprocals
- Number Bases
- Ratio and Proportion
- Squares and Square Roots

Mathematics is conducted in five 40 minutes sessions and one 30 minutes session per week, this includes a double 40 minutes period used for both teaching and testing purposes. The intervention was planned within this schedule and designed to meet the syllabus requirements. However, the assessment focus of the intervention differed significantly from the traditional reliance on tests only. Two teachers, R and B, assessed student understanding by using both interviews and journals while the third, Teacher J, used student self-assessment. Reasons for their selection of a particular assessment approach are given in Chapters 7 to 10. The use of alternate assessments occurred concurrently with testing. However, in this research, the focus on testing was minimised.

The classroom process was entirely in the hands of the teachers and regular discussions served to build support and camaraderie. Notes of classroom proceedings and my observations were used during informal interviews mainly on a one-to-one basis with the teachers. The three of us were able to discuss anything that we spoke about during the one-to-one sessions. All interviews were audio-taped, transcribed and reviewed by the teachers. Few sections of the transcripts were altered as a result of requests by the teachers.

PHASE 3: Follow Up Data Collection

The third phase involved following up the effect of the intervention, since I was no longer on the site after the intervention had occurred. I therefore used these occasions to find whether there was any continuity in the programme. Teachers B and J were questioned (by mail) six months after the completion of the intervention—about what problems they were having, what were they doing to ensure continuity of what they had learned, and whether student learning had improved as a result of the project. It was also a time to find out from the students what they were doing, that is, whether they were building on the skills acquired during the project and how they perceived the differences now. Students were questioned after the first six months. This gave them a chance to reflect on their learning in the first term and then compare term one with the second and third terms. It was not possible to question students further since they would not only have been promoted to another year level but would also have been regrouped for instruction according to career choices (e.g., arts, science, business). Additionally, after one year of the intervention, only one teacher remained at the school. Feedback from the students and teachers B and J served as a check for conclusions reached in this study.

In this research, I performed the role of teacher/researcher. A description of the data analysis is given next .

5.5 DATA ANALYSIS

The data from the case studies were analysed by looking for emerging themes or patterns. Banister et al (1995) perceived looking for emerging patterns or themes as a coherent way of organising interview data in relation to the research questions. Therefore, the analysis of journal entries was done by reading the material and categorising the information in a manner that allowed for (i) patterns to emerge and (ii) the frequency of common patterns or themes to be counted to provide some indication of the extent to which a view was held. Notes were also made of observations of students' work. These observations were then analysed and linked to the emerging patterns. Figure 5a briefly summarises the data analysis procedure. An overview of the categories used for data reduction and analysis is given in Appendix F.

The reduction of the data may be viewed as a continuous process. It occurred throughout the duration of the research and included selecting, focussing, abstracting, simplifying and paraphrasing. On the basis of ongoing analyses of the data (for example, looking for patterns or themes, regularities or explanations), several conclusions were drawn. Where possible, figures and tables were used to summarise the data analysis.

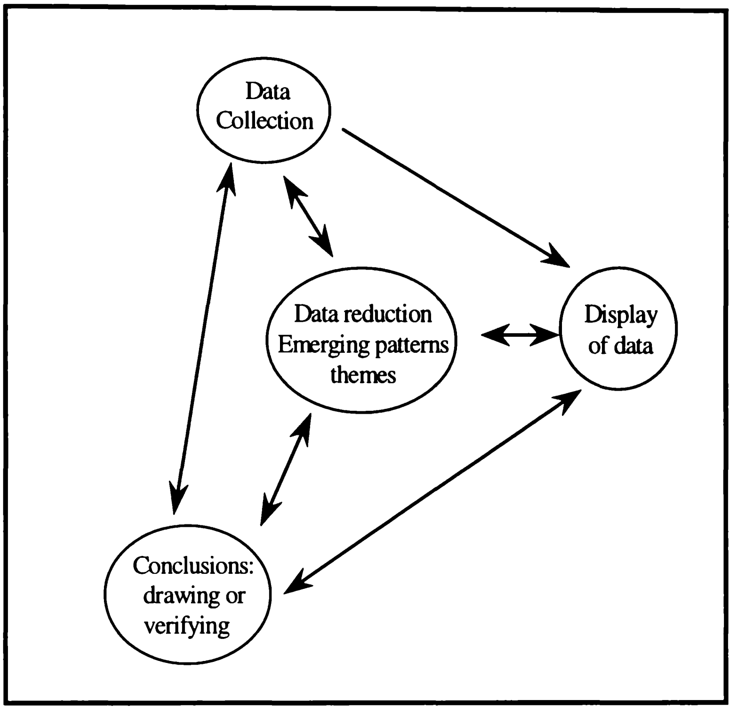


Figure 5a. Flow Model of Data Analysis Components

5.6 ETHICAL CONCERNS

Teaching is a profession that has both a knowledge base and a moral base (Airasian, 1996; Scriven, 1988). Like other professionals whose actions and judgements affect the clients in many ways, classroom researchers are responsible for conducting themselves in an ethical manner. Within research, ethical behaviour on the part of the researcher refers to what is the correct behaviour given the wishes of those being researched, the researcher and the cultural context of the research.

Since this was collaborative research, it was of utmost importance that an atmosphere of shared norms, trust and collegiality existed. Therefore, it was the researcher's responsibility to safeguard the privacy of the information collected from all participants and to use that information in a way that protected each person involved in the research process. Another ethical concern was that no harm was done to those involved in the research process because of their involvement. That is, the research process must be non-exploitative. To meet these ethical considerations:

(i) All participants were informed about the purpose, methods and possible uses of the data gathered in the research.

(ii) Participants voluntarily consented to partake in the research.

(iii) Confidentiality and anonymity were guaranteed.

(iv) Participants were kept informed of the research process.

5.7 SUMMARY

The use of a case study methodology within the qualitative paradigm was perceived as the best approach for this research since the emphasis was on descriptive accounts of the situation. The theoretical component of this research design was embedded and interwoven in the actions of the researcher and participants. The teachers' assessment questionnaire and the four assessment approaches trialed in this study provided valuable data. Chapters Six to Ten report and discuss the results of the data analyses.

CHAPTER 6

SECONDARY SCHOOL MATHEMATICS TEACHERS' VIEWS OF ASSESSMENT

6.1 INTRODUCTION

As discussed in earlier chapters, in this study I assumed a social-constructivist theory of learning that posits that teachers, like students, construct their own understandings and beliefs (in this case about assessment) in mathematics within the culture of their school and classroom (Fairbrother, Dillon & Gill, 1995). Further, teachers prior knowledge and experience influence their understanding about assessment in mathematics. Thus, an aspect of this study was to identify what views of assessment are held by a sample of secondary mathematics teachers. It was expected that their views would impact on students' learning and the likely acceptance of alternative assessment approaches for formative purposes in the mathematics classroom.

This chapter aims to throw some ray of light on secondary teachers' views of assessment in St. Vincent by addressing the following research question—*What are typical secondary school teachers' views of the assessment of mathematics*? As indicated in Chapter Five, a questionnaire on teachers' views of assessment in mathematics (see Appendix D) was designed to gather:

(i) background information,

(ii) information relating to reasons for assessing,

(iii) usage of different assessment approaches, and

(iv) ideas about whether they considered there was a need to reconsider assessment in mathematics.

The subjects for this aspect of the study consisted of twenty (n=20) secondary school mathematics teachers in St. Vincent, three female and seventeen male. This sample was distributed among 15 schools throughout St. Vincent, with a maximum of two teachers in any one particular school. Nine teachers were from rural schools. The questionnaires were distributed and collected from the sample of secondary schools by hand. Principals were informed about the nature of the research. An explanatory letter was included with each questionnaire.

The subjects teaching experience ranged from one term to more than fifteen years with a mean of 10.3 years. Participants' responses are coded for reporting purposes, F/T1 and M/T3 representing female and male teachers respectively. Teachers' responses to the questionnaire are categorised and discussed in succeeding sections of this chapter:

6.2 Teachers' Acceptance of Current Assessment Methods

6.3 Reasons for Assessing Student Mathematical Understanding

6.4 Reconsideration of Assessment Practices

6.5 Frequency of the use of Various Assessment Approaches

6.6 Words Associated with Assessment

6.7 The Need to Improve the Present System of Assessment

6.8 Summary and Discussion of Findings.

6.2 TEACHERS' ACCEPTANCE OF CURRENT ASSESSMENT METHODS

An examination of the teachers' responses revealed that thirteen were reasonably satisfied or quite satisfied about the current assessment methods used, one teacher was non-committal, while six were unhappy with them. These six felt that present methods were (i) too narrow and did not provide opportunities to encourage or develop students' critical thinking skills, (ii) did not tap into students' mathematical thinking, and (iii) restricted teaching accordingly. They wanted to see a greater range of assessment methods used. The comments of one teacher illustrates some of these concerns:

> the traditional methods of teaching and assessing the subject seem not to be as effective as they were before. We cannot truly assess students' performance until these obstacles of learning [e.g., reliance on testing] be removed ... Students should be challenged and shown the inter-relatedness

> of mathematics. Assessment techniques should not only include written tests but observations, discussions, SBA [school-based assessment] and interviews. (M/T14/9.96)

The majority of teachers who were satisfied with current assessment practices appeared to base their satisfaction on a belief that written test and examination results provide a true indication of student achievement and understanding. For instance, one teacher wrote:

> they [present methods] normally give a relatively accurate measurement of students' performance and of the effectiveness of the teachers' strategies. (F/T2/9.96)

One of the thirteen satisfied teachers wanted even more of the same. He said:

> I would like to see final term exams in all terms. Students need as much reinforcement and repetition in a subject such as mathematics where a solid foundation is absolutely necessary. (M/T16/9.96)

Three of the thirteen satisfied teachers seemed to contradict themselves. One, for example, while claiming to be happy with present methods, nevertheless wished to see a change in the balance of regional and school assessment. This teacher responded:

> Yes, a series of in-course tests is done each term. Thirty percent of this goes to the final mark at the end of the year. I hope CXC [Caribbean Examination Council] will introduce SBA [school-based assessments] in mathematics for the examination. (M/T18/9.96)

Fourteen teachers felt that present assessment practices promoted students' heavy reliance on teachers and peers' ideas and solutions rather than trying to do the work for themselves. This finding supports that of other researchers who contended that over- reliance on testing as the dominant assessment approach encourages cognitive passivity; where students expect everything to be furnished (Blais, 1988).

6.3 REASONS FOR ASSESSING STUDENT MATHEMATICAL UNDERSTANDING

Secondary mathematics teachers were asked to list at least three reasons for assessing student mathematical learning. Content analysis of the sixty responses to Question 2 revealed the categorisation as shown in Table 6.1 (overleaf).

Table 6.1. Teachers' Reasons for Assessing

Category	**No of responses**
Diagnosis of what a student knows or monitoring students' progress	18
Obtaining feedback for planning and informing instruction	11
Providing feedback for students; self-assessment	7
Obtaining feedback for monitoring or testing effectiveness of teaching	7
Measuring students' attainment	5
Grading	3
Providing opportunities for creative and critical thinking	3
Motivating students	3
Diagnosis of students' difficulties	2
Reporting	1

Table 6.1 reveals that the teachers in St. Vincent perceived the main reasons for assessing students' mathematical learning as diagnosing what they know or monitoring their progress, providing them with feedback, and obtaining feedback to illuminate their teaching and inform their instruction practices. As one teacher responded, "with proper assessments the teacher can measure the efficiency of his teaching and the effectiveness of learning" (M/T8/9.96). Although issues of selection and qualification – aspects of summative assessment – have dominated testing in St. Vincent, these teachers did not suggest these as reasons for assessing. The issues of grading, motivating students and providing opportunities for creative and critical thinking were perceived by three teachers in each case as reasons for assessing. While the tradition of grading will remain with us in St. Vincent, many secondary school mathematics teachers appear to be looking beyond this emphasis, to identify students' actual understanding.

6.4 RECONSIDERATION OF ASSESSMENT PRACTICES

The third concern addressed was the need to reconsider assessment practices. Although thirteen of the twenty teachers questioned suggested they were satisfied with the present assessment methods, all twenty respondents felt that assessment should be reconsidered. They felt that the present focus on right and wrong answers was too restricting and did not take account of students' procedures, logical thinking and reasoning. Further, it did not allow consideration of the usefulness of mathematics or allow it to arise out of practical or real life situations. One teacher claimed that mathematics

> seems to be a 'cut-and-dry' matter, where pupils follow rules and formulae or some sleight-of-hand method without understanding why. Additionally, routined time assessment measures how quickly students can respond but not necessarily how well they can think and apply their knowledge ... assessment should not be limited to paper-and-pencil tests. (M/T6/9.96)

Some teachers felt that the present system should be broadened to include assessment approaches that provide opportunities for:

- the inclusion of logical and higher order thinking, and the development of creativity (n = 15);
- continuous assessment throughout a child's school career rather than performance on a single external examination (n = 11);
- practical work as well as observations on the various approaches students use to arrive at their solutions (n = 10); and
- encouraging discussion between teacher and pupils and between pupils themselves (n = 9).

The teachers' responses reinforced the perceived need for exploring the use of alternative assessment approaches.

6.5 FREQUENCY OF USE OF VARIOUS ASSESSMENT APPROACHES

The teachers were given a list of assessment approaches and asked to indicate the frequency in using each assessment approach. Their responses, as summarised in Table 6.2 (overleaf), revealed the use of various assessment methods.

Analysis of the data presented in Table 6.2 shows the dominance of written tests as the primary means of assessment; all teachers used it. Clarke, Clarke and Lovitt (1990) argued that this dependence on a single form of assessment has not only shaped teachers attitudes but also their teaching practices. The data in Table 6.2 shows that a variety of assessment approaches were reportedly used by the teachers. While all teachers used tests, sixteen also used quizzes, fourteen used oral presentations and observations, and over half use students' self-assessment. These other approaches represent ways in which teachers can examine the depth of ideas that students hold about certain concepts and thereby gain a clearer picture of students' understanding. This finding may explain why many teachers felt that the traditional written form of assessment needed to be reconsidered.

Table 6.2. Frequency in Using Assessment Approaches

Assessment Approach	Daily	Weekly	Monthly	Not Applicable
* Written tests	1	9	10	–
* Quizzes	3	7	6	4
* Observation	14	–	–	6
* Oral presentation	8	4	2	6
* Student self-assessment	5	2	4	9
* Interviews/Conferencing	8	2	–	10
Peer assessment	3	2	4	11
Investigations	2	4	2	12
Projects	–	–	5	15
Journals	–	1	1	18
Debates	–	1	–	19
Portfolios	–	1	–	19

* Possible approaches more readily used

Although observation of students is usually carried out daily by teachers, it was surprising to note that six of the twenty teachers indicated that this approach was not applicable for assessment purposes. Further, the results showed that these teachers did not see debates, portfolios or journals as potential assessment techniques. One assessment approach not included in Table 6.2 but mentioned several times by some of these teachers as a significant alternative is that of continuous assessment in the form of School Based Assessment (SBA). SBAs could be considered as investigations and/or projects. However, twelve and fifteen of the twenty respondents respectively did not consider investigations and projects as applicable to the assessment of mathematics.

6.6 WORDS ASSOCIATED WITH ASSESSMENT

Teachers were asked to use descriptors to indicate their perceptions of assessment in mathematics. Their perceptions were classified under eight overlapping categories as shown in Table 6.3.

Table 6.3. Words Associated with Assessment

Words	No. of Respondents (n = 20)
Mode [practicals, school-based assessment, General Certificate Examination, Caribbean Examination Council examinations, local examinations, written tests, competition, brain teasers]	14
Criticism [inconsistent, repetitive, bias–sometimes one-sided, unreasonable, too long]	12
Skills Testing [calculation, timetables, speed, formulae, memorise]	7
Degree of Difficulty [easy, difficult, not within student ability to pass]	6
Scope of Examination [challenging, too comprehensive, syllabus restrictions]	5
Purposes [final grade, streamlining, passing]	4
Time [accuracy, limited time, too long]	4
Emotion [anxiety, fear, nervousness]	4

Analysis of their responses showed that some teachers used both the final external examinations and their school examinations as referents when describing their feelings about the assessment of mathematics. Others associated assessment with stream-lining students and preparing them for the job market. Seven teachers focussed upon assessment as skill-testing, that is, as determining students' ability to calculate, memorise tables and formulae, and to work accurately within a limited time.

Another important finding was the teachers' criticism of present assessment practices. Twelve of the twenty teachers feared that not only were tests unreasonable or in some cases too inconsistent but that they sometimes tended to be biased or one-sided. Additionally, four teachers felt that tests, especially external examinations were brain teasers and definitely outside many students' ability to pass. Five teachers were concerned that their assessment practices were restricted by syllabuses, while four indicated that the time allotted for some examinations was too long. Two teachers felt that students were beginning to view assessment of mathematical learning as a competition.

6.7 VIEWS ABOUT THE NEED TO IMPROVE THE PRESENT SYSTEM OF ASSESSMENT

Another major dimension of teachers' views of a subject is their response to change. The respondents views about whether there is a need to improve the current assessment system are summarised in Table 6.4.

Table 6.4. Teachers' Responses to Need for Changes

Responses	No. of respondents
Changes needed	11
Not eager to change but willing to adopt other approaches	2
No response	5
No change required	2

Although just six of the twenty teachers had previously indicated their dissatisfaction with the current assessment practices, eleven teachers thought changes were needed.

Table 6.4 reveals that two of the teachers surveyed indicated emphatically the need for things to remain constant while two other teachers were not eager to change their present practice but were willing to trial other approaches. This kind of response, according to Fullan (1993), is natural because many teachers fear changes, sometimes because interventions do not consider the subjective realities of teachers, that is, their views and perceptions. In the words of one respondent:

> when learning is released from the bondage of a system, which excludes us from being partners in decision-making activities, to one that includes our views and input, then and only then, will we more readily be open to changes. (M/T10/9.96)

Of the eleven teachers who indicated a desire for changes in the way assessment is presently being done in St. Vincent, five highlighted the need for broadening the range of assessment approaches to include School Based Assessments, practical work/individual projects, group work, oral presentation, interviews and quizzes. Three of the other teachers indicated a need for better internal assessment in terms of having a higher pass mark and "increasing the percentage of the in-course test marks to 50% of the final mark" (F/T9/9.96). That is, in some schools the final mark awarded to students is calculated on a 70 to 30 % ratio where 70% of a student's end of year final examination score is calculated and added to ten percent of each of the three term examination scores. This practice was introduced to make assessment fairer to students. The response of the three teachers is possibly an indication that teachers recognise the need to reduce reliance on a single test as a supposedly true assessment of students' learning that took place during the academic year.

Other indicators of the type of change needed are contained in the following three teachers' responses.

> Modernise mathematics to fit the computer era (M/T15/9.96)

> Assessment should be done in such a way that students can see their own progress (e.g., the use of graphs, tables, charts etc.). When students see their own progress they are challenged more. (F/T1/9.96)

> I would like to see a change in the type of class and home work assignments given. I am therefore encouraging other mathematics teachers to lessen the amount of written test type and encourage students to become better researchers. (M/T18/9.96)

In short, these teachers considered that assessment practices should widened to include student participation and as best to prepare them to meet the changes in their society.

Interestingly, of the five teachers who offered no response about the need for change, four wrote previously that assessment should be reconsidered. The responses of four other teachers indicated the need to align teaching, learning and assessment practices. For example, one teacher wrote:

> My approach to teaching takes me away from the traditional approach hence it allows for more meaningful and effective methods of assessment. (M/T7/9.96)

One teacher, in supporting the need for changes, argued that mathematics teaching, learning and assessment should be interesting and challenging. He also stated that poor performance in mathematics is linked to teaching and learning.

> We cannot blame students for poor performance ... the teaching/learning process lacks excitement because traditional approaches to teaching do not lend themselves to creativity. (M/T18/9.96)

The comments of most teachers suggest that they see a need to reconsider assessment purposes and practices in St. Vincent and the Grenadines. As one teacher noted, it is important that teachers recognise that "looking for right and wrong answers should not be the desired objective. We need to consider how students *arrive* at these answers" (M/T9/9.96).

6.8 SUMMARY AND DISCUSSION OF FINDINGS

This study revealed that most of the teachers perceived limitations in traditional assessment methods and thought that assessment practices in secondary schools in St. Vincent and the Grenadines needed to be reconsidered. This in turn suggests that teachers would be likely to consider and perhaps accept alternative assessment approaches in mathematics. Ernest (1989) noted, reforms in teaching only take place when deeply held beliefs about learning and teaching are confronted and changed. The majority of teachers seemed prepared to question current assessment practices.

One interesting finding that appears to contradict other research findings is that the twenty teachers did not suggest selection and qualification as reasons for assessing student learning. In fact, only one of the teachers surveyed suggested using assessment for reporting purposes. Of further significance are (i) the daily use of observation by 71% of the participants and (ii) the use of quizzes by 80 % of the participants.

On the basis of the findings presented here, when one thinks about secondary school mathematics teachers in St. Vincent and innovations in mathematics education the picture is far from being gloomy. However, as suggested by Fullan (1985), once teachers have examined their feelings and reflected upon their practices, many trials of new approaches will need to occur gradually to convince them to adopt these approaches. Additionally, teachers will require strong support systems to assist them in the transition (Nolder, 1991). The results of an attempt to help several teachers adopt alternative assessment approaches in their teaching are reported in the case studies presented in Chapters Seven to Ten.

CHAPTER 7

RESEARCH FINDINGS: SELF-ASSESSMENT

7.1 INTRODUCTION

This chapter reports in case study form the process and outcomes of the use of self-assessment. The findings are considered within the classroom context where assessment was conducted mainly for formative purposes.

Of the three teachers involved in implementing alternative forms of assessment, one decided to trial self-assessment. Teacher J had over thirty years experience using traditional teaching methods where the focus was on summative assessment. However, in recent times she became more concerned about the learning of students. She was the first teacher to commit herself to the trying an alternative assessment approach. Her choice of self-assessment arose from thinking how best to assess her third formers' mathematical understanding of Numbers and Number Theory.

The following considerations suggested to her that self-assessment would be the most appropriate means of assessing her students' learning, and that it might offer an improvement over traditional assessment:

- The class comprised twenty-eight students, grouped or stream according to ability for instruction. Basically, this group of students included all students who were below average performance.
- Students were content to just 'get by'; they had settled for the mediocre standards established by the opinions of others regarding their potential. (JI/F/11.9.96)

- Trying to deduce students' thinking when they are doing mathematics is not easy. Self-assessment seemed to have the potential of helping them become fully functioning human beings. (JI/F/11.9.96)
- Learning is more likely to be successful and enjoyable when students are self-directed ... when they are able to look more deeply into themselves, their performances, and be able to identify their strengths and weaknesses (JI/F/11.9.96; RJ/SA/12.9.96).

This chapter reports the findings from the analyses of the data collected from interviews, teacher's journal and students' work. The data is used in this chapter to provide answers for the following research questions:

- How did the teacher implement the chosen assessment strategy?
- How did the use of self-assessment influence the teachers' teaching?
- What effect did the use of self-assessment have on the students' learning of mathematics?

Hence, the remainder of the chapter is organised as follows:

7.2 Implementing the Assessment Approach

7.3 Self-assessment and the Teacher's Teaching

7.4 Self-assessment and Students' Learning

7.5 Summary and Discussion of Findings.

7.2 IMPLEMENTING THE ASSESSMENT APPROACH

Discussion in this section focuses on the initiation, development, and implementation concerns of self-assessment as an alternative assessment strategy.

Initiation Phase

To prepare students for the innovation, Teacher J set aside her double period of the second week in the first term where she used the correction of a pre-test on integers to introduce student self-assessment. Here she explained how the assessment would operate and that the purpose was to improve the learning of the students by them becoming partners in the learning process.

She described in detail to the students how they would be assessing their performance based on established criteria. Teacher J described the three categories under which students would be assessing themselves (and could expect to be assessed by the Caribbean Examination Council). The categories: computation, comprehension and reasoning may be viewed as processes/skills. Table 7.1 gives an overview of the teacher's description of each category.

Table 7.1. Teacher's Description of the Processes/Skills

Process/Skill	Meaning	Example
Computation	Calculate	Solve correctly word problems
Comprehension	Understanding	Explain the problem Describe or explain the process
Reasoning	Logical sequencing	Explain reasoning to peers and/or teacher
	Justification	Justify answers or procedures/processes
	Conclusions	Discuss accuracy of solutions and procedures
	Practical	Search for relationships among objects

It was also agreed, by students and teacher, that their weekly tests would be first graded by the teacher, then by the students themselves. Since Teacher J did not want students to be influenced by her marking while assessing their work, she recorded the marks in her mark book rather than on the students' test papers. The scripts were returned to the students who then assessed their performance and returned the scripts with their self-scores to the teacher. Students were asked to discuss with the teacher how they arrived at their scores and possible ways in which they could improve their performances. During discussions, Teacher J would record her marks alongside the student's mark and, if they differed markedly, another discussion would evolve as to possible reasons why the two marks differed by more or less than 10%. Students' self-assessed marks influenced their final mark; in most cases marks were modified in favour of students after teacher-student discussions. The approach taken by Teacher J may be linked to getting students to regard their work from the perspective of the teacher, a view suggested by Joyce and Showers (1988).

During the implementation, students were given guided questions to encourage them to (i) describe the mathematics they had learned, (ii) make linkages, (iii) monitor and reflect on their feelings, and (iv) comment on what they still needed to know. Both students and teacher discussed their expected roles. Much emphasis was placed on the need for students to participate in the assessment process, specifically to develop self-assessment skills whereby students would begin to "see themselves differently as they become more aware of their capabilities" (TJ/F/8.10.96). Further, Teacher J noted:

> Getting students to assess their work, then discussing their evaluations, will help all students because they have to talk about their work, explain why they gave themselves a particular score and how they rated their performance in the areas of reasoning, computation and comprehension. (JI/F/11.9.96)

The test used to introduce students to the assessment approach was one given during the first week of Term One. It required students to solve problems on integers. Two questions from this test are shown in Figure 7a.

(a) Calculate giving your answer in its simplest form $\dfrac{-8}{(1-4)\times(-2)}$ (4 marks)	(b) The altitude of a diver is $^{-}10$m while the altitude of a shark is $^{-}43$m. Find the difference in their altitudes. (3 marks)

Figure 7a. Two Teacher-made Test Items

At the beginning of the lesson, Teacher J explained the activity and enlisted several students in a 'trial run'. She emphasised self-grading, as well as ways in which student could score points by reflecting on what they were doing and by evaluating their performance on computation, comprehension and reasoning. For example, students were asked to describe how they would distribute the four marks for question (a) in **Figure 7a**. Some of the responses were:

> I'll give 1 mark for getting $1 - 4 = {}^{-}3$, then another for $-3 \times -2 = 6$ then another mark for correctly dividing $^{-}8$ by 6. That's 3 marks. I think it should be 3 marks. (Z5/SI/11.9.96)

> I'll do the same as Z5 but then to get 4 marks, I will give some half marks too. Like a half mark for having the correct sign in the answer and (pauses)

> well you did say we should have the right procedure (laughs) so give another half for knowing what to do. (Z14/SI/11.9.96)
>
> I think it [the question] worths only 3 marks. One for computation, 1 for comprehension and 1 for reasoning. You could lose a half mark for incorrect calculation. (Z5/SI/11.9.96)
>
> Well, Miss wouldn't put 4 marks if she didn't think it worth four marks. So we got to think how to give the four marks ... I'll say we use Z5's marking but give 1 mark for recognising and applying the correct strategy. (Z18/SI/11.9.96)

The teacher reassured the students that both marking schemes were acceptable, and that in the future she would adhere to a set of established criteria. This pattern of encouraging student participation in the assessment and learning processes was central to the progress of the implementation and the development of students' self-assessment skills.

Development Phase

As indicated in Section 4.3, the development phase of implementing this assessment approach is important, for it is here that the teacher can focus on whether both parties (ie. teacher and students) are meeting the desired goals, what gaps occur in their learning, and what needs to be done to meet the needs of students. Analyses of the data showed that the main focus of development activities in this setting was on responding to, and interacting with student thinking. Teacher J explained this as follows:

> I was concerned that students should get the most out of this assessment. By listening and talking with students about their goals and marking schemes, and even their assessment, I was able to encourage them to effectively develop self-assessment skills. (JI/F/18.10.96)

As well as helping students learn independently and effectively, Teacher J was also responsible for creating and managing the classroom environment in which students' ideas and views were accepted and respected, and their self-assessment skills were developed. She orchestrated a variety of activities for example, "group work, problem-solving games, discussions of students' perceptions of what [the assessment] required of them ..." (TJ/F/10.10.96) designed to help students develop self-assessment skills to enhance their learning. Within this orchestration, she constantly gathered information to make decisions about when to (i) move on, stop or change direction, (ii) question or whether to intervene, (iii) how much control students should be given, and (iv) whether students were benefiting from planned instruction (TJ/F/12.10.96; F-UI/F/6.97).

Implementation Concerns

Teacher J reported that very few difficulties were encountered during the initiation. She said:

> There was no problem because I took time out to explain to the class at the beginning what we were going to do. They gave some suggestions and felt happy about [the process]. I myself had doubts but their happiness soon removed them. (JI/F/25.9.96)

Although Teacher J was committed to trialing the approach, she experienced moments of anxiety and doubts when she reverted to traditional teaching practices. Notwithstanding those anxious moments, she was able to see the project to its completion and move beyond that point to continue using self-assessment.

One concern that was later seen as a disadvantage was Teacher J making daily journal entries about her progress and students' performance. She found it easier and more efficient to use a ruled record-book to record the final mark awarded to students for each problem in the given test and insisted that this method:

> Is much easier and fast. It can work well, and should be a more detailed view of students' performances. It will be easier for parents to follow their children progress on different topics. (JI/F/23.9.96)

In taking this stance, no notes were kept on students' conceptual (mis)understandings or test performances. The need for brief descriptions on student performance was recommended at that point rather than enforced. As a result, descriptions of individual student performance occurred only during our interviews.

7.3 SELF-ASSESSMENT AND THE TEACHER'S TEACHING

Student assessment can never be separated from the initiator—the teacher. In an early interview Teacher J responded in the following manner to the question, 'Why should we reconsider assessment?':

> Assessment over the years has been a way of measuring the result of drill and practice ... The constructivist approach to learning requires us to reconsider our assessment practices. If one believes that students learn by doing and reflecting, then that will call for a change in our assessment. In

> such a situation, we will be expecting that assessment will be a part of a learning activity where students are free to operate in an environment where they can make errors. (JI/F/11.9.96)

Considerations of this question and responses such as this sometimes lead to changes in individuals' practices, or in formal assessment practices (Herman, 1997).

Teacher J acknowledged and accepted that teaching and assessment changes were inevitably a part of the intervention process. In this section, I address the research question *how did the use of self-assessment influence the teacher's teaching?* The discussion centres around three main themes: (i) teaching behaviour, (ii) personal issues, and (iii) reflective practice.

Teaching Behaviour

Three changes seemed to occur in Teacher J's teaching behaviour. These relate to changes in (i) teacher-student discourse, (ii) student participation, and (iii) the role of the teacher.

1. Teacher-student discourse

Being able to communicate one's ideas is important to improving learning. One change that occurred in Teacher J's teaching was a focus on teacher-student and student-student communication. Rather than lecturing as the dominant teaching method, where students were perceived as passive learners, Teacher J orchestrated discourse in the classroom by posing questions and tasks that elicited, engaged and challenged student thinking. This was further extended by asking students to clarify or justify their solutions, a particular process, and/or an oral or written self-score. Teacher J reported that students were more eager to work, and more willing to interact with each others than previous students. Further, she speculated that these two significant changes occurred as a result of the stance she took to widening the range of assessment approaches used to assess student mathematical learning. Teacher J claimed:

> I have been teaching here for the last ten years and compared to last year students, these are more alive. They are keen to talk about their work ... even their form teacher commented about the increase in their [mathematics] performances on the second mark reading. The interest is there ... I just have to keep fanning it. (JI/F/1.11.96)

Students orally communicated their ideas about how they assessed themselves on the three processes. Such instances provided opportunities to help others to improve. Further, teacher-student dialogues helped to guide the learning process and led to the teacher gaining clearer insights of students' understanding. This is reflected in the following comment:

> I think it was during the third class discussion with [Form Z], that something happened which changed my teaching. We were discussing what progress students were making in their assessment of the processes [computation, comprehension and reasoning], when suddenly I had the urge to find out from an individual child what she meant by being 'fairly good overall' ... This child replied, 'I did well in all my tests so far, and this [test results] is not too bad'. This is quite disturbing. For before questioning her, this view wasn't discernible. What we discussed was that students would look at each category and evaluate their progress. Here this student was only comparing her test performance. A look at her work showed that she was still getting below 70% ... So although I was moving around from group to group, it seems that I needed to take time out and find out from individuals exactly what they were thinking. I learnt from this experience that her 'fairly good work' meant to obtain consistently a score between 60 and 70%. (JI/F/11.10.96)

It appears that Teacher J's instructional practices shifted from total teacher-control where the focus was on correct responses to one in which she attended to student thinking as well as correct responses. She recognised that differences existed in students' perceptions of certain criteria and that "these differences may be a result of students acceptance of mediocre work" (JI/F11.10.96). As a result she began to pay attention to "some students who were a bit weaker than others" (JI/F/11.10.96).

2. *Student Participation*

Another change that may be attributed to the use of this assessment approach on Teacher J's teaching is the level of student participation in the teaching/learning and assessment processes. Evidence of student involvement may be seen in the way Teacher J encouraged all students to participate in setting criteria to assess their performances. By providing many opportunities for her students to apply a limited but evolving set of criteria, this teacher helped students not only to make judgements but also to clarify, refine and expand the basis of their judgements (see Section 7.4). When asked about students' ability to meet established criteria, Teacher J felt that some students developed the skill faster than others. She further stated:

> It's not easy for students to gain a critical perspective of their own work; they need to be guided to become effective learners. (JI/F/3.12.96)

As a result, Teacher J resorted to routinely requesting students to justify and explain their reasons for, and the thinking behind, their ratings and judgements of their performances in the area of computation, comprehension and reasoning. "She encouraged a thoughtful and responsible stance toward self-assessment" (RJ/SA/16.10.96).

3. The Role of the Teacher

Teacher J found that her role in the classroom assumed a different dimension. Whereas this teacher once saw herself as the focal point of the class, she now respected and encouraged student opinions and insights. Teacher J declared:

> Before this I would always be talking; now it's my turn to sit back and observe them ... let them do the talking and reasoning (JI/F/11.10.96)

> While I have not reneged on my responsibility to teach, I have adopted a position more as a facilitator than a lecturer. I am convinced that no assessment innovation can truly succeed when we remain totally in control. We must give students some responsibility ... students should be able to contribute and acquire a sense of ownership. (JI/F/11.11.96)

> My own evolution was and still is a slow patient growth. Along the way I had tinkered with a variety of requirements and activities. I am constantly learning. Had I attempted a large scale self-assessment project without the opportunity to grow to understand my role, the student roles and other aspects of this approach, I doubt I would have come this far and be able to see its true potential. (F-UI/F/6.97)

Moreover, enhanced communication with the other teachers and students involved in the project meant a shift in her role from a gatekeeper to a gate opener. Rather than focusing on control and minimising the importance of student questioning, Teacher J now found that she was continuously engaged in finding varied opportunities for shared learning and discourse about student self-assessment and criteria for self-marking. However, there were anxious moments when Teacher J questioned her beliefs and instructional practice.

Personal Issues

One of the outcomes of the use of self-assessment resulted in Teacher J reflecting upon her practice and progress and student learning. The data revealed that there were changes in the teacher's concern about the control of the learning/assessment process and her professional growth during the implementation process. The effective use of time was also considered.

1. Control of the Learning/Assessment Process

The issue of how much control of the learning and/or assessment processes should be given to students was raised on several occasions. Two instances of this occurring are described.

The difficulty of students accepting responsibility for their learning was discussed during the workshop session. Teacher J hoped that this would not apply to her students and was therefore disturbed by the students' initial response. She said:

> I guess I wanted to think that my students would be different. I thought they would willingly accept such an opportunity and rise to the occasion. This was not so. In a nutshell, their first response was 'we can't do this'. Yes, I was disappointed. It took time and some effort to get them to accept this new role and become engaged in the process. I spent time letting them see that their thinking, processes and self-assessment were important. In the end the students decided this type of assessment was better than regular testing (JI/F/11.10.96).

Another instance occurred when this teacher was reconsidering the amount of control she had relinquished to students. Teacher J had just explained the tasks to students and they were working in their groups. "Rather than moving from group to group and observing what was happening she remained at her desk and appeared to be correcting papers or planning future lessons" (RJ/SA/11.10.96). When questioned about this stance, she replied:

> I can monitor students' participation in group work from here [her desk]. They know what to do. However, I'm still not sure of how much control students should be given. It is even harder to decide when to provide information, clarify an issue or whether to allow students to struggle with the problem before intervening ... (JI/F/11.10.96)

She was also concerned that giving students more responsibility might become an obstacle to other students' learning. She said:

> There are two sides to this ... I believe that they should be responsible for their learning but, because of the competitive attitude, I see where a couple of students are showing off. They feel superior to others because they are better at assessing themselves and setting criteria. This may prevent the weaker ones from trying (JI/F/15.11.96).

During our discussion, Teacher J realised that there was the possibility of the above having a positive effect on student learning. We agreed that by observing others doing well, some students might be motivated to perform similarly. Two weeks later, when questioned, Teacher J responded that based on her observations of her class she concluded that the students' higher degree of motivation may have been the result of "competition, or students sharing with others what they are doing ... of course it could be students' desire to emulate others that's responsible" (JI/F/29.11.96).

The data suggest that a reduction of teacher control as a means of fostering students' independence is likely to be more effective when the teachers themselves are constantly monitoring, assessing and reflecting on the learning outcomes and the changes that occur in their students.

2. *Growth During the Implementation Process*

Evidence from the Teacher's journal and interviews revealed that some degree of professional growth (e.g., assessing products, processes and student disposition) was experienced by Teacher J during the implementation. Such changes are evident in the following responses:

> Previously, in the marking scheme there wasn't a place for students assessment of themselves; it was just one grade. Since I began using this assessment and getting students to reason, I have structured the marking scheme to included students' assessment of themselves ... I take their overall performance—attitude etc. because I am convinced that it gives a better picture of their progress. (JI/F/24.10.96)

Having a keen interest in student-centred learning, she encouraged students to take the lead in their own learning and be responsible for producing evidence of the progress they had made. Teacher J said:

> Even before our discussion I knew that things had to change ... certainly in my way of doing and seeing things. But as we discussed things, gradually I came to realise that I was still trying to stick to the old way of doing things ... Believe me, if I wasn't convinced that we need to help students perform better, I wouldn't have made it this far. (JI/F/11.11.96)

> I have seen changes in many students. In the beginning they gave up easily and felt they could never perform well in the subject. Now they have more positive attitudes that seems to be a result of their perseverance, reasoning, logical sequencing, quick thinking, awareness of their strengths and weaknesses, and self-assessment. Yes, some are very good in marking their

> own work. Most of all, in spite of the challenges ahead, they are happy. (F-UI/F//6.97)

As a consequence of Teacher J's decision to support her students' learning, most students' self-assessments improved noticeably. That is, "these students began to view testing as a vehicle for measuring their successes, strengths and weaknesses" (F-UI/6.96), rather than as a terminal point for learning.

However, while it is relatively easy to accept new approaches, it can be very difficult to implement them, especially consistently. In the first few weeks of the intervention I recorded in my field notes that,

> I was surprised and quite satisfied with the extent to which the teacher was willing to be flexible and allow students to play a more central role. However, after one month had passed I realised that Teacher J was gradually reverting to the "transmissive" mode of teaching and learning. (RJ/SA/22.9.96)

During our discussions, I tried to find out each teacher's feeling regarding the implementation of their chosen assessment approach. Teacher J's explanation suggested that she was at the "coping stage"; she invariably experienced moments when she unconsciously reverted to her former practice. "Noticeable too was the need for her to maintain the school culture while trialing this approach" (RJ/SA/22.9.96). Basically, Teacher J had committed herself to using formative assessment in an environment where summative assessment was the norm. It is likely that the pressure of summative assessment, the prevailing constraints (teacher shortage and strikes), new demands, time pressures, and uncertainties may have led to her becoming overwhelmed and hence reverting on occasions to prior practices.

A similar situation occurred during the follow-up phase when Teacher J was incapacitated for a couple months. Speaking of the frustrations she felt over trying to re-establish the assessment practices, Teacher J said:

> At the time I was hospitalised my students and I were working as a team. I knew exactly where I was heading. Up to that point it was good. However, because of the nature of my operation, I remained at home convalescing a little longer than was first predicted. During my absence, students were taught by different maths teachers [who were available at that time]. I returned to a classroom that was chaotic and my desire to continue the programme nose-dived. If I didn't have the HOD's support I wouldn't have tried a second time. (F-UI/F/6.97)

The above response indicates that it required more than the teacher's mere desire to participate in the intervention. The success and continuity of the project required a teacher who was committed and had access to support from others within the department.

3. Time Management

Teacher J suggested that the use of self-assessment demanded more time compared to paper-and-pen tests. Management of her time proved a challenge during the initial stages of the implementation. Teacher J declared that:

> The timing of the intervention and the time needed to see it through may been affected. Because of the strikes other teachers were asked to cover additional classes, while at the same time we were concerned about meeting deadlines [e.g., mark reading, writing examination questions], syllabus requirements, reporting student performance to parents and being accountable to the head of department. (JI/F/15.11.96)

This research was indeed conducted at a time when there was a shortage of teachers. Given the factors outlined by Teacher J, it is not possible to conclude that the use of this approach was time-consuming. Other effects that occurred as a result of using this assessment approach are described in the teachers' reflection on the teaching/learning and assessment processes.

Reflective Practice

One aspect of assessment is reflection. According to Teacher J:

> [Self-assessment] should be a part of every teacher's [practice] but because we take it for granted we hardly ever are aware of doing it. This intervention has made me realise the value of reflecting on what is happening in the classroom, long-term as well as short-term goals, and the consequences of my actions ... (JI/F/25.9.96)

At different times during the implementation process, teachers were asked to reflect on the process. These reflections were discussed. Two instances of Teacher J's reflections on student learning and the continuity of the assessment practice are presented below.

Describing her students' responses to the use of the assessment approach, Teacher J stated that students appeared to be proud to be given this opportunity and that such feelings were reflected in their participation and progress. That is:

> Looking back, I can remember one student, [student Z22], who did not like maths because she was a weak student, actually came to me beaming and eagerly wanting to explain what she was doing and how she was assessing herself ... Then when talking about how they assessed themselves, I could see the happiness in their faces, like they were really proud they were doing this ... I think some of [students] looked into themselves and saw where they were failing, then realised that they could do the work if they really put the effort into it. (JI/F/25.9.96)

At the end of the academic year, after the completion of the trial, Teacher J reflected on the process and stated that she had seen the benefits of using self-assessment in her classrooms. "What began as a small project, is now spreading. It is slowly gaining interest; another teacher had decided to trial this assessment approach" (JI/F/6.97). Although, Teacher J still saw grades as having a prominent role in assessment, she had called for more teachers to join hands across St. Vincent and widen students' opportunities for involvement in the assessment process.

In summary, the above discussion has shown that as a result of Teacher J's use of self-assessment significant changes occurred in her teaching behaviour. For example, teaching moved away from being predominantly 'chalk and talk' to become an interactive process between her and the students. Teacher J also experienced changes in her role, from guardian and dispenser of knowledge to facilitator and guide. This led to changes in the dynamics of the classroom, that is, there was a shift from a teacher-focussed to a student-focussed classroom environment where the use of the assessment process gave students a measure of control of their learning. The evidence provided in the following section further indicates the shift in teaching, learning and assessment. It highlights the students' involvement in the assessment and learning processes.

7.4 SELF-ASSESSMENT AND STUDENTS' LEARNING

Teachers are not the only stakeholders in education whose perspective about the use of the assessment approach should be understood. Students' perspectives are important. Students were interviewed during and after instruction about their self-assessment practices. Their responses are used in this section to address the research question *what effect did the use of self-assessment have on the students' learning of mathematics?*

Student Involvement in the Assessment Process

Researchers have argued that the ultimate goal of self-assessment is to create autonomous learners who are self-analysing, self-evaluating, self-motivating and self-renewing (Boud, 1995a, 1995b, 1995c; Boud & Feletti, 1991). Accomplishing this goal requires students to be active partners in the learning and assessment processes. In this present research, students were engaged in developing internal feedback channels as a means of:

- setting their own criteria for good work
- assessing their mathematical understanding and performance under three areas: comprehension, computation and reasoning
- grading their weekly test and comparing self-grades with the teacher's grade
- reflecting on the mathematics they learned in the course of a unit on Numbers and Number Theory.

The students' initial reaction to the use of the assessment approach is considered first.

Students' initial reaction. Initially, with the exception of two students who later revealed that they always tried to assess their work, developing self-assessment skills was a difficult process for most students (*n*= *26*). Their comments indicated that this was because (i) it was a new experience that required them to change their way of thinking about their roles in the learning process and (ii) some were wary about their role and what was expected of them. Two students described their concerns:

> If we are to assess ourselves now, how would this affect us later. What exactly is Miss looking for? How would we know exactly what she wants? ... I hope this wouldn't disadvantage us in the exams. (Z3/SI/12.9.96)

> I feel it would be quite difficult to assess myself like Miss. It is almost like I am on my own ... This whole thing is new, (long pause, stares into space, her face darkens, closes her eyes) it's different and very scary (Z8/SI/12.9.96)

This concern is understandable, since students were coming to this innovation from a background where the teacher was perceived as the 'knower' and disseminator of knowledge and where they saw their role as passive recipients. This was a situation described by Teacher J as *spoon feeding.* Therefore it was not surprising that in earlier parts of the innovation more than one half of the class failed to analyse their work adequately in the three categories. As a result "much class time was spent discussing some students' assessment" (JI/F/17.9.96).

Subsequent sub-sections discuss students' involvement in relation to the setting of goals and criteria, assessment of their performance, grading their written work, and reflecting on and altering their behaviour accordingly.

1. Setting Goals and Criteria

In the following example, the entire class was involved in establishing a set of criteria to mark the following word problem (question b in Figure 7a, given in Figure 7b.

> The altitude of a diver is $^{-}10$m while the altitude of a shark is $^{-}43$m. Find the difference in their altitudes. (3 marks)

Figure 7b. Teacher-made Test Items

Students were allowed to define their criteria for assessing their own work. After a little uncertainty, and with a few examples and probing questions from Teacher J, students developed the list presented in **Table 7.2.**

Table 7.2. Student-generated Assessment Criteria. Two Attempts

First Attempt	After Several Attempts
• proper procedure	• determining a possible strategy
• effort	• successfully communicating the strategy
• neatness	• correctly applying the strategy
• right answer	• right answer

Their initial discussion seemed to dwell on aspects of *doing* mathematics instead of on understanding the problem. For example, although neatness was not included in the final set of criteria, most students considered it to be an aspect of *doing* mathematics.

The subsequent criteria reveal that understanding the problem in order to determine and apply a correct strategy, and then computing it accurately were considered very important elements for good performance.

This is revealed in the following quote:

> If you were given a question and you don't interpret it correctly[stresses correctly], you don't understand the meaning behind the question and so you may interpret it incorrectly. It is important first of all you understand the problem, then follow the instructions to correctly answer the question. You must understand the question and work on the instruction to calculate the answer. (Z12/SI/12.9.96)

Thus, encouraging students to become involved in setting assessment criteria for evaluating their work shifted the vision of students as objects to students as active cognising subjects.

2. *Assessing their own Mathematical Understanding and Performance*

As previously stated, students were involved in assessing their mathematical understanding and performance. One aspect of this required students to describe a good or weak student assessment. The students felt that once the total marks awarded for the question were given, so that students knew the expectations for a successful attempt (in this instance it was 3 marks), then "a good self-assessment would be a [self-score] that was very close to [the teacher's] score" (Z24/SI/12.9.96).

In distributing the given mark for the question in Figure 7b, two students allocated the marks as shown in Table 7.3.

Table 7.3. Student Allocation of Scores

Criteria	Students		
	Z1	Z2	
• determining a possible strategy	(1)	(1)	mark
• successfully communicating the strategy	(0)	($\frac{1}{2}$)	mark
• correctly applying the strategy	(1)	($\frac{1}{2}$)	mark
• right answer	(1)	(1)	mark

When questioned about their scoring, Student Z1 declared:

> I think there is no need for us to have that criteria [successfully communicating the strategy]. I left it out because if a student can come up with a strategy and correctly applies that strategy then she should be able to get the right answer ... unless she has problems when calculating it. (Z1/SI/10.9/96)

Student Z2 perceived all the criteria as relevant since their inclusion would help students to assess their work from different angles. She concluded:

> While I agree with you, [student Z1] I still think you need to look at all the processes involved and encourage students to see what is needed to score full marks on word problems ... you must look at it [the problem] from different angles. (Z2/ SI/10.9/96)

While other students generally agreed with Student Z2, stating that the inclusion of the criteria was relevant, they also saw the logic in Student Z1's reasoning. This discussion process engaged students in expressing their understanding and judgements in qualitative ways while explaining their idea of appropriate criteria. When students helped in establishing criteria they learned the expectations about what counted as successful work and as a result were able to structure their learning and increase their ownership of the learning process.

To further facilitate improvement of their performances, students used their established criteria or marking scheme shown in Table 7.4, their knowledge of what is meant by comprehension, computation and reasoning, and their communication skills.

Table 7.4. Student-defined Criteria for Processes Performance

Description	Score (%)	Grade
Good	90+	(A)
Fairly good	70 - 89	(B)
Fair	50 - 69	(C)
Weak	Under 50	(D)

The first group of students interviewed began by making positive comments about parts of their work that met the criteria. When I pointed this out, students' responses became more detailed. For example, one student commented initially:

> I think I am good in computation and fair in reasoning and comprehension (Z9/SI/12.9.96)

She later elaborated:

> I'm fairly good in comprehension because I understood the problem, reasoning: fair, needs to be further developed; and my computation is good. (Z9/SI/12.9.96)

On closer examination of student responses there appears to be an important relationship between being able to understand the problem and to think logically and solve the problem. As revealed in Table 7.5, from the ten students interviewed on that day, two students rated themselves as performing good in reasoning and comprehension whereas two other students felt that they were weak in these two areas.

Table 7.5. Students Self-analyses

Comments	Descriptors			
	Good	Fairly Good	Fair	Weak
Comprehension	**	***	***	**
Reasoning	**	***	***	**
Computation	**	**	***	***

(Each * represents 1 student: N = 10)

There were some instances where students tended to mark themselves up (Section 7.4). However, on such occasions, students through dialogue would provide sufficient evidence to support their self-awarded grades and be guided towards refining their assessment practices. The students' involvement in the assessment process (e.g., establishing criteria, assessing their own performance) required them to adopt new roles, something which most achieved.

3. Students Grading their Tests and making Comparisons with Teacher's Grade

Part of student self-assessment, as planned by Teacher J, required students to grade their weekly and/or fortnightly tests. A typical scenario for this assessment cycle follows. One test was designed to measure students' understanding of indices. A particular student who was awarded 57.5% by Teacher J for test performance gave herself 75%. A discussion ensued wherein the student challenged the correctness of the teacher's marking of one question. The student substantiated her interpretation by referring explicitly to the problem in Figure 7c (overleaf) and by revealing in her discussion, her thought processes regarding the problem.

Teacher J acknowledged the student's analysis of her work, then pointed out that her performance was due to insufficient comprehension of the problem. The student was given her scores for each part of the question.

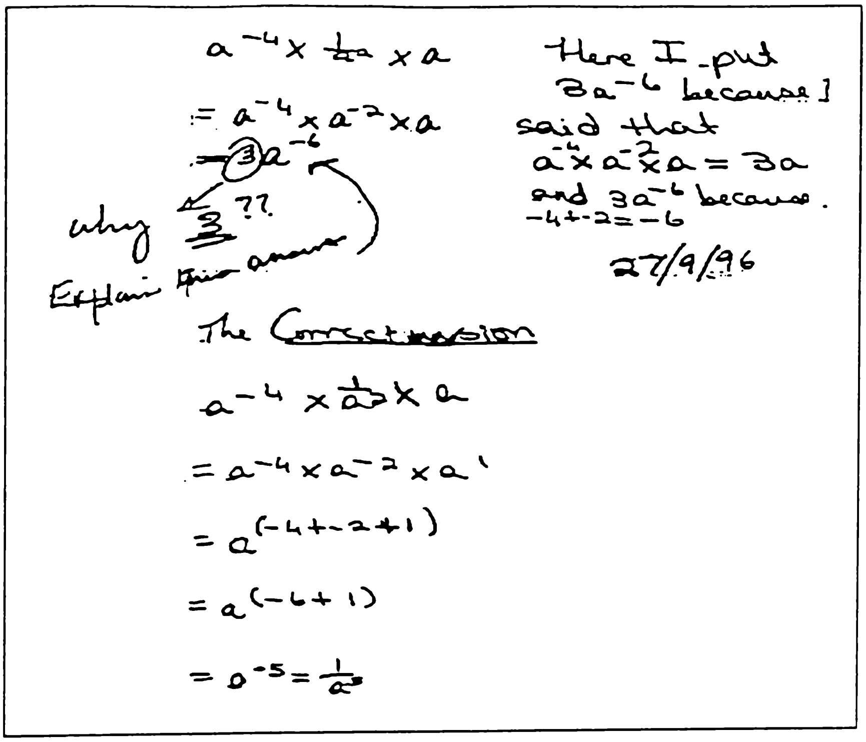


Figure 7c. A Student's Problem Solving

After comparing the two scores the student concluded:

> I probably overmarked myself. I was sure of that problem. This mistake cost me a few marks ... It was while speaking with Z11, after giving our work up, that I realised I had made a mistake on another problem and that the solution for that problem could be wrong. (Z4/SI/4.10.96)

Discussion with this student revealed significant conceptual misunderstandings, that is, the student calculated a x a x $a = 3a$ and failed to interpret a as a^1. It was only after much probing that the student was able to identify this mistake. When asked to re-assess her performance she stated *failure to comprehend the problem* as the major error. Whereas she had rated her performance as good on comprehension, computation and reasoning, after her discussion with the teacher she described her performance as follows:

> I'm fairly good in computation (1/2 mark), comprehension is weak, no, fair for I did know two facts: when multiplying you add the indices and a negative index can be rewritten as 1 upon the positive index ... (pauses) another fact is adding two negative numbers gives a larger negative number. So I did recognise a strategy. Because I didn't add the 1, that was a careless mistake, I'll say fairly good for reasoning. (Z5/SI/4.10.96)

When asked to mark the question again the student awarded herself 1 mark for recognising a strategy, that is, $1/a^2 = a^{-2}$, (the same as the teacher's) and 1/2 mark for incomplete application of another strategy $a^{-4} \times a^{-2} \times a = a^{-4\,+\,-2} = a^{-6}$ and for correctly adding two negative numbers. This teacher-student dialogue not only encouraged the student to analyse her thought processes but it also provided her with the opportunity to identify strengths and weaknesses in her performance. Therefore, self-assessment was used not only to facilitate self-grading but to get the student to reflect on her performance, challenge in a positive manner the teacher's marking and justify her reasons for describing her performance on two occasions. Hence, self-assessment meant more than grading (Boud, 1990; 1995a, 1995b, 1995c; Falchikov, 1995); it involved students developing the ability to determine characteristics of a good performance of their work by examining their strengths and weaknesses on given problems (Adams & King, 1995; Boud, 1995a, 1995b, 1995c).

Reflecting on and Altering Behaviour

Self-assessment requires students to learn about learning through reflection on their own activities (Adam & King 1995; Boud, 1995; Tanner & Jones, 1994). After the first test, two students from each of the assigned group (*n=14*) were interviewed to find out their reactions at that point about the assessment approach, particularly their role in the process. From their reflections, these students concluded that there were positive changes in their approach to given tasks.

Additionally, data from the teacher's record revealed that more than one half of the class had shown marked improvement in their performances on the pre and post tests on Integers. This is illustrated in Table 7.6.

Table 7.6. Upward and Downward Changes in Student Performance on Pre and Post Tests (scores rounded to the nearest whole number)

Changes	No of Students	Score Change					
		1	2	3	4	5	
Upward	19	5	1	7	3	3	(students)
Unchanged	2						
Downward	7	3	3	1			

Table 7.6 reveals that approximately two thirds of the students performed better on the post test, with almost half increasing their scores by three or more. Teacher J considered this improvement to be significant since it was better than she had expected. Additionally, students who improved were in no doubt about the reason.

One of the fourteen students interviewed compared her performance on the pre test with that on the post test and concluded:

> I performed better on this [second] test because of the way we are now doing maths. You have to think about every step. Then I also remembered how we discussed certain problems and that helped me. I am now enjoying maths. (Z24/SI/20.9.96)

Students were also encouraged to reflect on their learning journey at regular intervals. Tables 7.7 and 7.8 summarise the responses of twenty-eight students to the following questions.

Table 7.7. Student Responses to Question 1

Question 1	Response				Total
	Yes	No	Uncertain	No response	
Do you reflect on your work? (9.10.96)	15	3	2	8	28

Table 7.7 shows that more than half considered that they reflected on their work. The students who offered no response may not have understood what 'reflect' means. With respect to the five students who said they either did not reflect on their work or were uncertain as to how this occurred, the interview revealed that there were instances when they did, to some extent, reflect on their learning. For example:

> My work today was okay but last Wednesday's test [performance] was shocking. I didn't do so well ... When I went over my work at home, I could see the mistakes I had made. (Z11/SI/11.10.96)

> Sometimes I am a bit slower [completing tasks] than at other times. Like today, I hardly finished this exercise. (Z3/SI/11.10.96)

When explaining her understanding of negative numbers, one of the two students who indicated her uncertainty as to whether she reflected on her work said:

> In Form 2, Miss told us that when we have two negative numbers coming together we add them. That's what I knew ... but now I found out (pauses and scratches her head) I found out that you add them and keep also the sign. So $^{-}6 - 7$ is $^{-}13$. (Z11/SI/11.10.96)

Table 7.8. Student Responses to Question 2

Question 2	Response				Total
	Daily	Every other day	Weekly	No response	
How often do you reflect on your work? (9.10.96)	10	4	1	13	28

In answer to the question "How has reflecting on your work helped you?" the fifteen students in Table 7.8 who replied 'yes' felt that opportunities provided to help them become efficient assessors (markers) of their work and to discuss the processes involved in their work helped to reaffirm their goals and motivated them toward meeting each goal. Further, they felt that with practice they gradually began taking control of their own learning. They not only worked better but their attitude improved. These students concluded that from the experience they had gained a deeper understanding of how to assess themselves and to improve their assessment and simultaneously improve their performance. This view is reflected in the following comments:

> We knew what was required of us in terms of how to score each question and with practice many of us did well. (Z14/SI/11.10.96)

> Self-assessment helped me to start thinking about the problem even before I began writing ... It made me think (laughs), now that's new. (Z1/SI/11.10.96)

> [Self-assessment] helped me to look at my level of reasoning. I was able to see changes in the way how I was doing my work ... This has helped me because when you look at it, we are required to know our potentials—what we can and cannot do. We have to make choices about the type of fourth form we will be going to; being able to assess ourselves now will help us a lot in making those decisions .(Z28/SI/11.10.96)

Thus, the data presented here appear to support the claim by Black & Wiliam (1998) that with practice, students who self-assess themselves become more committed, conscientious and effective learners in that they are able to apply knowledge of their learning to new areas.

Follow Up. Six months after the innovation, students were followed up to find out the effectiveness of self-assessment on their learning. Most students found the innovation to be generally beneficial. When asked to reflect on their practices, twenty of the twenty-eight students concluded that it was the 'best thing that happened'. Some students claimed:

> I felt good about self-assessment because we explored others' ideas and it allowed us to work in groups and to have free discussions about our ideas. (Z8/F-UI/6.97)
>
> Self-assessment helped us to improve our grades because like if you failed the last test, and you came out with a higher mark than you expected, this will help you to improve your assessment and help you with your work. (Z4/F-UI/6.97)
>
> Being able to assess your own work is really more important than passing any exam. Even during the exam I was my own examiner ... If you did a test and didn't do it well and had to do it over, as you are going over it you will be able to see or look to find out what went wrong. You may say I'm not too bad after all, I did my corrections, I did something else and I put more effort into this; now I can move on and do what I'm doing. (Z3/F-UI/6.97)

The students' views were supported by a number of teacher observations.

1. The use of self-assessment supported student learning of mathematics by making it more personal to them.

2. Students found the unit on Numbers and Number Theory more enjoyable and applicable than other concepts, e.g., polygons. Where project work was used to assess student understanding of polygons, they found that acquiring certain self-assessment skills was an advantage. (F-UI/F/6.97)

2. Discussing how they assessed themselves enabled students to identify gaps in their understanding of mathematical concepts. (JI/F/11.11.96; JI/F/6.97)

4. Providing opportunities for students to focus more on the processes and rightness of solutions helped to develop their confidence when explaining their solutions. (JI/F/11.11.96; F-UI/F/6.97)

3. The act of reflecting on their work helped students to effectively monitor their performance. Two questions linked to this are (i) What do I need to know or do to solve the problem, and (ii) how do I arrive at a reasonable solution? (JI/F/11.9.96).

Hence, self-assessment, in this setting, was a valuable teaching and learning tool that seemed to aid student learning.

The consensus of 20 students (over 70 % of the class) was that the skills developed from the use of this approach were now being applied or extended to other subject areas and outside the classroom. This claim is best illustrated through one student's words:

> Self-assessment plays a greater role in assessing our mathematics than investigations can. Although we have to assess what we are doing or investigating ... investigation includes being able to assess your work. I guess you can say it has become a part of our daily activities (Z26/SI/6.97)

When asked about the impact of this assessment approach on their attitude toward learning mathematics the same 20 students replied that it had a positive effect. Student responses are summarised in Table 7.9.

Table 7.9. Students' View of the Impact of Self-assessment on their Attitude toward Mathematics Learning

Effect	No. of Students
Positive	20
No change	4
Uncertain	4

Student responses, for example, were:

> [We] now enjoy maths. We are all doing something. (Z12/SI/29.9.96)

> I'm enjoying maths very much, more than the rest [of my] subjects. (Z15/SI/29.9.96)

> The teacher is now more interested in what everybody has to say, especially those who don't understand. (Z3/SI/29.9.96)

> I still think it takes up time but I am learning ... if you know what you are doing you can increase your marks. I'm getting there. (Z27/SI/29.9.96)

Another student claimed that because she was usually successful her feelings had remained much the same. She said:

> It hasn't changed how I feel about maths. I always manage to pass every test. No, I haven't benefited from this approach. (Z6/F-UI/6.97)

The changes that occurred in the students' attitude toward mathematics may have resulted from the increased teacher-student interactions. Such an increase may have made it easier for all students to participate in classroom activities.

The four students who remained hesitant and participated to a lesser degree than others in the assessment programme, viewed self-assessment as a slow and long process. One student claimed:

> I still think that it kept us from pushing more work. Too much time was spent talking about what we were doing. Frankly, I preferred if we had used that time differently ... working on more problems or just doing what was necessary for us to know. (Z27/F-UI/6.97)

Another student claimed that establishing "criteria for good performance was the teacher's job" (Z10/F-UI/6.97).

This discontentment by a few individual students was alluded to by Teacher J in an interview session. Here Teacher J voiced concerns about one student's unwillingness to participate in the activities. She exclaimed:

> I've tried encouraging her but she is so casual; I can't seem to reach her to help her. Maybe she is satisfied with her present performance ... I was hoping that everyone would benefit. We win some and lose some. I'll keep trying. (JI/F/11.10.96)

This raises a problem. Some students might not wish to accept more responsibility for their learning as they are quite happy to do little more than take notes and work problems as directed (Boud, 1995b). Or students' rejection of the assessment practice may be linked to the fact that this is a novel situation and some students may be happy to remain with the teacher as the sole source of knowledge. As Boud (1990) pointed out some students are apt to reject accepting more responsibility for their learning and may exert pressure on the teacher to revert to previous practice. Failing to do this, they may opt out of the initiative. The role of the teacher in such instances is to resist without alienating students and to provide time for such changes to be accepted (Boud, 1990). But the question remains of how far the teacher should go. Certainly there will be times when self-assessment will not be beneficial to all students, but the teacher has to ensure that all students have access to the assessment approach. She cannot abdicate her responsibility in favour of giving students full control (Boud, 1990; 1995b, 1995c). However, as Teacher J emphasised, the child was encouraged. One may further agree with Fullan (1993) that students as well as teachers have to be willing to accept the change before meaningful learning can take place. It is therefore the teacher's responsibility to ensure that all students are participating in the learning process and that the assessment strategies are as beneficial as possible in varying situations. One way in which this may be achieved is by monitoring and assessing the instructional process, moment by moment.

Teacher J considered that self-assessment had facilitated student learning to some extent. She stated:

> Getting students to assess themselves in the areas we chose: comprehension, computation and reasoning helped them because they were able to pinpoint their weaknesses and to realise that they could achieve much more than they normally try to attain. (JI/F//25.9.96)

> My main conclusion is that students learned because they were involved in the assessment, learning and teaching processes. I do believe that students learned something which could positively influence their ways of making decisions, assessing their own work and also of monitoring their own performance. (JI/F//3.12.96)

She also noted that getting students to reflect on their practice was essential:

> Self-assessment is a form of debugging the whole process, trying to fix what went wrong and redoing the model by reflecting on its process so that on the next attempt students will have a more refined tool to work with ... Self-evaluation can be used to encourage students to think about their own learning and presentation of material. It puts them on the other side of the desk to have a look at what they have actually done. This is part of reflection. (JI/F/11.11.96)

From her discussions with students it became clear that emotions played an important part in the instructional process. Teacher J claimed that she had seen evidence of changes in students' attitude toward mathematics. In her view, some students had gained a greater appreciation for mathematics. She said:

> Midway into the innovation, I noticed striking and tangible changes in some students' behaviour toward mathematics. Students from time to time spoke their feelings of enjoying maths, being interested, anxious or enthusiastic and a sense of fulfilment. Some students continued performing well on every test. (F-UI/F/6.97)

> When they were talking about how they assessed themselves, I could see the happiness on their faces, like they really were proud they were doing this ... I think given that opportunity some students were able to look into themselves and see where they were actually failing. (JI/ F/25.9.96)

Hence, as well as offering a chance for students to inform themselves about their learning, self-assessment provided motivation and boosted student self-esteem (Boud, 1995a, 1995b, 1995c; Stenmark, 1989; 1991). It is therefore important that teachers structure self-assessment activities in ways that prevent students from feeling negative about their attempts. Thus, when effective self-assessment is carried out the result is good self-esteem (Boud, 1995a, 1995b, 1995c).

7.6 SUMMARY AND DISCUSSION OF FINDINGS

Self-assessment in this chapter is defined as the process in which students determine their strengths and their weaknesses on a given mathematical task with the aim of improving learning. It also involves students establishing a set of criteria to grade weekly and/or fortnightly tests and to justify the extent to which they have met those criteria by comparing their grades with the teacher's grade. Several significant findings emerged from the data on self-assessment. These may be summarised as follows:

Implementation

- Students were encouraged to establish appropriate marking criteria. Once students became familiar with the assessment criteria they began to see how the criteria applied to their own work, they became consultants for each other (Section 7.4). Additionally, as they learned to reinforce and establish new criteria they were offered limited hints, thus encouraging them to move towards the goal of becoming independent learners (Collins et al, 1989). These findings support the claim that students' participation in establishing assessment criteria should be encouraged. According to Adams and King (1995), when students are encouraged to set criteria, their motivation and desire to complete the task are more likely to increase.

- The discussions that occurred during the weekly double-mathematics periods allowed the students time to reflect on their strategies and provided immediate feedback to enhance their current understanding and future learning experiences.

- Providing timely and constructive feedback allowed misunderstandings to be detected and discussed (discussed in Sections 7.3 and 7.4). This process helped maintain student motivation. If students genuinely could not detect where they were going wrong, they were informed by the teacher rather than left to become frustrated and disinterested in the subject. Students were motivated and willing to persevere when they were able to assess themselves effectively.

- Teacher J stated her appreciation for being able to communicate with colleagues and receiving support from them as well (discussed in Section 7.3). Analysis of the data showed that this teacher was committed to the intervention. Although she experienced momentarily setbacks, the vision of getting students to become more responsible for their learning motivated her to complete the intervention and to develop and carry on the practice. The success that she gained inspired one other teacher to include self-assessment as an alternative to written tests.

Teacher's Teaching

- The role of Teacher J changed from 'gatekeeper' to 'gate opener', and involved facilitating all students to improve their learning. She now worked alongside the students, encouraging them continually to become more sophisticated in their mathematical skills and understandings, and in their ability to assess themselves. Hence, the use of self-assessment changed the classroom focus from teacher-centred to student-centred. It also provided an opportunity for Teacher J's professional growth.

Student Learning

- In spite of its novelty, many students were very interested in the use of self- assessment. As a result of their participation they began to realise that learning results from what they are doing rather than from what might be done to them. For them, self-assessment was useful and relevant not only in mathematics but across the curriculum, and also in making educational choices such as fourth form subjects. Self-assessment was therefore relevant to their needs.

- In this study students developed the art of critically assessing their understanding and performance and using that information to move toward achieving their next goal. It is essential therefore that as teachers we respect and nurture this capacity in our students from the onset of the school year.

- As shown in this case study, students were involved in discussions, problem solving and reflections. Unlike traditional assessment, self-assessment did not depend on examinations as a measure of ability; it involved more than testing and utilised different media.

- In all cases, students felt that their work and contribution were taken seriously and that their ability to mirror their teacher's assessment of their work was an accurate reflection of their work on Numbers and Number Theory (Section 7.4). Students felt a sense of ownership and control over what they needed to learn, and an appreciation of what they had actually learnt, together with an understanding of why they have learnt. It is suggested that when students develop a sense of ownership they are less likely to resort to a passive approach to learning (Harris & Bell, 1990). Teacher J provided opportunities for students to be supported in developing and refining their self-assessment skills, in order to help them grow in their understanding of themselves as learners. Support structures were established by allowing students to participate in collaborative group activities.

- Observations by the teacher and myself, together with the student interviews, revealed that (i) in the initial stage of the implementation a few students were hesitant and attempted to avoid participating in group activities. However, with practice, most students' interests were kindled and they benefited from participating in the intervention, and (ii) students became more responsible and self-reliant (discussed in Section 7.3 and 7.4). As both Brew (1995) and Mousley (1996) noted, giving students more responsibility and the importance for students to recognise that their contribution to the instructional process was valued. However, the development of this skill is an ongoing process and cannot be realised over a short period of time.

The results of this case study on self-assessment are mixed. Self-assessment was used largely to encourage students to be actively involved in assessing their performance by making them partially responsible for assessment (rather than passive watchers). Although, some researchers may not condone the practice of self-grading, in this research it was an important aspect for it gave students, particularly those of 'below average ability', an opportunity to take ownership of their learning. However, student' self- assessment meant more than self-grading. It went beyond that to encompass other skills that supported self-awareness and self-evaluation

Unlike Boud's (1995c) claim that overemphasis on establishing criteria would shift the focus away from students engaging in establishing and working with criteria, the students in this study were encouraged to set up criteria and to justify their reasons for selecting each criteria. Further, trialing of self-assessment practices in the midst of existing traditional assessment practices proved both feasible and practical. Thus, formative assessment could be linked to self-assessment in a deliberate rather than accidental way (Black & Wiliam, 1998). The outcomes of this case study were similar to those studies reported in Section 4.3 and support the thesis that self-assessment enhances student learning, broadly conceived. It also showed that classroom assessment can be an ongoing process, and not simply a culminating event.

This study suggests that students could benefit from training and practice in the art of self-assessment. For example, by focusing on a best and worst piece of work, students could be taught in advance how to mark more effectively. Student self-assessment and the resulting teacher-student dialogues were invaluable in helping students gain a clear picture of their performances. Self-assessment provided a vehicle whereby students could (i) look at their work honestly, (ii) were able to clarify ideas of what they were expected to learn, and (iii) monitor their progress.

Further research on self-assessment in secondary schools is needed. Research that focuses on the extent to which the use of self-assessment in mathematics can enhance student learning would be useful.

In the following chapter, Chapter Eight, I discuss the findings regarding the use of journals as an assessment approach for formative purposes in mathematics.

CHAPTER 8

RESEARCH FINDINGS: JOURNALS

8.1 INTRODUCTION

This chapter reports on the role of journals in the formative assessment of students' mathematical learning. Findings from two teachers, Teacher B and myself (Teacher R), along with those from two classes of Form 3 students and their journals *(n = 54)* are presented and discussed. Data were gathered from interviews with Teacher B and the students, observations of the students in both classes, systematic field notes of my experiences as one of the two class teachers, and from reading students' journal entries. Subsequent sections of this chapter are:

8.2 Implementing the Assessment Approach

8.3 Journals and Teachers' Teaching

8.4 Journals and Students' Learning

8.5 Summary and Discussion of Findings.

8.2 IMPLEMENTING THE ASSESSMENT APPROACH

As mentioned in Chapter Five, the use of alternative assessments was a novel experience for the teachers and students involved. As a result of the professional development workshop, Teacher B and I decided to trial this assessment approach (as well as interviews, see Chapter 9) as a way to assist in the assessment of students' understanding of the concepts of numbers and number theory. In this section I address the research question: *how did the teachers implement the chosen assessment strategy?* A description of the initiation and development phases, and concerns that arose during the implementation are given.

The Initiation Phase

Students in each of the two third forms, along with their mathematics teachers, discussed the nature of the assessment and the aims for trialing this approach. Students were informed that they were the focus of attention and were expected to take a more active role in the learning and assessment processes. Each student was given an exercise book to be used as a journal and was instructed that she was fully responsible for her journal for the duration of the intervention. Students were also made aware that I would be collecting them, for research purposes, at the end of the intervention and that they would be returned to them later, if desired.

In our introduction, we discussed how journals are kept for specific purposes and contain records of daily events. They also can be used as personal reflections and as a means to record information. Students were asked to use illustrations, diagrams, charts, pictures, newspaper clippings or anything that they felt which would show their understanding of a particular concept. They were also encouraged to leave enough room after each entry for 'afterthoughts'.

To give students an opportunity to express their views more formally in writing, we, the teachers introduced 'expositions'. These included discussing a topic, writing an explanatory letter to a friend, or researching a topic or concepts. First, we modelled an example, where students actually looked at the features of our journal writing. This was followed by students' attempts at a journal writing task. They were asked to write to a friend telling how they felt about mathematics. Some of these responses were shared and discussed during whole class settings. Initially, some students were reserved but as the term progressed many students wanted to share new information or ideas they had researched.

The Development Phase

The focus of this phase was to encourage students to express their understanding of mathematical concepts through expository writing, researching and communicating their ideas. To encourage students to make frequent journal entries, Teacher B and I decided that once every two weeks students would be given an assignment which required them to research a topic. We also decided that it may be best not to have students make daily journal entries as a quick turnover in collecting, assessing and returning students' journals was not really achievable. Hence, students were encouraged to write at least once per week and on the occasions when we gave them special activities. They were expected to write about the topic or complete the task in their journals, then submit the journals to be assessed. The remainder of this section describes two aspects of this phase, namely, (i) establishing marking criteria and format of feedback, and (ii) encouraging students to make frequent journal entries.

1. Establishing Marking Criteria and Format of Feedback

The marking criteria were established jointly by the students and their teacher. Students suggested that a good piece of work should have definitions, examples, computation of some sort, neatness, and should show knowledge of the concept. When marking their entries the focus was on correct solutions, errors and misconceptions. Students' entries were not graded for grammar, although the correction was noted on the student work. What was graded was the mathematical soundness and clarity in expressing the concept. Comments were conveyed on postie notes and, where necessary, students were given a smiling face saying 'see me'. This indicated to the recipient that there was a need for discussion. Some postie notes used in this assessment were:

- 'Please write'.
- 'Good, keep it up'.
- 'Now try another approach and solve this' or 'Going great. Why not try another approach'.
- 'This is interesting. Please continue ...'
- 'Kindly write and explain, to the student who is at home sick, the work we have been doing after standard form. She would really love the help. Thank you'.

The journal entries and postie notes allowed the teachers to track students' development (or lack of it).

An examination of students' journals disclosed that on the 12 occasions when students were asked to try another approach to solve a problem, only eight out of a total of 54 students heeded this direction. The postie notes that asked students to write a letter were better followed up by students. There were 10 such postie notes and nine students responded positively. One may assume that because this activity was done during a sharing session, students attached more significance to it, and therefore responded in that manner. Postie notes such as 'please write' or 'we need your help' seemed to have little or minimal effect on students' actions. For instance, there were three 'we need your help' and six 'please write' requests. Students' responses to these posties were zero and two respectively. Postie notes, written by both teachers and students, became integral communication components of journal entries. They seemed less formal and thus more user friendly.

2. *Encouraging Students' to make Frequent Journal Entries*

Assessment activities were organised to encourage students' making frequent journal entries during and after instruction. The following are two concept composition Journal-writing prompts (Figure 8a) that were given to the students in both third forms. The first example shows the use of journals *before* instruction, while the second is an *after* instruction task.

Example 1 You are to go to the library and research the topic indices. You may want to use any text book as a guide. Be prepared to share and discuss your findings with the class. The idea was to get them to reflect on their work [researched area] and to explain their understanding of the concept. (BI/M/24.9.96)
Example 2 Write a letter to a friend explaining how (i) decimal places and significant figures are similar and different, or (ii) what I know about standard form. (SJ/26. 9. 96)

Figure 8a. Two Journal-Writing Prompts

Apart from ensuring that every student wrote in their journal at least every fortnight, these activities required also that students (i) expressed their understanding of mathematical concepts, (ii) were open in their thinking of mathematics, and (iii) were exposed to other students' perspectives or solutions. The first *before* instruction example, is an activity that required students to engage in research skills connecting their library skills classes with mathematics. The task was used to extend students' levels of knowledge. This rich information base activity done prior to the beginning of the unit on Indices helped develop a mindset for studying the topic, and helped students form connections between what was already known and the new data. When this topic was introduced the following day, there was a reverse in roles. That is, we, the class teachers acted as facilitators while the students became teachers. They delivered the instruction based on data collected. The teachers sat among them and directed certain leading questions to the class to assess students' understanding. At the end of this lesson the journals were collected, assessed and returned the following day. Students were rather pleased with the level of their involvement and contribution to the instructional process, and asked to have more lessons of this type. This is an indication of the symbiotic connection between teaching and assessment (D. J. Clarke, 1997).

On other occasions *during* instruction students were asked to explain how they solved a particular problem, why they chose a particular strategy or solution, or why a particular student's answer made sense? This approach allowed students to concentrate on process, not just product, and to reflect on their learning and how it related to what they already knew. During instruction, time was allocated to encourage not only writing but voluntary sharing of journal entries. This practice helped to remove some of the students' initial reservation about the use of journals in mathematics. Further, the use of explanatory letters, as journal entries, served the purpose of helping absent students to easily grasp the instruction they had missed.

An *after* instruction activity might require students to do something for homework, or time was set aside for students to write about their work immediately after an exercise. To gain specific information, we provided students with writing prompts such as 'what was easy or hard about this exercise or topic?'; 'where did I go wrong?'; 'how do I feel about the finished task?'. Students' journal entries were then examined and commented on. This was later followed up by getting students to look at their corrected work, then write their views. Students would then compare their previous evaluation with the present one (see Section 8.3).

Another *after* instruction activity that we found helpful in encouraging students to write in their journals was having them formulate their own problems. Sometimes students were asked to pose a mathematical problem. For example, having completed addition and subtraction of bases, and place value, students were asked to pose and solve a problem on multiplication of bases. It was an open-ended question in the sense that students had a choice of working with the same base or working with different bases. The level of difficulty was left to the student. These problems were used in the following session where students presented their tasks and explained their solutions.

Implementation Concerns

The introduction of journals as an assessment approach in the mathematics classroom caused some concerns. These related to students' initial reception of the assessment approach, the frequency of their journal entries, marking students' journals and the timing of the implementation.

1. Students' Initial Reception of the Assessment

Some students in both third forms initially laughed at the idea. They generally compartmentalised subjects and felt that keeping a journal was related more to English than mathematics. For instance, one student stated:

> We have to keep journals for English but it would not be the same for mathematics ... This is more numbers, adding ... computation, working out problems with just numbers. (X22/SI//9.9.96)

It seemed that the students did not associate writing with mathematics at all, despite writing being involved in problems and problem solving. Hence they could not initially see the relevance of journals to mathematics. This is illustrated by the student who said:

> Word problems are just word problems; you don't need to keep a journal. You can simply draw a diagram or just solve the problem ... [after some thought] Well ... [laughs] maybe you can write interesting ones in your journal [laughs]. (Y5/SI/9.9.96)

Other students were concerned that this journal writing would detract from the time needed to cover the mathematics syllabus. For example, two students commented:

> Frankly, I prefer if we just do what is necessary for us to know and to complete the syllabus. If we do this, then when we have exams the other classes are bound to be at an advantage because they will be ahead of us (X20/SI/9.9.96)

> Journal writing may be a good idea but we might spend too much time focussing on it rather than concentrating on what is really necessary, which is, the syllabus and the need to catch up with the other forms. (Y1/SI/9.9.96)

Thus, the initial responses of some students did not appear to be supportive of the use of journals as an assessment approach in mathematics.

2. *Frequency of Student Entries*

Another concern was the frequency of students' journal entries. Although students were encouraged to make regular and chronological dated entries, there were times when this did not happen. Some students who were initially hesitant scarcely had more than half a page of written work after the first two weeks. As a result, Teacher B asked me to speak to his class, about the importance of journals in mathematics and to encourage them to write in their journals. This occurred on two occasions. When questioned about their reluctance on the first occasion, students mentioned lack of time or that personal success in mathematics made journal keeping superfluous. This is illustrated by three students who replied:

> I am not having problems with maths. There is no need for me to write in a journal because I'm always doing well in my tests (Y26/SI/23.9.96).
>
> It is taking up my time. I hardly have enough time after school or when I get home (Y21/SI/23.9.96).
>
> I don't mind keeping a journal but we have so much homework to do, then chores at home. I am always going to bed late. (Y17/SI/23.9.96)

3. *Marking Students' Journals*

During the implementation of this assessment approach students were made aware that their journals would be assessed periodically to evaluate their progress. Initially, students were very wary about having their journals read by another person. I noted,

> Students became very vocal—"Miss it's not possible nor right for you to assess our feelings" or, "Miss, you can't assess our feelings." I allowed them to vent their dissatisfaction before re-gaining their attention and discussing the nature of the assessment. Students agreed that instances such as, when asked to write to a friend or to explain how a problem was solved, would be occasions when the teacher could mark student entries. They also decided on the marking criteria for quality work. For example, they suggested that the following should be considered: explanations, examples, definitions, comprehension and reasoning. (RJ/25.9.96)

The following were three students' comments about this.

> I do not think that you should mark our journals because we may have things in them that are personal. Or we might write things about you which may offend you and your feelings towards us may change. (X22/SI/9.9.96)
>
> How can you mark our work when we are not writing about the same thing and we may see things differently. (Y26/SI/9.9.96)

> If you ask us to work out a problem then that's different because we know what is required from everyone. It [the task] is the same, although we may write about it differently ... We can all be assessed based on the quality of work, the rules, explanation and methods of solving the problem. (X5/SI/9.9.96)

4. *Timing of the Intervention and Workload*

Initially we decided to examine students' journals fortnightly. However, Teacher B found it difficult to do so and as the term progressed he decided that once per month was a more feasible time. He suggested that the timing of the intervention and the workload from his other classes were making it impossible for him to keep reading the journals fortnightly. This meant that Teacher B did not necessarily become aware of a need at the time that it was an issue. For example, one situation that was brought to his attention when he later examined his students' journals was the fact that some students failed to make weekly entries. Student Y26 wrote in her journal on 9.10.96, but the next entry was not until 14.11.96. This was about five weeks later. As it happened Teacher B did manage to address this issue. His 'postie note' read, "Dear [student], why aren't you writing often? Please try, I'll like to hear from you". (14.11.96). This brief response conveyed to the student that her teacher had read what she had written and had examined the frequency of her entries. It also showed that he was interested in her work. Following this entry, that student's entries became more regular, sometimes three times per week.

In sum, the implementation of the use of journals required the collaborative efforts of the teachers and students. There were times when we as teachers failed to follow up the frequency of students' journal entries. On such occasions a reassessment of our practice led us to provide opportunities for encouraging student participation and modelling of desired outcomes. The data showed that students were initially hesitant to incorporate this new assessment. However, with practice, encouragement and sharing of their journal entries many students wrote at least once per week.

8.3 JOURNALS AND TEACHERS' TEACHING

This section addresses the research question: *how did the use of journals influence the two teachers' teaching?* The data revealed that both teachers developed a greater awareness of the need for more student involvement in the learning and assessment processes as is highlighted in the following quotes:

> In the assessment process that has evolved in my class, students have much more control when writing in their journals than they ever had before in any math class. I endorse this action and hope to continue doing so in my other classes. (BJ/ M/4.11.96)

> From observation, although the teacher has encouraged students to use this assessment approach, most students seem to think they only need to write once in awhile. I think as teachers, if we want to help our students become more responsible, we've got to get them to become more active and keeping a journal is a good start. (RJ/30.10.96)

> If students are to show their understanding of a particular problem, then they need to be able to explain and write about it. They need to be more open and involved in the learning process. (BI/M/11.11.96)

Other changes that occurred in our teaching practices were a shift in our focus towards (i) finding out more about students' mathematical understanding and their desires, and (ii) reflecting on our practice to inform teaching and learning. These changes in our teaching are described in the succeeding sub-sections.

Assessing Students' Understanding

Focussing on students' understanding rather than looking for what was either correct or incorrect represented a shift in our traditional assessment practices. It meant that we were even more concerned with student thinking and communication of their mathematical ideas and thoughts. Thus, students' writing helped us to focus on what they knew and could do, and consequently provided more insight into what they actually knew about a topic than single answers on a written test. The following journal entries illustrate instances when assessing students' journal entries provided us with insights about their understanding and/or misunderstanding. In the first example, shown in Figure 8b (overleaf), the mathematics concept taught was indices.

When I examined the first part of student X1's journal entry, my initial thoughts were, 'it's due to an incomplete understanding' of indices. Later, I wondered whether it was more of a partial understanding of integers and indices. A look at her math report helped to arrive at this conclusion. However, based on further examination of student X1's work, I concluded that she knew her multiplication and division of powers facts but was experiencing difficulty in basic algebra. With this information I (i) prepared individualised subsequent instruction for that student, and

(ii) recapped the concepts of Indices and Integers to ascertain other students' understanding.

An examination of student X1's journal entry in Figure 8b revealed the following:

25.9.96 Dear Journal Today I have something different for you to listen to. I'm suppose to tell you all about indices {the big Kuwana}. Well, what I learnt is that Indices is just another word for 'to the power of'. But as you can see it doesn't look bigger ... anyhow it's not just to the power of whatever number it is above of. It has a lot to do with brackets. If a sum is like $(2a)^2$, it's the same as saying 2 x (2a). There are two sides to it. If there are no brackets whatever number comes in front of the power that will be multiplied two times, e.g. $4a^2$ = 4 x a x a = 4a. Another way of writing this is 4^1 x a^2 = 4 x a x a = 4a. If I was ever to get a test on this in the future I would get this. Math Report Integers = 100 % A+	The next day, she wrote: I also learned that you can combine integers with indices. For example 4^3 x 4^{-1} = 4. Because the base is the same and you are multiplying, you add the indices. That is: $= 4^{3-1}$ $= 4^{3+(-1)}$ $= 4^2$ = 4 x 4 = 16 I also learned about division of indices. For example, $2^6 / 2^4 = 2^2$ Because the base is the same and you are dividing, you subtract the indices. That is $2^6 / 2^4 = 2^{6-4} = 2^2$

Figure 8b. A Student's Understanding of Indices

Two further students' journal entries that were the focus of our attention and led to new insights followed by a conscious effort to provide for the students' needs are now presented. The example in Figure 8c exemplifies how examination of students' journal entries followed by informative feedback can prompt students to reflect on, and deepen their understanding of mathematics. However, while student Y14 demonstrated the development in her understanding of this concept, her explanation appears to be a bit vague, that is, 10_5 is recognised as having one bundle of five, but is given a base ten value of 5. This was another occasion when assessment data collected from students' journal entries were used to inform teaching and learning.

Thursday 7/11/96

401	101	5 505
$\underline{\text{x } 10}_5$	$\underline{\text{x } 5}$	5 101 r 0
$\underline{4010}$	505	5 20 r 1
		5 4 r 0
		5 0 r 4

I tried explaining to Sara how to solve this problem. But before this problem was explained to me I was confused and explained it like this

401	Five x 1 unit = 5 divided by 5
$\underline{\text{x } 10}_5$	5 x 9 = 45 divided by 5, 9/5 = 1 r 4
$\underline{4010}$	

The numbers continued and I didn't know whether to stop or continue. So I then chose the safest way that I know. That is, to change both numbers to base ten, multiply the base ten numbers, then convert the base ten answers to base five.

Reflections

I was able to recognise my mistake where I looked at 10 base five and said that the 1 is a bundle of 5. Then I realised that it is already in base five. There was no need for me to use it as a bundle of 5. I should have said since the numerals are all base five numerals then set a zero, 1 x 1 = 1, 1 x 0 = 0, and 1 x 4 = 4. So right away the answer is 4010 base 5. Now I don't have this problem for if while working and the number came out to be larger than 4, then I'll change it by dividing by 5. Similar to base ten, 12 x 8 = 96 not 816. Here you deal with bundles of 10 and not bundles of 5. Now I don't have that problem anymore for I can work them out using the same or even with different bases. Now those are easy. You just change to either the same base and multiply or change both to base ten, multiply them, then change the answer back to which ever base you are asked for.

Figure 8c. Teacher-Student Discourse led to Student Reflecting and Further Explanations

The next example, in Figure 8d, looks at the concept of bases. Students were asked to write to a friend explaining how they would multiply bases. Student Y12 wrote:

Friday 8.11.96

Another student wrote:

12 x 3 (base 2)

$$\begin{array}{r} x3 \\ \hline 4 \\ x3 \\ \hline \end{array} \qquad \begin{array}{r} 2 \times 1 = 2 \\ 2 \times 1 = 2 \\ \hline 4 \end{array}$$

$$\begin{array}{r|l} 2 & 12 \\ 2 & 6 r 0 \\ 2 & 3 r 0 \\ 2 & 1 r 1 \\ & 0 r 1 \end{array}$$

Ans: $\underline{1100}_2$

The same rule applies for addition as for multiplication

Anything more than the base, you divide by the base.
These are so easy.

Figure 8d. Student Posed Problem and Explanations Provide Further Insights

In this example, student Y12's procedure is partially correct, although her explanation of the problem revealed very little about how she solved the problem. The student may be credited for several things. From both observation of her work and discussions with her, Teacher B found that she knew how to change from other bases to base ten and the reverse. However, student Y12 failed to recognise what numerals are included in base two. The effect of this student's journal entry on Teacher B's practice was reflected in his immediate response to arranging with the student to explain her solution. Thus, incorporating journals as a formative assessment tool in mathematics enabled the teacher to pinpoint students' difficulties and thus help them to improve their understanding.

Learning about Students' Needs

As mathematics teachers, we are sometimes guilty of failing to find out students' learning needs when these are not evident in their written work. In this project we used students' journal entries to provide such information. For example, one month after the intervention began, students were asked to write what changes they would like to see in their mathematics class. Their responses varied from one word, such as 'nothing', to several descriptive sentences as shown below.

> I suggest that we can balance the periods. Whenever we read journals it should be a learning process instead of a time waster ... Some students think that it takes up too much time (X6/SJ/14.10.96)

> Asking each student individually if they have any contribution to make may be a better way because some students do not like to answer unless they are asked individually. At the same time those with problems can give their views in a summarised form [written] without orally communicating with other students or fear of looking dumb or being interrupted by others as you are stating your point or problem. (X28/SJ/14.10.96)

> Encouraging students to discuss the problems. I believe this has the greatest effect because students can listen and learn from others, and see where they went wrong. (X6/SI/14.10.96)

> I would like to see all other maths classes following our class because we make sure that everyone understands before moving on. We know what we are going to do and so can prepare ourselves for the class discussions. (Y7/SJ/14.10.96)

In shifting the emphasis away from us, the teachers, as the sole decision-makers of what was best for students, and by considering the data collected from students journals, we were able to address several issues in the instructional and assessment processes. These issues included (i) providing and promoting a classroom environment that was conducive to discussion and more student-student interactions, and (ii) finding ways to make journal writing more attractive and less time consuming while simultaneously ensuring that the syllabus was covered. In trying to address these issues, Teacher B and I (along with teacher J, the other teacher involved in this research) discussed the problems. We agreed that establishing a supportive classroom would have to be left up to the individual teacher's preferences, while it was suggested that journal writing *during* instruction could be encouraged by setting aside fifteen to twenty minutes of our weekly double or eighty minutes instructional time. This therefore meant that students would only be assessed in the first or the last sixty minutes on that day.

Teachers Reflecting on Practice

Teacher B and myself realised that our own practice had to reflect the requirements we placed on our students. This was illustrated by Teacher B during an interview. Reflecting on the progress of the intervention, he said:

> Looking back I can see that there were certain things that influenced my ability to ensure that this intervention was a success. The idea of keeping a journal myself, though good, was tiring too, for at the time I was caught up

> with other professional development activities that required immediate attention. What seems obvious to me now, is that by not practising what I preached, I was inadvertently conveying a message about the value of journals, something that was contrary to my new vision, this new way of looking at learning and assessment. I will agree that it was not the best option to take when I decided to mark students journals once per month. Looking back I was defeating my own goal of promoting journal writing. I never, for a moment, imagined that I was instilling anything but positive ideas about having journals in my students. Yet, there were times when we met I realised that I had to make certain adjustments or everything might just have been a big flop. (BI/M/5.12.96)

Further reflection on our practices revealed that our experiences gained from trialing the assessment approach had taught us some ways to make journal writing useful for our students. We found time and modelling desired outcomes to be important elements in the success of journal writing. Towards the end of the trial, Teacher B allowed time *before, during* and *after* instruction to encourage student writing, but this was not without tension as other activities constantly impinged upon classroom time. While he still lectures because of feeling pressured to cover all the required material, his "early zeal remains" (BI/M/12.96). What seems vital for the success of journal writing in the mathematics class is that our responses to student journal entries give them the assurance that they can talk to us and share their feelings and concerns with us. Thus, reflections can be a powerful change agent. They enabled us, the teachers, to recognise how our actions may affect the class attitude towards the use of journals in mathematics.

8.4 JOURNALS AND STUDENTS' LEARNING

The literature has shown that the use of journals as an assessment tool can aid student learning of mathematics. To find out *what effect did the use of journals have on students' learning of mathematics* this section considers students' (i) views of the use of journals, (ii) connecting school mathematics with real-life situations, (iii) summarising, constructing and reformulating thinking, and (iv) openly communicating feelings and opinions.

Students' Views of the Use of Journals

To identify the students' ideas about the use of a journal as a learning/assessment approach in mathematics, students were asked to write their views about two questions, (i) whether they saw the inclusion of journal writing as an advantage or disadvantage, and (ii) how they felt about engaging in journal writing. This was done on two main occasions, namely during the fourth week, and again eight weeks later at the end of the project. Students' responses to the two issues are summarised in two complementary tables: Tables 8.1 and 8.2.

Table 8.1. Student Views about the Inclusion of Journals in Mathematics

Response to Question 1	Number of Students (n = 54) Forms X and Y	
	4^{th} wk	12^{th} wk
Advantage	8	44
Disadvantage	8	7
Uncertain	38	3

The most significant feature of the data in this table is the shift of students from being uncertain during the first four weeks (70%) to reporting particular advantages at the end of twelve weeks (81%). Eight students initially expressed concern about possible disadvantages when using journals in the mathematics classroom.

Some students said it was time consuming. According to student Y17, "it will be a burden to be writing every day" (Y17/SJ/7.9.96). Another student wrote in her journal:

> Because I am so taken up in my journal, I hardly have the time to concentrate on other subjects. Even if I do get a little time to do another subject my mind is so filled with maths that I cannot concentrate. (Y21/SJ/7.9.96)

This concern was voiced at different times during the trial. One student who had indicated that the use of journals could be a disadvantage explained how journal entries could mislead rather than aid students' learning.

She stated:

> If the information was recorded incorrectly, in the first place, you will keep on reviewing the incorrect information which will result in failure. (Y26/SJ/7.9.96)

Other students considered that writing journals in mathematics was an unnecessary repetition of work. As one student explained quite strongly:

> I don't like journal writing because for me it seems that you'll just be repeating stuff that we do in our classwork book. (X4/SJ/7.9.96)

Advantages expressed by eighty-one percent of students at the end of the twelve week project included 'better understanding', improved study skills and being able to express one's feelings and thoughts.

This is illustrated by student X28 who wrote:

> I think journal writing has had a good effect on my study habits. Before I would be studying for about one week before an exercise. Now, I am able to test my brains every night by trying to remember what was done in class. So I can study every day as I recall what we did and write it in my journal ... I like journal writing because it helps students to develop certain skills and confidence in mathematics. It helps in their academic performance. When compare with discussion, it is less time consuming. (X28/SJ/4.12.96)

When asked in what ways the use of journals helped to build her confidence, she replied:

> Before I never liked asking questions in case someone thought I was exaggerating. Since writing the questions in my journal and having Miss respond to them, I now feel good about asking questions in the class, because it's part of the learning. (X28/SI/5.12.96)

The feeling of the majority of students who subsequently considered that the use of journals had certain advantages are summed up in the comment of the student who exclaimed:

> Why didn't teachers think of it [journals] before? I think there would have been more passes if it was established earlier. It's very good; students can reflect on what they are doing and have done. It makes many things clearer and understandable. (Y15/SJ/4.12.96)

An analysis of the students' responses at the end of the twelve week period to the second question resulted in six categories of views as shown in Table 8.2.

It is apparent from Table 8.2 that most students saw journals as effective in helping them review their work, and also as promoting their learning, particularly by promoting better understanding, performance, recall, and the ability to express one's thinking. Comments such as the following were typical of the students' responses.

> Journal writing is good ... you can express your views written instead of orally. Reflecting helps to refresh the memory of some things that may have been forgotten or helps to check your understanding. (Y18/SJ/4.12.96)

> I think journal writing is good to some extent. For example, when you reflect on what you have done in class, you get to see some things that you may not have understood then, and failed to ask Miss. It gives us a chance to write in our own words what was done. (X8/SJ/4.12.96)

Table 8.2. Students' Views about using Journals in Mathematics

Response to Question 2	**Number of Student (n = 54)**
	Forms X and Y
Assists Review	46
Promotes learning	
• better performance	42
• express one's thinking	42
• better understanding	40
• better recall/memory	38
• receive helpful feedback from teacher	36
• clarify one's thinking	34
• reduce misconceptions	31
• change of attitude towards mathematics	27
• explain to others	27
• extend one's knowledge	19
• ability to identify errors and/or level of understanding	8
Is less stressful	37
Reduces dependence on mathematics textbook	29
Helps with reflections	13
Enables support by peers	5

Entries such as these gave us, as teachers, insights into the attitudes and needs of individual students. They enabled us to uncover certain anxieties such as stress, time and syllabus pressure, that students were experiencing and to provide where possible opportunities to minimise such effects.

Connecting School Mathematics with Real-life Situations

One effect of the use of journals on student learning may be linked to the purposes of the assessment task. Involving students (in the assessment process *during* instruction) in acts of writing helped them to reassess their knowledge of certain mathematical concepts and to make connections with real-life situations. An example of this occurred while introducing the concept of numbers. Form Y students were asked to write in their journals some of the purposes numbers serve in our lives.

Their journal entries revealed that students considered numbers as used for:

- giving information, putting things in order
- counting, statistics, time, dates
- measuring (telling the quantity needed, like the mass or weight)
- selecting TV channels, telephoning, post boxes
- buying and selling, shopping, banking, money
- describing your form or class
- grades in maths, percentage
- baking, fishing, sewing, cooking
- selling, weighing and shipping bananas, cocoa and copra
- telling you the distance travelled
- playing, scores in a game

Discussion with Teacher B revealed that during the class discussion several students 'began to see a broader use of numbers' (BI/M/11.9.96). He then extended the students' list by getting them to look at two other examples, namely '426 E 48 St, Brooklyn, New York, 11233, and freezing point of liquids'. Teacher B explained:

> While this lesson served its main purpose, to get students started on their journal writing, it served also as a springboard for me to find out what they know and to challenge them to look beyond their way of seeing numbers to include other uses of numbers. I therefore had them thinking of zip codes, direction and street numbers, things that we don't use but are familiar with, and then I pointed them to negative numbers. (BI/M/11.9.96)

Getting students to write *during* instruction enabled them to clarify ideas and more fully integrate new materials, as also noted by Countryman (1992). Further, through writing, the students were taken beyond normal classroom assessment tasks, to an assessment task that required them to make sense of mathematics (National Council of Teachers of Mathematics, 1989). In this case, the assessment task on numbers was structured to get students to recognise its relationship to our everyday lives.

Students Summarising, Constructing and Reformulating Thinking

Further examination of students' journal entries confirms Waywood's (1991) finding that most entries are summaries. Over 90% of the entries began: 'Today was ...', 'Today I ...', 'Today we learnt ...' 'Today's lesson was ...'. Less than 4% began with a definition. For instance, 'Significant Figures—the figures of a number ...'. 'Base ten—a number system based on ten numbers ...'. The use of summaries included reviewing learning so that new and old ideas are connected and reflecting on what has been learnt so that gaps may be identified and new questions explored. Figure 8e shows one instance when student X18 went through this process of actively constructing and reformulating her thinking.

Week 10 Wednesday

This is how I would do them:

Unlike bases $15_6 \times 2_4 = —_4$

Step 1

6 ones = 6 x 1 = 6 Change to base ten, then to base 4 since I

1 5_6 5 x 1 = 5 want to bring them all to base 4 before multiplying

11

Step 2 Step 3

$11/4 = 2 \text{ r } 3 = 23_4$ $(4 + 2 = 6)$ $12/4 = 1 \text{ r } 2$

$2/4 = 0 \text{ r } 2$ $12/4 = 3$ $23_4 \times 2_4 = 32_4$

If I got a number higher than 3 I divided the number by 4, since we are using base 4 system The remainder was put under the ones column... The other number was then turned into 4 parts. Next you add the 2 ... then multiply by 2 which give 12. Since it is more than 3, I divided it out and it turned out to be 3. See the problem Later, as I went over my work, I realised that can't be because when you change it to base 10 the answer is different 112_4 ... What I had done before was wrong. After I had turned it to base 4, I just multiplied normally carrying a 1 instead of the 4. See the new answer.

$$\begin{array}{r} 1 \\ 23 \\ \underline{\times\ 2} \\ 112_4 \end{array} \qquad \begin{array}{l} 6 \div 4 = 1 \text{ r } 2 \\ 5 \div 4 = 1 \text{ r } 1 \end{array}$$

Figure 8e. Student Journal Entry showing Development of Thought Process

The journal entry in Figure 8e provides an indication of the student's understanding of the concept; specifically, it shows a partially correct solution. However, without the student's written explanation it could be assumed that there was incomplete understanding. By writing about the assessment task, she was able to reframe the knowledge in her own words, extending and deepening her understanding of operations in number bases. Hence, writing down the thoughts and procedures involved in the steps of the problem solution added another dimension to the processing. The student had the written words which were used to give immediate feedback for clarification and reflection. As Countryman (1992) noted, it is often at the point of utterance or writing that an idea is given form.

Communicating Feelings and Opinions

Journals also provided students with the opportunity to express their feelings and opinions. Reading students' entries led to changes in teachers' teaching and consequently students' learning was affected. As discussed previously, students were asked their views about the effect of this assessment approach on their learning. It was also necessary to gauge their attitude towards the use of journals. Students were asked, on the first day of the intervention, to write how they felt about mathematics and what they liked or did not like about learning it. Students who disliked mathematics typically wrote that it was a boring subject or that they had difficulty passing it. For instance, one student wrote:

> I hate maths because it is my worst subject, I do bad in it. I do not understand some things. (Y14/SJ//9.9.96)

Other students, however, expressed a liking for learning in mathematics.

> I enjoy maths. I like using different methods that I know and to check back my answer to a problem that was challenging. (Y25/SJ//9.9.96)

Another student felt that mathematics is a nice subject and her love for it helped her choose her future career.

> I feel that maths is a nice subject and it has helped me to choose one of my future occupations that of an Accountant. No matter who is teaching it, no one can change how I feel about it. I just love it. (X23/SJ/9.9.96)

Reflecting on the students' responses, both teachers realised the importance of making assessment an integral part of teaching. As Teacher B wrote:

> No wonder some students hate math. It's therefore up to me to try and get them to see math as something that's enjoyable. I somehow have to try and

check more often to find out whether students understand what they are learning. (BI/M/12.9.96)

All students were later asked whether changes had occurred in their attitudes towards mathematics since the implementation of journals. Four students failed to offer any comment, forty-three students indicated that their attitudes had changed positively, and seven students said that their attitude had not really changed very much. Some of their responses are shown in Table 8.3.

Table 8.3. Students' Responses to 'Change in Attitude Towards Mathematics'

Positive Changes	No Change
I began to understand and enjoy maths more than before. (X6/SJ/4.12.96) I like maths now. I like the way it is taught because students' attitudes are changing and I think it [journals] should continue to be used. (X23/SJ/4.12.96) My attitude towards math has changed. It has become more stabilised. I want to go to Form 4B which is a business education class and you have to be very good in math to do accounts. Since, I have taken a much more serious approach to math, I have gained a higher percentage in my tests. (Y12/SJ/4.12.96)	My attitude towards maths was always positive so journal writing will not changed that. (Y26/SJ/4.12.96) My attitude hasn't changed much because I still think maths is quite difficult but the discussions we had when students read their journals have helped me and others a lot. So I am now approaching maths with a more willing and open mind. (X20/SJ/4.12.96)

Journals were also used to communicate students' learning needs to the teachers. One example of this is given in Figure 8f (overleaf) where student X5 was working out two problems involving indices.

This journal entry reveals an urgent call for help. The student knew that the two problems were incorrectly solved but rather than leaving it there, she attempted to show what she knew and then wrote a note in her journal asking for her teacher's help. According to Black and Wiliam (1998), the student has to come to this impasse and seek a course of action to attain the desired outcome. Her course of action was to communicate to the teacher that there was a gap and to seek further help. Thus, far from being a passive object, the student was actively orchestrating certain steps to address her situation. This journal entry also seemed to reveal a profound misunderstanding of indices. I knew from a previous assessment that this student had difficulties with other concepts. Hence, the entry served to reinforce my idea that there was need for scaffolding. I therefore met the student after school to discuss the tasks and give her some extra help.

Week 5

Tuesday

See Me! (Please write)

(i) $(b^2 \text{ x } y^3)^4$

$= (b^{2+} \text{ x } y^{3})^4$

$= (b^5)^4$

$= b^{(5+4)}$

$= b^9$

THIS IS WRONG

$(4m^4)^2 / (5n^2)$

$= (4m^4 / 5n^2)^2$

$= 20mn^{(4-2)}$

$= (20 mn^2)^2$

$= 20mn \text{ x } 20mn$

$= 400mn^2$

Miss, I don't really understand these things. May I come to you so that we can discuss them further. Please !

It doesn't seem I am going to get high marks on this but I am going to ask Miss. I know they are wrong.

Figure 8f. A Student's Call for Help

During our meeting it was necessary for me to probe further. The outcome of our discussion revealed an inability to express mathematics ideas on paper. As a result, the student and I arranged for her to have extra tutorial help twice per week, with her parents' consent, to enable her to overcome the gap between her present performance and the desired learning goals

Journal entries such as the example above provided an effective means of communication between students and teacher, and from a formative assessment perspective allowed the teachers to alter their instruction or provide additional help as needed.

8.5 SUMMARY AND DISCUSSION OF FINDINGS

This chapter discussed data on the use of journals as an alternative assessment approach. The findings are summarised as follows.

Implementation

- Part of this study was concerned with students self-assessing using journals in the sense that they were asked to report on their learning and associated difficulties. To do so, the teachers created *before*, *during* and *after* instruction assessment opportunities for formative purposes. A *before* instruction activity required students to write down something they knew or wondered about the concept or problem, or alternatively they would research the topic. Writing activities that occurred *during* instruction afforded students the opportunity to write about their thinking, feelings or difficulties they were having in solving a task. This activity could also be a continuation of the before instruction activity (Section 8.2). An *after* instruction activity required students to write about something they learned, or to pose a problem and explain how they arrived at their solution to a friend or someone who was absent (Section 8.2). These prompts, used to activate students' thinking, helped to (i) promote interest and competence, (ii) reinforce learning, (iii) relate prior knowledge to new information, and (iv) encourage critical thinking. This finding that journal writing helps students become active participants in their own learning is similar to the conclusion reached by Countryman (1992) and Miller (1992).

- Several writing prompts to encourage students to either reflect on previous work, or to find out new information thereby getting them to shape their thinking (Sections 8.2 and 8.4).

- The data indicate that journals do not have to be read by the teacher every day; they nevertheless should be read frequently if insights into students' understanding and concerns are to be gained and acted upon. The findings point to the fact that some students found journal writing very time consuming (Section 8.4). As a result, on other occasions a few minutes from some lessons was set aside for the procedure. In the initial stage the teachers modelled the desired outcome. This was continued several times throughout the trial.

- The effectiveness of using journals to assess student mathematical understanding may be affected by the role the teacher plays in the assessment process (Sections 8.2 and 8.3). This was seen in the case of one teacher not practising what was required from the students. Although the teacher wanted students to faithfully make journal entries he himself was unable to maintain that standard; perhaps, as a result, some students failed to make regular entries.

- Both teachers found time to use the information collected to inform their instructional practices. They also had to make other adjustments such as changing the frequency of students' journal entries and of their assessment of the journals. As a result both teachers and their students benefited from the use of this approach in the mathematics classroom.

Teachers' Teaching

- The findings show that students' written responses in journals can influence teachers' pedagogical practices positively by giving them an increased understanding of students' conceptual knowledge and learning needs (Sections 8.2 and 8.3). Instructional practices were influenced in at least four ways: (i) reteaching immediately, (ii) designing and scheduling a review or recap of the lesson based on student needs identified from their entries, (iii) interviewing students to probe more to understand their thinking or clarify an assumption, and (iv) using prompts during a lesson to ascertain students' understanding of the concepts or topic under discussion.

- The use of postie notes or smiling faces began as a one-way communication but resulted in a channel being opened for a two-way communication. Postie notes were used initially by teachers to highlight or indicate the need to see a student urgently or to get the student to respond immediately to a task (Section 8.2). However, some students interpreted this as being the norm and soon they were sending the teachers messages in their journals using postie notes.

- In sum, these features described above are representative of a shift in the norms of their classroom environment, namely, a shift from individual or independent work where the focus was on the teacher being the knower and the giver of knowledge, to a student-focussed approach towards the learning of mathematics. Hence it was necessary for students to become active participants in the instructional and assessment processes by the teachers committal to helping them make the changes needed for the trialing of the assessment.

Student Learning

- During the initial phase of the trial many students were wary about the effects of this assessment approach on their learning (Section 8.4). They were mainly concerned that it would be time consuming and hence hinder their attempts at covering the intended syllabus for that term.
- Students were hesitant about the role of journals in mathematics. Most students felt then that while it was necessary to use journals in other subjects, it was not needed in mathematics. Additionally, some students and one teacher voiced their concerns about having the time, or the timing of the trial.
- When questioned at the end of the intervention, 10 of the 54 students remained uncertain about the effect of journals in mathematics on their learning or claimed that the inclusion of this assessment was more of a disadvantage than an advantage. Forty-four were convinced that journal writing provided them with various advantages.
- 46 of the 54 students felt that journals may be used in mathematics to assist students in reviewing previous work. 42 were convinced that the use of journals promoted learning by the changes that occurred in their performances and ability to express themselves. 37 suggested that mathematics became less stressful while over half the class agreed that journals in mathematics help to reduce their dependence on the prescribed text.
- Writing about how they felt about mathematics helped the students focus on what worked or did not work for them (Section 8.4). It also allowed them to express their own ideas or reframe the ideas in their own way thus developing a personal

understanding of new material. This situation reflects what Gopen and Smith (1990) refer to as the intertwining nature of thinking and writing. Additionally, students were encouraged to develop their thinking skills by committing themselves to making frequent journal entries. The data also support Le Gree's (1991) view that writing helps reduce the passive nature of classroom mathematics

- Students' perceived journals as being personal rather than being open to someone else reading their entries. Although the teachers differentiated between journals and diaries, students still felt that they should not be assessed since people think differently. After much discussion and further thinking the students accepted the request for marking, and indeed suggested possible ways in which journal entries may be assessed; they also helped to establish the marking criteria (Section 8.2). The latter arrangement supports Carter et al's (1993) call for transparency in the grading of student journals from the beginning of the project.

The data reveal that journal writing facilitates communication between student and teachers. Through writing, the students were able to communicate their mathematical understanding and shared many positive and negative feelings as well as personal concerns and challenges. The data gave the teachers insights into the attitude and needs of individual students and uncovered mathematics anxiety or peer pressure. Whenever negative attitudes toward mathematics and/or journal writing were revealed the teachers tried to identify the cause and helped change them where possible. There were also individual students who used their journals to indicate their need for special attention or to speak with us privately. However, this mainly occurred during the initial part of the intervention; the frequency declined as students became more comfortable in their classrooms.

As with any single mode of assessment of students' understanding, the use of journals has its strengths and limitations. Journals alone cannot reveal to a teacher all that she would like to know about students' understanding. They can, however reveal to a teacher a great deal about what students know and how they are connecting ideas to generate a larger picture. We still have much to learn about how to use journals as a way for students to show growth in understanding over time.

CHAPTER 9

RESEARCH FINDINGS: INTERVIEWS

9.1 INTRODUCTION

This chapter reports data on the use of interviews as a formative assessment tool in the mathematics classroom. The findings focus on the results from two teachers' trialing this approach as a means of gaining greater understanding of their students' learning in mathematics.

The context for this case study is one in which students in two third forms ($X_{n} = 28$ and $Y_{n} = 26$) were assessed formatively by their mathematics teachers (B and R/ myself) using interviews as an assessment instrument. Students were all interviewed on at least three occasions, *before*, *during* and *after* instruction. However, most interviews were conducted *during* the instruction. This assessment approach was used in conjunction with student journals; hence instances from Chapter Eight are referred to in this chapter. During the trial students were required to (i) pose problems, (ii) solve problems (open-ended or closed), (iii) discuss how they arrived at their solutions, and (iv) carry out research work, that is, to find out about a concept or to complete an extended task.

Using interviews to assess student understanding of Numbers and Number Theory was a novel experience for the students and one of the teachers. Insights from the week's Professional Development workshop on learning, alternative assessments and student involvement in the learning and assessment processes, served to sensitise Teacher B to the need for more student participation. As a result this teacher decided to trial journal writing and further indicated a willingness to trial interviewing to help broaden present assessment practices and to gauge its effect on students for future practices. As researcher/teacher, I also used these same two approaches with another third form. My choice of assessment approach to try was influenced by two factors (i) my interest in encouraging student participation, and (ii) my previous experience of using interviews to explore student mathematical understanding.

The remainder of the chapter is divided as follows:

9.2 Implementing the Assessment Approach

9.3 Interviews and Teachers' Teaching

9.4 Interviews and Students' Learning

9.5 Summary and Discussion of Findings.

9.2 IMPLEMENTING THE ASSESSMENT APPROACH

This section considers the data in relation to the first research question: *how did the teachers implement the assessment approach?* It focuses on three areas, namely, the initiation phase, the development phase and implementation concerns.

The Initiation Phase

Both third forms were introduced to the alternative assessment approaches (interviews and journals) at the same time. We used the school hall to accommodate all students. Teacher B began the session by interviewing me about the trial and expected student participation. This took about two minutes and was recorded. We then replayed it to the students who listened and asked several questions, such as why their forms were chosen, how this trial would affect them as learners, whether the assessment was part of their exams, and whether they would be tested weekly.

These questions were answered by both Teacher B and myself. The students' questioning session was also taped, then replayed so that students could listen to themselves and become more comfortable with being recorded. Students' exclamations indicated to us that allowing students to listen to themselves served as an 'icebreaker' in that they were less restrained.

> I didn't think it was me; let me hear again
>
> [Laughs at another student] Hear, hear that, that's ...
>
> Just listen, you sound good

This is good; let's do it again. (SI/10.9.96)

At this point we allowed the students further experience of listening to themselves and others as they talked about themselves. This activity was limited to a certain extent due to insufficient tape recorders to distribute to students. There were only four tape recorders to be distributed among the fifty-four students. However, the emphasis was on getting students to accept the presence of the tape-recorder in their classrooms.

Our reason for using the interview as an alternative assessment was to enhance student mathematical learning. To do this we decided to (i) probe student thinking, that is, to find out how students solved problems, their strengths and weaknesses, (ii) encourage discourse and in the process help students to recognise gaps or errors in their learning, and (iii) provide learning opportunities to help students achieve desired outcomes.

The Development Phase

During the trial, students were interviewed individually and in group situations. The latter was seen as an advantage because it allowed more students to be assessed at the same time. It also was used to encourage student-student interactions, and to help students to develop the art of listening to others and considering the perspective of others.

Both flexible and semi-structured interviews were used. Flexible interviews were open-ended interviews that were generated on the basis of student work. Although the task might be fixed, questions were intentionally quite general, allowing students to determine the direction and content of the interview. Examples of these are found in Sections 9.3 and 9.4. Other tasks and questions presented to students as the interview progressed were based on students' responses to previous questions and tasks. For example, two non-specific questions used were

- How did you do it? (asked 33 times)
- How would you explain this? (asked 77 times)

Other questions asked included, 'Do you agree? Why/why not?' (26 times), 'Is there another way?' (12 times) and, 'What were you thinking?' (14 times). These questions were found to be useful because they encouraged students to verbalise their thinking but gave no indication of how students should respond. For instance, while correcting students' responses to their first test on Integers, I became aware of the different solutions students had for the task shown in Figure 9a.

Task: Focus on specific aspect

(a) Calculate giving your answer in its simplest form.

$$\frac{-8}{(1-4)\times(-2)} \qquad \text{(4 marks)}$$

Solutions: $-1\frac{1}{3}$, $1\frac{1}{3}$, $-\frac{8}{6}$, $-2\frac{1}{4}$

Figure 9a. Student Responses to Task

On this basis, I wrote, "having assessed their work I need to discuss these solutions and interview at least three of these students in the next lesson". (RJ/12.9.96)

The chosen sample to be interviewed included students who responded correctly and incorrectly. Some students consented to remain and be interviewed collectively during their lunch break, while others were interviewed during instruction. During interviews some tasks were varied and modified in order to focus on particular aspects of thinking, and others were made more difficult in order to test the limits of students' understanding of a concept. A semi-structured interview began with a task designed by the teacher to probe student understanding on a particular concept or to test a hypothesis. This mainly occurred as a result of (i) examination of student work, (ii) something overheard in a group's discussion, or (iii) after analysing an interview. In the semi-structured interview setting, most tasks and questions were prepared prior to the interview.

Both teachers implemented the assessment approach and shared their views of their ability to do so and their progress over time. Analysis of data collected revealed that there were different teacher outcomes. This is mainly because as teacher/researcher, I had a different agenda and hence was committed to completing the project. Teacher B and I began by attempting to involve more students in the assessment process by interviewing them and getting them to verbalise their thinking, but this did not occur as often with Teacher B. One plausible reason may be "the tension that existed between his desire for change and the realities of his mathematics classroom" (RJ/18.9.96). Like my colleague, I too shared feelings of high and low points throughout the 12 week trial. These moments occurred mainly when students voiced their concern about catching up or finishing the syllabus. At such times, I experienced some level of frustration that led me to question myself.

> What can I do; how can I move on to the next step? What can I do to help students see there is more to math than completing a syllabus? Is my role of researcher affecting my role as teacher? (RJ/18.9.96)

Similarly, Teacher B reflected on the implementation of the assessment approach and described his feelings.

> I keep reverting time and again to my previous way of teaching. As they say 'old habits are hard to give up', even though you have the very best intentions. There were times when I couldn't find the time to interview, even one student. Because of insufficient time, I found myself telling students the answers rather than finding out what they know and getting them to spot their errors. It [traditional way of teaching] still gives good results. There are some topics that are best taught in this manner. However, there were good times, especially after our sharing sessions. I felt ready to take the plunge, fully energised ... I had another burst of inspiration and began anew. This had good results. Whenever this occurred, the feedback from students was enormous. But, alas, again you had to find the time to analyse the interviews. As I mentioned before, I found group interviews helpful, just 5 to 10 minutes of interviewing gave a wealth of information about the student understanding and other students' position in a particular group. It was sufficient information to guide my teaching and to prepare or plan work to help such students overcome any difficulties. (BI/M/5.12.96)

On the basis of our regular discussions during non-teaching periods, we re-assessed and modified our plans, eventually changing the frequency of interviewing students from trying to include everyone to selecting and interviewing at least five students daily. We felt that this was a manageable number in terms of analysing tapes and planning for further probing or teaching. Further, our focus was always on the individual student even in cases when students were interviewed while working in their groups. In these cases, we would individually interview one or two students from each group.

Implementation Concerns

The preceding discussion indicates that although both teachers had moments of questioning their actions, one teacher, the researcher continued to move towards the aims of the alternative form of assessment, that is, enhancing student learning through greater student involvement in assessment, while the other teacher wavered and occasionally reverted to traditional teaching practices. Reasons for differences of outcomes are discussed below.

Teacher B and I met weekly to discuss and support each other. During these discussions we shared what we were doing and the direction it was taking. We also met during the final week of the innovation to reflect on the merits and limitations of the implementation process and to consider whether the trial had worked. Analysis of data seems to indicate several reasons for differences in implementation outcomes. These reasons relate to (i) personal commitments, (ii) ways of teaching, (iii) syllabus constraints, (iv) traditional teaching practices, and (v) influence of external examinations. Although syllabus constraints may be viewed as an aspect of the traditional approach they deserve consideration in their own right. Each is now discussed.

1. Personal Commitments

Personal commitment was a concern for both teachers. On the one hand, I the 'expert or researcher', came to the research with an advantage in that I was aware of the different views of student learning, and the level of autonomy and control that can reside with the students. This advantage dictated a different set of classroom activities that closely mirrored the objectives of the trial. The focus was on student thinking and students as active participants in the instructional and assessment processes. Thus, students were required to explain what they knew about a concept, and the connections they were making.

On the other hand, Teacher B felt that because of involvement in other extra curricula activities, time needed for analysing data and preparing for interview sessions and further teaching was greatly reduced. He apologised for inconsistencies in his delivery of this assessment project. He explained:

> Things are not so good with me at present. I have a major exam [professional studies] in a couple weeks time and I am way behind. Every moment I can spare seems to be used up by different commitments. I am involved in school's netball, basketball and athletics; then there is the steel band, the junior team. Not to mention my family. At present, I seem to be pressed hard for time. While I would love to interview more students ... and I see the need for more individual interviews as you pointed out, I think at present this is not feasible. I just can't find the time to analyse more interviews. Just listening to ten minutes of recorded work requires almost an hour to be spent analysing and preparing work. As I mentioned before, I found interviewing two or sometimes three groups resulted in sufficient information to inform my teaching and to help students. I'll say again, my intentions are there, I would love to see this through but I'm very busy at present. (BI/M/11.10.96)

This factor had not been previously considered by me. However, as Teacher B demonstrated, this factor is a valid concern that can affect a teacher's ability to "match their words with action" (RJ/11.10.96). Hence, as Fullan (1993) noted, the implementation of any project is a highly personal experience because it is the individual who finally makes changes to their practice or thinking.

2. *Ways of teaching*

The two teachers differed in their views of learning and the locus of control of learning. Whereas one teacher, the researcher, gave students more opportunities to own their learning, the other teacher controlled most classroom-based assessment activities. Teacher B decided which problem to pose, what questions to ask, and what kind of responses to accept. In summary, what a student was able to demonstrate about her learning was conditioned in part, by the teacher's decisions about what to assess and how to assess it. An example of this occurred when one student asked Teacher B, "if $2^1 = 2$, then would $2^{-1} = {}^{-}2$?" (SI/19.9.96). Rather than finding out more about what prompted the student to ask this question, Teacher B's response was to give her an answer. When interviewed later that student explained her reasoning as:

> If we say that $2^1 = +2$, then it's only logical to think that 2^{-1} will be -2. (SI/19.9.96)

Interviewing this student allowed her to struggle with her understanding of the problem and as a result recognise where the gap in her understanding occurred. She declared, "I was mixing up indices with integers" (SI/19.9.96). This probing activity also served to help the others in that group come to a clearer understanding of indices and integers.

One thing that was common to both teachers' practice was that they followed the same syllabus using the prescribed text—Oxford Mathematics Book 3, along with other supplementary texts. What differed was the teaching approach used by each, that is, a mainly lecture approach in the case of Teacher B versus a mixed approach with less use of the lecture type, by me as researcher/teacher. Hence, the outcomes perceived by both teachers were influenced to some degree by the teachers' different experiences and views of learning.

3. Syllabus and time constraints

The issues of syllabus and time constraint featured prominently during the interviews. Teacher B spoke about the demands of the syllabus at the third form level and how this affected his ability to be creative. He explained:

> The biggest problem is the workload; they give you so many students in a class and you are expected to perform miracles with each one. [Pauses] You may show them where we need to reduce the syllabus covered here [Form 3]; even if you take the initiative you are in the minority. So you are back to square one. (BI/M/16.11.96)

Teacher B continued:

> The syllabus requires you to instil certain values and attitudes in students but I question whether the way we operate allows for this to occur. What I've tried to do was to allow faster students to work on additional problems while I interviewed others ... The workload of this syllabus is not realistic. It does not give us teachers room to manoeuvre. Consider interviewing students, how can you cope when you need additional time for analysing those tapes. I agree that even if you do five per day, it's five less but you need to transcribe that information, analyse it and keep some record of it. You must have some record and that adds to the burden. I have made some suggestions at the last department meeting for the removal of about two topics from the third form syllabus. If this is heeded then the syllabus would be less demanding, less restrictive. Teachers would have the time to stretch out the units and can include other forms of assessment along with testing. (BI/M/16.11.96)

Teacher B's suggestion was supported by other mathematics teachers in the department and was acted upon by the Head of Department who conveyed this to the Mathematics Curriculum Officer for secondary schools. Thus, being able to share our concerns about the demands of the syllabus in trying to implement an alternative assessment approach was effective in attempting to bring about changes to the third form mathematics syllabus. While previous research has not directly pointed to the syllabus as a factor that may hinder implementation of an innovation, it was perceived by both teachers in this research to have a constraining effect on implementing interviewing as a form of assessment.

4. Traditional teaching practices

Traditional teaching practice was seen as another factor that had a counterproductive effect on teachers' ability to implement and sustain the implementation of the interview as an alternative assessment approach in mathematics classrooms. When questioned both teachers voiced similar concerns. Teacher B said:

> Assessment in math over the years has just been a way of measuring the result of drill and practice. The reason why we test is to know how much the student has acquired from teaching. If we were looking at the constructivist approach to learning then we would have to reconsider our assessment practices. In my mind there is nothing wrong with drill and practice because the more students gain success in things, the better they should become over a period of time and there are some areas that are best taught using this approach. However, I have been guilty of the practice and the use of interviews has forced me to rethink this practice. (BI/M/5.12.96)

We also articulated ways in which we perceived traditional practices impacting on the implementation and continuity of using interviews as an alternative assessment for formative purposes. The consensus was that because the present classroom reality is focussed on summative assessment, and where the teaching method is geared to meet such a focus, then making changes had to compete with these established practices. For example,

> Mathematics as presented in our classroom is too deterministic. That is, we feel that there could be only one right answer so we look for only one solution, either right or wrong ... If one takes the view that students learn by doing, listening, talking and reflecting, then that will call for a change in our assessment. In such a situation we will be expecting that assessment will be a part of a learning activity from the students' standpoint. I am looking at situations where a student would probably have done a number of things right ... but I need to know that she thinks about what she is doing and why what she is doing is producing the correct or incorrect result. This is what I set out to do but the reality of it is that it cannot be achieved overnight. There are too many other factors working against its success. We need to veer away from traditional ways of teaching and learning math. (BI/M12.96)

Comments such as those reported above indicate the impact of traditional teaching practices on the teachers' ability to implement interviewing as a form of assessment.

5. *The influence of external examination*

While there was no real focus on the influence of external examinations, both teachers indicated this factor as a deterrent to implementing the assessment approach. Teacher B stated:

> I don't know, but we need to change our way of assessing students in math. Another thing is that all our assessment is geared towards CXC [Caribbean fifth form terminal examination] in the secondary school or the common entrance examinations in the primary school. Because CXC examinations require students to take two papers, the long paper and the multiple choice, all our effort is put into these two areas. [Pauses] It is a very difficult task to

> get teachers to concentrate on anything except X, Y and Z. So our assessment is based directly on what's happening in or by external examining bodies. (BI/M/ 4.9.96)

When discussing what the Caribbean terminal examinations required we felt that it was time for other changes to be made that will give teachers more control of the assessment of students' progress.

A similar concern was voiced in the following response:

> When we are released from the bondages of external examinations and have more control of assessing our students, students who you would have had for at least two years, then and only then can we use successfully nation-wide other forms of assessment. At present, I think we need to use interviews to find out students' reasoning skills. Certainly, I saw this as a barrier towards successfully implementing the project. (BI/M/5.12.96)

The above comments reflect both teachers' views of the influence of external examination, the issue of formative and summative assessments, and the ability to implement the assessment approach. Such comments as above also point to the need for more internal control of students' assessment in mathematics, namely, that of school-based assessment, a concern discussed in Chapter Six.

6. *Continuity*

One issue that was later addressed was that of continuity. The data for this were collected six months after the trial from the one Form 3 teacher who remained at the school and who continued with Form Y. When questioned about the ability to continue with the approach, Teacher B stated that although the desire and willingness to keep trying still remained, it was difficult to continue. This difficulty was related to a shortage of staff which led to a heavy work load for other teachers. Teacher B described the situation as:

> This last term, we were terribly short of staff. I had to be teaching thirty-two periods. [One teacher] went on leave and another left to take up another job. So, I had to be carrying two extra forms ... I have been under a lot of stress. Things are not easy at the moment but I hope next year will be much better. I will try my best to keep trialing some of the things we did. (BI/M/14.12.96)

This issue points to the need for any implementation to be gradual or incremental over time. That is, teachers need time to acquaint themselves with the changes and to gradually implement such changes. As Fullan (1993) contends, it probably also requires teachers to have a clear vision of what they are working towards.

The above discussion revealed the successes and difficulties that both teachers encountered when implementing the interview assessment approach. Researchers have indicated that during implementation, difficulties or obstacles that impede continuity may occur naturally. However, they also believe that planning at the school level is a necessity if such difficulties are to be addressed (Fullan, 1993).

9.3 INTERVIEWS AND TEACHERS' TEACHING

This section considers the perspectives of both teachers as it answers the research question: *How did the use of these strategies influence the teachers' teaching?* The discussion that follows reveals that the impact of this assessment on the two teachers' practice was varied. The effects may be seen in the changes the two teachers made towards (i) providing contextual and meaningful tasks, (ii) probing students' thinking to find out their understanding of specific areas or concepts and to test their limits of understanding, (iii) building student confidence, and (iv) acknowledging student ideas. Several interview excerpts are used to provide further insights into the nature of each of the above.

Providing contextual and meaningful tasks

Developing activities that were contextual and meaningful was something new for both teachers. During the professional development workshop, we looked at what tasks involving Numbers and Number Theory could be used to get students to see mathematics as a part of their everyday activities. This was not an easy process as we wanted to move away from the usual word problem found at the end of each chapter in the text. We were concerned about (i) wording; appropriate and relevant, (ii) interpretation of the question, (iii) level of difficulty, (iv) prior knowledge needed to complete the task successfully, and (v) marking criteria. While it was easier to come to an agreement on some of these factors others, such as level of difficulty and the marking criteria, were discussed more earnestly. One possible reason for this is that we both had different ideas about marking criteria. In the end it was decided that the students should be given the opportunity to do this. It was decided also that we would look for activities that were familiar and of current interest.

One reason for this, as expressed by Teacher R, was:

> If the assessment task can relate to students' everyday life and if students understand the benefits that could be derived from working on the activity,

then the opportunity for successfully completing the task may be great and more enjoyable. (RI/F/4.9.96)

Two of these tasks are outlined in Table 9.1. Each of the above tasks was presented to students in a different format. For example, the first task above was introduced by having the students write in their journals some of the purposes numbers serve in our lives.

Table 9.1. Assessment Tasks

General Context	Focussed Context	Situated Setting
Familiar Activity	Numbers and Number Theory	Using the local newspapers, search for ways in which numbers are used and in what situations. Describe each situation using examples. Write a summary of what you did before, during and after completing the task.
Current interest	Ratios	Design a suitable plan for the netball court and the games room of your school. State (i) reasons for choice of scale, (ii) all measurements, and (iii) an estimated cost for constructing the court and games room.

Compared to previous teaching, finding or consciously trying to include relevant authentic problems represented a change in the teachers' practice. The change had both teachers moving away from the limits of the textbook to looking for tasks that were contextual and meaningful.

It represented a change in the teachers' way of thinking and may be seen as the teachers developing mental models (Costa & Kallick, 1995; Grennon Brooks & Brooks, 1993) from which to interpret teaching, learning and assessing in mathematics. For instance, Teacher B suggested the first task because of the belief that students were unaware of the many ways in which mathematics may be used in real-life settings.

He exclaimed:

> The textbooks do not indicate to student these ways; instead we begin by looking at the history of numbers, Arabic, Roman and Egyptian. Students are not really interested in these. I agree, we should have this knowledge but now I am aware that we need to go beyond this and give them first hand experiences. (BI/M/20.9.96)

Prior to this project, however, the teacher did not object to following the textbook.

The second task is a modified version of a problem from the students' text (Bennt, Bynoe, Goldberg, Singh, Wardle and Weeks, 1996), Oxford Mathematics Book 3, p. 29). The question required students to compare ratios. We rephrased the question as *A plan is made of your school. It is found that the length of the Biology Lab, 15.6m is represented on the plan by the line 7.8 cm long. Find the scale of the plan in the form 1:n.* This was then modified as shown in Table 9.1 to include an assessment task that was of current interest. That is, at that time there was much discussion at the school about the possibility of having an additional hard court and Physical Education room. This task, we thought, would get students to demonstrate a particular behaviour, for instance, being able to compare ratios. We extended the problem to include an estimation of the cost. Students responded favourably to researching these tasks. I was impressed by the depth of investigation conducted by some students and shared this situation with others in the mathematics department. I explained:

> We don't need someone from planning to do this job. I've shown the principal several of these and we think they are very good. One student even suggested where [we] should buy the lumber and plumbing material. She compared the stores' prices ... This is good. (RI/F/20.9.96)

Additionally, we felt that not only did these tasks provide students with situations which required them to use their knowledge in meaningful contexts, but they also generated discussions with a high level of student participation, interest and insights, and provided an occasion whereby we could probe student understanding.

Probing Student Understanding

The goal of using this alternative assessment was to discover and understand student mathematical thinking in order to enhance their learning and to help them overcome difficulties encountered in mathematics. Although the learning/assessment task was fixed, initial questions were quite general and were based on student responses. For example, the task shown in Figure 9b was modified (Bennt et al, 1996, Oxford Mathematics Book 3, p. 80; #15), and used to examine the depth of student understanding of computing integers.

Slim saves his money with a corp bank. He keeps a record of his savings. He starts with $10. Here is a record of his entries for six weeks: 3, ⁻2, 2, ⁻6, ⁻3, 7. Find out how much he has in the bank at the end of the six weeks.

Figure 9b. Modified Assessment Task on Integers

Three students were interviewed *during* instruction. They were able to recognise the problem as one of adding and subtracting Integers, that is "using negative and positive signs, the negative for the withdrawals and the positive for the deposits" (Y1/SI/13.9.96). The responses of two students are given below.

Teacher B; What does each sign refer to?

Y1: The positive sign shows his savings or money in hand and the negative sign his withdrawals. So you'll be adding and subtracting.

Teacher B: Explain to me how you solved the problem.

Y1: I think it is $11. [Another student shakes her head in disagreement with this response] ... I didn't start with the $10, I started here, 3 – 2 = 1, 3 – 6 = ⁻3, ⁻3 – 3 =⁻6, ⁻6 + 7 = 1, and $1 plus $10 equals $11. If you has started at $10 then it would be first you add 10 and 3, then you minus? Then you minus, then you add [pointing to the numbers]

[Someone in the background] Oh yes it's that, minus, you get ⁻3.

Y3: I have a different way. I don't know if it is correct [pauses, looks hesitant].

Teacher B: Go ahead and tell me.

Y3: 7 minus ⁻3 equals 10, I'm going backwards [working backwards], I don't know if it is correct [pauses hesitantly] ... 7 minus negative 3 equals positive 10, 10 minus 6 equals 4, plus 2 equals 6, minus negative 2 equals 8, plus 3 gives you 11.

Teacher B: Where is the $10 he began with?

Y3: Well, it was just an idea, I was trying to solve it by working backwards.

Teacher B: Why did you say 7 – ⁻3?

Y3: I just said minus ⁻3 [pauses] I was working backwards.

Teacher B: Why can't it be 7 – 3? [Student appears not to have understood] What is the 7?

Y3: It's +7, +7 – 3

Teacher B; So will you say it's 7 – ⁻3 ...

Y3: Oh no! It's 7 – 3 equals 4 [the student continues in this manner], 4 minus 6 equals ⁻2 ... The $10 is now accounted for.

Each student interviewed individually was able to explain her thinking and the strategy used to arrive at a solution. Thus, the use of interviews required both teachers to probe student thinking in order to gain a clearer picture of their understanding.

Another change that occurred in our teaching practice was that of withholding giving the correct solution. As previously stated emphasis was placed on listening to individual students while they worked on the task and encouraging them to verbalise their thinking through probing. Teacher B found himself listening to and accepting each student's response. In the case of Y3, further questioning helped her to see the gap in her thinking. This could be seen as one of the occasions when Teacher B went the extra mile, stepping out from the 'comfort zone' of telling to holding back and eliciting student responses. Doing so did pay off for it resulted in student Y3 having to actively process the information by reflecting on her problem-solving processes, before changing her thinking and accepting that of the other two students. Thus, a teacher listening to students as they verbalise their thinking can challenge them to identify gaps in their thinking.

Building Learners' Confidence

Another effect of the use of interviews on our teaching practice may be seen by our focus on building students' confidence in mathematics by providing opportunities to help all students learn mathematics. Using this assessment approach "necessitated a change in practice, primarily having student learning at heart, looking for things other than academic performance" (RJ/5.12.96). The following is a one-to-one interview conducted *during* instruction. The purpose of this interview was to find out the extent of the student's understanding of indices, one unexpected outcome of which was that of providing a student with the opportunity to develop confidence in addressing an audience.

Students were given several tasks to work on individually, then asked to discuss their responses with their peers. As I went around the classroom, I taped their discussions of their solutions and asked certain questions to help students come to a clearer understanding of any particular question. On one such occasion I interviewed student Z1 while she worked on tasks involving indices. I asked her to explain how she solved the problem $(b^2y^3)^4$.

> Z1: b and y are by themselves. That is, you separate the problem into two parts then solve. The answers have to be separated also because (i) the problem was separated into two parts (ii) you cannot multiply nor divide unlike variables; only with like variables can you add and subtract indices, and (iii) the power is raised so you multiply the indices.
>
> Teacher R: Why is there a space here [$b^2 \quad y^3$]?
>
> Z1: Because each part was worked out separately. So you multiplied them and get that.
>
> Teacher R: Look at this [b^2y^3]; is it the same as yours?
>
> Z1: Yes, you just don't need to put the space but when working them out you need to put the space.
>
> Teacher R: Have a look at your text book; now tell me whether we should leave a space. Read the first one for me.
>
> Z1: a^2y^4 means a^2 times y^4. Ooh! [laughs] I understand now. No there isn't any space between them.

First, student Z1 (a repeater who previously indicated a need for help) reacted initially in a way that indicated a belief that I wanted justification of an error. Since (i) I wanted students to become acquainted with the idea that teachers can genuinely be interested in both correct and incorrect responses, and (ii) there was a negative classroom stigma attached to being a repeater, 'dumb or less intelligent', it was therefore important that student Z1 should be encouraged to participate more in the learning process. Additionally, providing her with opportunities to talk about her work in front of others helped her to feel good about her work.

She commented:

> Miss, you wanted to know what I was thinking. You just listened; you never said that's wrong, only "why this or why not this, or try this". I felt that you wanted to hear about my work so I felt good. (Z1/SI/ 4.10.96).

In trying to help build the student's confidence by getting her to talk about her work openly, I had stumbled on a pattern of reasoning that required her to leave a space to indicate that you are working with different terms. Student Z1's reasoning appeared to be consistent with that of another student who also consistently replied, "leave a space". Further probing revealed that this may have been a taught procedure or that it may be linked to the notion that a x b may be written as $a\ \ b$ indicating the removal of the multiplication sign. Teacher B explained:

> It is the practice of some teachers to cover the sign when teaching multiplication of unlike terms. Later they then erase the sign leaving a space. I think this may account for students leaving a space because they think it should be there. (BI/M/11.10.96)

The above discussion reveals ways in which both teachers' practices were affected by the use of the interview as an alternative means of formative assessment. It highlighted also that both teachers were required to shift from 'chalk and talk' to probing for understanding, from using mainly text book tasks to situating tasks within a meaningful and real-life setting. Additionally, there was a shift in emphasis from students listening passively, to students actively participating and being encouraged to develop confidence by openly verbalising their thinking. This is an essential step in getting students to communicate their understanding (National Council of Teachers of Mathematics, 1989, 1993, 1995; Stenmark, 1989).

9.4 INTERVIEWS AND STUDENTS' LEARNING

In this section I examine the findings from the student perspective to answer the research question: *what effect did the use of these strategies have on the students' learning of mathematics?* The data are reported in terms of (i) students' responses to and reception of the interview approach used to assess their mathematical understanding, (ii) students reflecting on their thinking, and (iii) students actively constructing their knowledge as they modified and/or changed their thinking.

Response and Reception

Students were asked to give their views about the use of this assessment approach before and after the trial. While not all students used the same terms to describe their feelings about this approach, where their responses appeared to mean the same thing they have been grouped under the same categories, as presented in Table 9.2. Some students listed one, two or three reasons.

A few students' initial reactions to the interview as an assessment tool showed apprehension. The main stated objection was, 'its easier to write than to explain orally'. Among the possible advantages mentioned were mathematics lessons becoming more interesting, and mathematics becoming more understandable as the students reflected on their processes, and found their mistakes. However, the vast majority appeared to be not in the least apprehensive.

Table 9.2. Students' 'Before' Responses to the use of Interviews

Student Responses	Frequency (n= 54)
Positive	
It seems interesting	34
You'll get to go over your work and find mistakes	12
It will help you understand maths more	10
It will make maths lessons nicer and easier	5
	[n = 49 students]
Negative	
It's easier to work out the problem than to tell someone how to do it	4
I don't like talking about my work	5
I see it as wasting time	3
I think it is too childish	1
	[n = 5 students]

Table 9.3 (overleaf) indicates the students' views after twelve weeks exposure to this assessment approach. Students remarked that the actual experience was enjoyable. Further, being able to explain their thoughts helped them to be able to spot errors, know what they were doing and come to a better understanding of new material.

Looking back at students in Table 9.2, who were initially hesitant about being interviewed, their main concern was, not wanting to talk about their work. When questioned at the completion of the trial, two of the five students indicated that they still felt negative about the use of interviews (see Table 9.3 overleaf). One of the five appeared to be indifferent at the end of the trial. She wrote in her journal, "I don't really like it but I am coping" (Y7/SJ/12.96). When questioned, she replied:

> At first, I seldom participated because it seemed like everyone's watching me. I felt that if I said something wrong everyone hearing would laugh or look at me. I just don't like talking in front of other students ... It's better by myself. (Y7/SI/4.12.96)

Table 9.3. Students' 'After' Responses to the use of Interviews

Student Responses	Frequency (n= 54)
Positive	
Being able to explain what you are doing help	36
It has helped me to understand better	32
It was enjoyable	29
It has helped me to see my mistakes ...	27
It's enlightening and stimulating	23
We were able to concentrate and know what we were doing	11
We need more open discussions	6
It helps build your confidence in maths	5
It challenged you to go over your work and to think about what you are doing	5
We had fun while learning at the same time	2
	[n = 52 students]
Negative	
It's challenging	2
Sometimes you understand a topic ... and may not know how to explain it	2
I just don't like talking	1
	[n = 2 students]

Further probing revealed that this student's indifference stemmed from being labelled as a repeater of that form. As mentioned in Section 9.3, within the classroom sub-culture, students who failed to be promoted to a higher form by virtue of failing the end-of-year examinations where perceived by others as being 'dumb' or 'less intelligent'. As a result, this student was initially reserved. This reservation was gradually reduced as she became more involved. Further, student

Y7's changes in performance may be linked to the effect of using interviews to get her to verbalise her thinking. She claimed:

> When I spoke about my work it was always helpful. I got to look at my mistakes then, and when I didn't understand the question, talking about it or just explaining what is happening helped me too. For example, when I was mixed up with squares and square roots. I thought I was right and that [another student from a higher form who helped her] was right too, and so I did poorly on the test. Then I sent you the note and you interviewed me. By working out the problems that you gave me then, I was able to understand how to find squares and square roots. So I will say talking helps but it is better if you are interviewed by yourself. (Y7/SI/ 4.12.96)

This claim points to the value of interviews in the mathematics classroom. As Peck et al (1989) suggested, when interviews are used in conjunction with written tests they can provide students with immediate feedback and encourage them to learn mathematics. Further, while this student's need for individual interviews was voiced repeatedly, Liedkte (1988) found that when students were interviewed as a group the discussion that ensued help group members to change their attitudes. This suggests that learning will occur once the learner sees the need for it and can accommodate her experiences with new experiences (Grennon Brooks & Brooks, 1993).

Students Reflecting on Their Thinking

Reflecting on the processes involved in solving assessment tasks helped students to understand what was required of them. This was particularly true for student X_3 who realised that her strategy of working backwards was not an efficient strategy because she did not include a vital piece of the information, yet had arrived at the correct answer. The outcome of the discussion which followed the interview with students X1 and X2 helped students of that group to recognise (i) that there was more than one path to arrive at the solution, and (ii) that one's process of arriving at a solution was important. I said to the students:

> There were different ways of arriving at the same solution. This is something that I want you to bear in mind, that some mathematical problems may have more than one way for arriving at a solution. We may arrive at it in different ways; this is similar to how you get to school using different means of transport and routes. What I loved about this discussion is that no one thought that her method was the only way; you were all willing to listen to others as they explained their methods. Also from our discussion we saw what happens when a negative number is subtracted from a positive number, e.g., $7 - {}^{-}3$ and $6 - {}^{-}3$. (RI/F/11.9.96)

Getting students to look beyond finding a correct solution, to focus on their attempts or strategies used to arrive at the solution or to complete the task was a new experience for these students. Analysis of students' responses clearly revealed students' perceptions of their learning process. The evidence from the interviews seems to suggest that the assessment approach had an effect on student learning in that it shifted their focus from looking for the 'correct answer' to looking at different ways of approaching a task. This approach enabled students to be actively engaged in constructing, modifying and reconstructing their knowledge on problem solving and problem posing. Further, the students' responses to interview questions suggest that by using this assessment approach students became able to explore and deduce ways to solve the problem.

However, one student's response at the completion of the trial revealed that she perceived her performance as remaining unaffected by the use of this assessment approach.

> No changes have taken place in my learning. Although I am participating more in maths now, I'm still performing at an average level that I am normally used to. (Y12/SI/4.12.96)

In commenting on the effect of this approach on student learning, I noted:

> [The] increase in their involvement may be a result of getting them to talk about the task and what problems they are having, getting them to identify errors, listening to their explanations and acknowledging their ideas, and guiding them towards a better understanding of topics. (RJ/5.12.96).

The above focus on learning that required students to be insightful problem solvers may have helped students to actively seek solutions (Meier, 1992; Schoenfeld, 1992), and to modify their views or perceptions that mathematics involves looking only for the correct answer (Baroody, 1987). Further, providing students with learning prompts helped them to reflect on the processes they used to complete the task, the prompts serving as interview questions.

Students Actively Constructing Their Knowledge

Interviews were used to assess student mathematical thinking. In the preceding discussion several instances may be linked to students actively constructing their knowledge in the process of explaining their understanding of a concept or task. One of these instances was when students acted on new material based on prior knowledge or experience to form new mental structures, as illustrated in the following excerpt. This excerpt is used to show students modifying and/or changing their thinking during the interview. In this excerpt, students are discussing the value of 5/0 and 0/5, a previous multiple choice question.

Teacher R: What would this be?

X20: It's like saying 2 x 2 = 4 then changing it around and getting the same answer. [Pauses] No, that can't be.

Teacher R: Why not?

X9: No, you take five things out of 0 things because you don't have anything so how could you divide it by five.

X20: That's meaningless, it makes no sense trying to do that.

Teacher R: Are you saying that this one [5/0] is 0 while 0/5 is meaningless.

X20: I think 5/0 = 5 and 0/5 is zero. If you had 5 things and you don't divide it by nothing you still have 5. You don't have to share them among anyone

X9: 0 is a number

Teacher R: You'll still have 5

X9: I think it's wrong.

X20: 5/0 is 0

Teacher R: So you have changed your answer..

X20: Can the second one go as a decimal?

Teacher R: How would you put it as a decimal?

X20: Zero divide by five.

X9: How that can be a decimal?

X20: I'm just thinking. [Looks at the problem once more; suddenly she remembered something] Oh, I know. I know. Since anything multiplied by zero is zero then anything divided by zero is zero. [Pauses] So, 5/0 is zero and I've changed my mind about 0/5 = 0 because you are not dividing by zero here. [Removes her calculator, does some calculation] The way I understand it is from the calculator, 0/5 = error.

X9: Not error for the first

X20: [Uses the calculator once more] Zero divided by five is zero and five divided by zero is –3. No that can't be ... [works it out again] this is saying –3.

X9: Mine is saying error. Oh it's a minus backward three, not minus three.

Teacher R: Can you tell me what it means?

X20: I think it's a special Σ for error. It means it's not possible.

I was impressed with the interactions that occurred in this interview because the student had her friend nudging her and challenging her thinking. I felt that the student who began somewhat confused learnt something as she appeared to be constantly modifying her thinking. She was also able to recall prior knowledge and used that knowledge along with the help of her calculator to come to an understanding of the task. Thus, as Ginsburg et al (1993) concluded, it is important to ask students why they think the way they do.

Eliciting students' responses to gain insights of their thinking and understanding was further explored by Teacher B in the following excerpt. Teacher B was interviewing two students to find out their understanding of decimal places and significant figures. He began: "let's say that I didn't know anything about decimal places and significant figures, how would you explain to me what these are?" (RJ/10.10.96). The following conversation ensued.

Y5: Behind the point. After the decimal point.

Teacher B: What does that mean?

Y5: There is a difference between significant figures and decimal places. Significant figures deals with rounding off and decimal places like giving to a number of places. [Pauses], I can't explain.

Teacher B: Please try again.

Y5: They are different. For example, if you have a number like .0012 and you round it off to 2 decimal places that will be .00 but to 2 significant figures it is .0012. With significant figures the zeros that come after the point are not counted as significant.

Teacher B: Are you sure about that?

Y5: Well [pauses] Well, I think the zeros between [stresses this word] two non-zero digits are significant.

Teacher B: How many significant figures are there in the number 1.006?

Y5: To which one. That will be 2, 4, [thinking aloud] 4 significant figures.

Teacher B: Why 4 significant figures?

Y5: They [the zeros] come between 2 non-zero digits so they are significant figures.

Teacher B: Let's go back to decimal places.

Y5: With decimals when rounding off, the zeros are not counted before or after the decimal point and with significant figures the zeros are added after to hold the place.

Teacher B: Is this so?

Y5: Yes.

Teacher B: Is there anything that we could add to this?

Y22: Zero between two other digits. In 0.0012, the first significant figures would be 1, the 2nd would be 2. The zeros are only counted if they come between 2 other whole numbers. With significant figures, if you have 3 digits and you want it to 2 significant figures you will drop the third number and add a zero.

Y5: Just so? Don't you have to round off first?

Y22: Yes you round off. With decimals you don't need to add the zero. Like 40/100 is the same as 4/10 = .4, there is no need to write .40 but if you had 446 you'll have to put back the zeros.

Teacher B: Show me.

Y22: Like 446 to two significant figures will be 450 because forty-six to the nearest ten is fifty, and 450 [pauses] 450 in standard form is 4.5×10^2. Look at this. We don't need to write the zero. They aren't significant.

Teacher B: What can you say about decimal places and significant figures?

Y22: For significant figures we look at all the digits and decimal places only those after the decimal point.

In this example, Teacher B did not have any idea what student E meant by her opening remark 'behind the point', 'after the decimal point'. It was only as the interview progressed that he gained insights into her thinking.

Assessment of student learning is seen here as an active process that required active thinking by the student (Perrone, 1991). Rather than focussing on memory only the student had to use prior knowledge to come to an understanding of what the task was asking her to do. Just as teachers constantly assess students, so too should students be assessing themselves (Boud, 1990 1995a, 1995b, 199c). The responses of several students indicated that the interview experience was interesting and resulted in greater understanding of the subject (see Table 9.3). For instance, one student stated that the experience produced "great knowledge because of the need to understand so that you could apply what you learned to other situations" (X11/SI/4.12.96).

9.5 SUMMARY AND DISCUSSION OF FINDINGS

The main findings of this chapter may be summarised as follows:

Implementation

- The interview approach was adapted, further developed and modified during the implementation process. This may be useful or otherwise, depending on the adaptation and the solution. For example, adaptation can be useful when it improves the fit of the method to the situation or getting students to focus on their thinking, acknowledging and accepting their ideas and looking for tasks that are context-based and meaningful to students. As such, there were mixed outcome results for both teachers implementing the assessment approach. One teacher referred to changes that occurred in the implementation as 'stalls and spurts'. For the other teacher, although occasionally assailed by doubts, the focus remained on using interviewing to enhance student mathematical learning. The differences in outcomes are not unexpected with an approach such as this. Individual teachers are likely to have spurts and stalls, until they either embrace the changes, modify the changes to suit their needs or disassociate themselves from them.

- The teachers interviewed students who had correctly and/or incorrectly solved the problem. This indicated to students that both teachers were actually interested in their work rather than merely seeking justification of an incorrect response.

- Some assessment tasks were modified to look at either student understanding of a specific concept or task or they were focussed on identifying limits of students' understanding. During the latter, the teachers would pose the question and students were asked on several occasions to pose a similar problem, then solve it. This provided their teachers with further insights into their thinking (Section 9.3).

- One of the two teachers suggested several personal constraints, which occurred naturally, as obstacles that hindered the successful implementation of the use of the interview in assessing student mathematical learning. These constraints (e.g., extra curricula activities) pointed to the need for more time during the lesson to interview more students, and to analyse and prepare instruction to follow up the data collected (Section 9.2).

- The syllabus, time, external examinations and traditional practices were viewed as deterrents to successful implementation. Both teachers agreed that daily assessment practice of secondary school mathematics in traditional classrooms is much less likely to sustain an emphasis on process as opposed to product.

- The implementation depended on the willingness and ability of the teachers to weave it in among other intervening factors and to change or modify their instructional practices.

Teacher's Teaching

- Broadening the assessment of mathematics to include the use of interviews as an assessment tool resulted in identifying more than was possible with traditional paper-and-pen tests. It included the teachers being able to help students to (i) generalise common problem situations, (ii) identify errors or gaps, (iii) generate alternative strategies, and (iv) reflect on their learning and the processes involved in solving mathematical tasks.

- Both teachers remarked about changes in their teaching. This included spending time with students to find out their thinking, preparing tasks to get students to verbalise their thinking, and allowing students to solve problems rather than telling them the answers. Additionally, the level of student participation was seen as a direct influence of each teacher's views of learning mathematics.

- The two teachers reported using interviews to not only assess student knowledge but to also help build student confidence in verbalising openly their thinking. This was a good device especially for students who were repeating the third form.

Student Learning

- Almost all of the fifty-four students perceived the use of interviews in their mathematics classroom as having a positive effect. Although five students initially assumed that it would have a negative effect, by the end of the trial two had changed their minds. Of the remaining three, two did not like to verbalise their thinking, while one student appeared indifferent.
- 36 of the 54 students associated positive changes in their performances to the use of interviews, that is, the ability to explain their thinking or the strategies they were using. Further, 32 agreed that this assessment approach helped them to better understand mathematics. One student preferred to be interviewed in another room or privately, not in front of her peers.
- When given problem-solving prompts, the interview data revealed that students used a variety of strategies to solve the assessment task (Section 9). While there might be other strategies that are more direct in supporting the knowledge construction process, the careful choice of certain tasks helped to facilitate active construction of knowledge.
- Students shifted their focus from looking for the 'correct answer' to looking at different ways of approaching the task thereby shifting their role from passive learners to learners engaged in constructing, modifying and reconstructing their knowledge on problem solving and problem posing.

The mode of assessment described in this chapter involved the use of interviews. Since this ongoing, informal assessment approach was used alongside journals and summative assessment one cannot make any clear cut conclusions regarding these findings. However, based on the data collected from the students and teachers it is reasonable to conclude that the use of interviews as an alternative assessment approach proved helpful for planning classroom instruction and consequently enhancing student learning. It also enabled teachers to examine the growth in students' understanding and their ability to reason and think. The data suggest that secondary school teachers in St. Vincent should find interviews to be a very practicable assessment tool, even while in the process of changing their assessment practices.

CHAPTER 10

RESEARCH FINDINGS: OBSERVATIONS

10.1 INTRODUCTION

In this case study, the classroom observations of the teachers are analysed with respect to the use of observation as an alternative assessment approach. As previously mentioned, teachers did not choose to consider this approach as an assessment technique. However, (i) during our weekly discussions, it was mentioned frequently, (ii) 14 out of 20 teachers surveyed used it as an assessment approach, and (iii) because the focus of this study is on the use of alternative assessments for enhancing student learning, I have decided to include observation as an assessment approach. This chapter reports ways in which teachers used observation to inform teaching and learning. As a result, the chapter addresses only the second and third research questions. The findings reported here result from an analysis of teacher interviews, teacher journals and student interviews and work. The remainder of the chapter is divided as follows:

10.2 Observation as an Alternative Assessment

10.3 Implementing the Assessment Approach

10.4 Observation and Teachers' Teaching

10.5 Summary and Discussion of Findings.

10.2 OBSERVATION AS AN ALTERNATIVE ASSESSMENT

The use of observation represents another way in which teachers can examine the depth of ideas that students hold about certain concepts and thereby gain a clearer picture of students' understanding. Although observation of students is carried out daily by teachers, it was surprising to note that six of the twenty secondary school mathematics teachers surveyed indicated that this approach was not applicable for assessment purposes (see Chapter 6). Similarly, observation was not chosen as an assessment approach to be trialed by the three classroom teachers.

However, an examination of the first six teacher interviews of the intervention revealed that the word 'observe' or a synonym (examine, see, look at, note, watch carefully and/or follow up) was mentioned at least twenty times. The focus was on watching students, listening to student discourse, and as a result, questioning students to encourage participation and explanation of their thinking.

Figure 10a provides an overview of instances of teachers' tendency to refer to observing students' work, their interactions, performance and dispositions.

- Move around the class examining students' work and encouraging hesitant students ... (9.9.96)
- Looking at students' work ... (9.9.96)
- Seeing how involved they were ... (9.9.96)
- Seeing how they are making the links ... (9.9.96)
- Observation of students' interactions ... (9.9.96)
- See how students are performing ... (16.9.96)
- Noting whether they could make the connections between ... (16.9.96)
- I can see students enjoyed working in groups. (16.9.96)
- It was good to see students helping each other ... (1.10.96)
- When I looked at students engaged in group activities ... (1.10.96)
- Group leaders happily carried out their responsibilities ... (1.10.96)
- I noticed that when asked to express 5760 in standard form ... (11.10.96)
- I could see the happiness on their faces ... (15.10.96)
- I examined several students' work ... (16.10.96)
- I observed that they had difficulties ... (16.10.96)
- From observation, some students have shown interest in ... (18.10.96)
- I watched carefully some students' participation in... (25.10.96)
- When I questioned them about this observation ... (25.10.96)
- When we followed up this lesson ... (25.10.96)
- From my observations, grouping students ... (25.10.96)
- I noted that they had difficulties ... (25.10.96)

Figure 10a. Instances of Teachers' Reference to Observing Students

It appears that informal observation is seen by the teachers as a tool that goes with the trade but not necessarily as a formal assessment approach. Hence it tended not to be given the same status as traditional tests or quizzes. It is in this regard that Hopkins (1993) suggested that the key to thorough knowledge of student performance is not in the quantity of right and wrong answers; rather it is in knowing a student's strengths and weaknesses and identifying gaps in the learning process. This comes from direct observation of (i) how students perform on given tasks, (ii) patterns of errors and successes, (iii) when and in what context successes and difficulties occurred, (iv) the consistency with which certain behaviours occur, (v) affective reactions and coping strategies, and (vi) the ease and capacity of students in assimilating and expressing new knowledge. These are discussed further in Sections 10.3 and 10.4.

10.3 IMPLEMENTING THE ASSESSMENT APPROACH

Classroom observation is more than merely sitting and watching students; it is looking with a purpose, and recording and encoding what is observed (Hopkins, 1993; Nicholson and Anderson, 1993). However, such observation is more difficult than it sounds. This section briefly addresses the research question: *how did the teachers implement observation as an assessment approach?* As stated earlier, this can only be indirectly addressed since it was not chosen as an approach to be trialed; hence the brevity of discussion.

When asked to describe her approach to observing student learning, Teacher J replied:

> At first I tried jotting down a few notes on specific students at the end of each class. Then I abandoned that because it was impossible to continue doing so. Next, I tried writing notes at the end of each day but somehow that didn't last for long. Much as I would have love to make notes so that parents could have more information, I just found that it was impossible to do this since there was an increase in the workload. (JI/F/2/10.96)

This teacher felt that the observation process required systematic record-keeping, something which did not seem manageable. However, the teacher recognised that some aspects of student performances became apparent when they were observed on several occasions, as is reflected in the following excerpt where students were working on squares and square roots.

Researcher: How did you introduce this topic?

Teacher B: Well, I began with a discussion about the 3-figure tables and why it was called so. Then we defined the terms squares and square root ... I asked them to find the square of 14.5. Without any other instructions students began working the problem.

Researcher: Would you say that by observing students working on given tasks helped you to assess their understanding?

Teacher B: Certainly, I found out what students knew and could do. Some students used pen and paper to work out [14.5 x 14.5]; others used the tables or a calculator. This [students' responses] were discussed ... Again observation of students' journals helped me to identify those students who were doing extra work ... research and weren't confined by the textbook only. When I looked at some journals, some students had written a half page while others had more than a page on the difference or similarities between squares and square roots. Apparently those children [with more than half of a page] were adding to the information gained in the classroom by reading additional texts and probably getting support from adults. I would say, yes, there were positive changes in students' attitudes and the desire to add more or to find out more about what they learned [in the classroom]. (BI/M/15.10.96)

The above interview excerpt suggests that once instruction begins, teachers have a twofold task to accomplish. They must deliver the instructions while simultaneously assessing the progress and success of the instruction. If necessary, such instructions can then be modified (Airasian, 1996). Teachers need to constantly be aware of what is happening in her classroom. However, doing this tends to be a complicated task, since instruction, assessment and decision-making are occurring simultaneously. For example:

> I found it difficult to bring the class back to the topic when certain students went off on a tangent. It took me a long time to get the student to understand ... (BI/M/1.10.96)

> Observing how students were working made me realise how difficult it was for the slower students to keep up. Sometimes you could see the confusion on their faces and on other occasions that ray of light as they understood the concept. On the other hand, I was concerned about what percentage participation or free rein these students should be allowed and its effect on their learning ... As teachers we are constantly teaching and assessing students; therefore we need to find the balance ... for example, when to give more feedback or how to implement a lesson to involve all students. (BI/M/12.96)

To determine what type of indicators teachers used to monitor the effect of the innovation on students, they were asked how they knew when it was successful. The following comments reveal that teachers found it relatively easy to tell whether the intervention was running as planned.

> Some students got impatient, they were bored and lost interest ... Maybe they felt they were not challenged sufficiently. (BJ/M/12 .96)

> They were tested and very few seemed to have understood. Then I would reteach and reassess, or I got [the students] to tell me what they knew and to pinpoint their mistakes. If they could do so then I knew that the assessment was effective. (F-UI/F1/6.97)

> Students assessed their performances orally or in writing, they seemed enthusiastic about it ... especially when their assessments were close to the teacher's assessment of their work. (RJ/12.9.96)

Thus, teachers could determine the effectiveness of the assessment approach largely through their observations of their students responding to the classroom tasks.

A further analysis of the three teachers' views of observation revealed the characteristics shown in Table 10.1.

Table 10.1. Characteristics of Teachers' Perceptions of Observation Assessment

Observation
• Done constantly throughout the school year (Section 10.2)
• Student-centred. Students and their characteristics are the focus of the assessment (Sections 10.2 to 10.4)
• Unplanned and spontaneous; occurring with the instruction process. There was no need for observation to be structured (Sections 10.2 to 10.4)
• Teachers' impressions are noted mentally and therefore rarely written down (Sections 10.2 to 10.4)

The fact that each teacher and their class was located in a confined space facing and interacting with one another from 40 to 80 minutes per day, means that they could observe a great deal of their students' reactions and dispositions. While informal classroom observations are useful, ad hoc observations conducted without some form of documentation tend to be forgotten or inadequately remembered. Not surprisingly, researchers have sought a degree of structure to observations (Bell, 1993; Clarke, 1996; Wolf, 1993). To ascertain that one has an accurate indication of what students can do, multiple and systematic observations are essential. This is necessary to ensure that the decisions made by the teacher are based upon data that show consistency of performance or dispositions.

10.4 OBSERVATION AND TEACHERS' TEACHING

This section looks at the research findings and seeks to answer the research question: *how did the use of observation influence the teachers' teaching?* The following portraits demonstrate how teachers critically evaluated the learning process, modified instruction and extended student learning through the use of observation. An examination of the data revealed that the teachers observed students to (i) examine particular learning, (ii) identify gaps and help students overcome such gaps, and (iii) form descriptions of students.

Observation to Examine Particular Learning

Observing students as they actively engage in meaningful learning activities and examining the work that they produce presents a view of what students know and can do (Clarke, Clarke & Lovitt, 1990; Ginsburg et al, 1993). The following two scenarios provide examples of the use of observation as an assessment approach. During an instructional session on significant figures, Teacher B gave his class a set of problems to solve. He then circulated around the class going from student to student observing their work. At the end of that day he wrote in his journal:

> Decimal places was a breeze. Most students had a good knowledge of decimal places but were mixing up s.f. with d.p. Their good background in decimal places was a useful prerequisite for s.f. However, when it came to deciding, for example, the third s.f. some students failed to do this correctly. They did not look at the fourth s.f. to determine where to put zero as a place holder. I had to reteach this topic. It took me a long time to get students to understand that when there is a zero at the start or at the end of a number the zeros are not counted as s.f. It is only when the zero is between two digits that it is counted as a s.f. And it took even longer for them to know when to use zeros as place holder. For example, express 17634 to 3 s.f. A number of students wrote 176 and failed to put the two zeros at the end. When I questioned them about this observation, a number of students were confused because they claimed I told them that the zero at the end was not a s.f. I had to explain the difference and this I believe cleared up the confusion. (BJ/M/25.9.96)

In the next scenario Teacher J is looking at squares. She attempts to introduce this by connecting two areas previously covered, namely standard form and indices. Students were first required to estimate the answers. This was to help them overcome certain difficulties that the teacher believed they may encounter when using the Three-Figure tables. Teacher J's observation of student work revealed that students encountered difficulties (i) when the numeral had three or four digits, and (ii) by having an incomplete process, that is, putting the number in standard form but forgetting to find its square, and/or by expressing the number in standard form but inaccurately calculating the index. In the words of Teacher J:

> I had a look at several students' work. They seem to have missed out several idea ... the number is expressed first in standard form, then squared. Another problem existed with indices, for example, $(10^3)^2 = 10^5$. Students are confused with the multiplication rule. You can tell that they are not reasoning for $(10^3)^2 = 10^3 \times 10^3 = 10^{(3+3)}$. When applying the multiplication law of indices they would add and this was done by some students when raising the power by another quantity ... I observed that they had difficulties when it came to shifting the point, if it was 1002. You had to stress that it should be written in standard form because the tables only give you the square of numbers between 1 and 10. This incomplete knowledge surfaced once more when we looked at square roots. To help students overcome these hurdles I took time out to explain and allowed them to use their calculators. It was only after this was done that students showed signs of understanding the problem. (JI/F/16.10.96)

The two classroom scenes captured above present a view of the effectiveness of observation as an assessment approach. Teachers can unobtrusively gain insight into students' approaches to the task as well as their persistence in completing the task, and thus provide opportunities to challenge students to modify their thinking.

Another instance where observation was used to assess student learning was revealed during one of our weekly-meetings. On such occasions we shared observations, made inferences and discussed any emerging patterns of students' performance and attitude toward mathematics. As Teacher J reported, students were asked to solve the assessment task in Figure 10b.

Mrs Walker has \$463 in the bank. She writes cheques for \$184, \$206.78 and \$290.95. Describe the state of her account now. If on the following day, she deposits \$393.86 into her account, describe the change to her account.

Figure 10b. Assessment Task made by Teacher J

> Each student was given a worksheet for recording her thinking about the problem. As I circulated to observe the students' approaches to the task, I noticed that my initial assessment of students' understanding was on target. That is, most students had a general idea of the task. Many recognised it as an integer problem. However, I realised that inaccuracies were occurring in

> determining the correct solution. One student misinterpreted and subtracted rather than added the deposit ... (TJ/F/11.9.96)

Figure 10c shows how two students approached the assessment task.

Student Z8

$$\begin{array}{r} 463 \\ +\ \underline{393.86} \\ 856.86 \end{array} \qquad \begin{array}{r} 184 \\ +\ 206.78 \\ \underline{290.95} \\ \underline{681.73} \end{array}$$

$$\begin{array}{r} 184 \\ \underline{+206.78} \\ \underline{390.78} \end{array} \qquad \begin{array}{r} 856.\cancel{8}^{1}6 \\ \underline{-\ 681.73} \\ 175.03 \end{array}$$

$$\begin{array}{r} 463 \\ -\ \underline{390.78} \\ 72.22 \end{array}$$

Add all negatives

Add the 2 positives then subtract small from big keep the sign of the bigger number.

ANS. = \$175.03

Mrs Walker began at \$463 but had to pay out too much money. After the 2nd cheque, she only had \$77.22, not enough for the next cheque. She'll have an overdraft. After the deposit, she has some money, \$175.03.

Student Z17

You know how much is in hand and what is deposited so adding those will give you the positives.

Next add all the cheques then take away the 2 numbers.

<u>Working</u>

$463 - 184 - 206.78 - 290.95 + 93.86$

$$\begin{array}{r} 463 \\ +\ \underline{93.86} \\ 556.86 \end{array} \qquad \begin{array}{r} 184 \\ +\ 206.78 \\ \underline{290.95} \\ \underline{681.73} \end{array}$$

$681.73 - 556.86 = 124.87$ Ans = \$124.87

Mrs Walker owes the bank \$124.87 because her withdrawals were more than what she had deposited

Figure 10c. Students' Partially Correct Responses

In this task the emphasis was on problem solving. The assessment task was given to help students organise their thinking, and to frame an answer. It (i) reflected as closely as possible what learning was required of students, (ii) exposed student understandings, and (iii) acted as an impetus for developing the necessary skills. This task may be perceived as an authentic-performance assessment task in which student performance was likely to be influenced by contextual factors. As Drummond (1993, p.24) asked, *when we start to look at student learning, what is there to see? How can we learn to see it more clearly?* One way would be to probe student thinking for the level of understanding followed by observations to determine each student's growth, progress and understanding. Teacher J indicated that the "students were quick to spot their mistakes when they had to explain their answers". (TJ/F/11.9.96)

As an assessment approach, the observation of student learning becomes most effective when teachers give appropriate feedback to students who can then improve their learning (Hopkins, 1993). For example, I reported that:

> I [had] observed a few [3] students and made little jottings as reminders to follow up some of my hunches about their performances. Later, I discussed their work with them. As a result, they were able to change their thinking ... As the term progressed I continued paying special attention to their work to see if they could make the connection between indices, standard form and squares. Based on those observations I concluded that sometimes they knew the work but as we moved on to another topic, they failed to make the connections. (TI/R/11.10.96)

In trying to understand student thinking, I interviewed these three students, from my class, individually. One student responded:

> I thought I understood the problems and did them. However, when they were corrected I had more than half wrong. This was because I had the powers wrong. For example, I had $0.005 = 5 \times 10^{-2}$. During our discussion with you I realised that I was confused with where to put the decimal point in numbers less than one ... It helped me to see where I have made mistakes and to look at maths with a much wider perspective than before. (X14/SI/8.10.96)

This response suggests that the student perceived her teacher as working for her benefit, a factor that may account for the gain in interest, and desire to get good grades. The assessment was seen by the student as an opportunity for her to enhance her learning by building on what she has learnt, and helping her to identify gaps in her learning rather than as an opportunity for the teacher to pass judgement on her work.

Identifying Gaps in Student Learning

According to my observations:

> A number of students had difficulties with standard form. They did not know when to put the index as negative and how many places to move the point ... I think some of the problems the students encountered were due to their introduction to the topic in earlier forms. When I questioned these students some replied that they were taught to do it this way and now they were confused. One student, X_1, was certainly confused. I noticed that when asked to express 5760 in standard form she wrote 5760 x 100, similarly 10869 was written as 10869 x 10000 ... I chose to intervene then. So I took her aside and questioned her a bit further. I concluded that, she knew certain facts. However the facts were mixed up. We went through these problems. Then I gave her similar ones to do which she did with ease. (TI/R/11.10.96)

This offered me insight into the students' understanding of standard form. In the case of 5760 = 5760 x 100, the zero in 5760 was ignored. By intervening, I found out that this misconception occurred because of the connection student X1 was making with zero as a place holder and significant figures. Additionally, X1's failure to express the number in the form [a x 10^n] where 'a' lies between 0 and 10 was a consistent behaviour rather than a simple error. The scaffolding that ensued, as a result of my observations, helped student X1 to recognise the misconceptions and to "acquire a better understanding of the concepts of standard form and significant figures" (TI/R/11.10.96). A month later while discussing this student's performance on a mathematics test on square roots, I was able to look back and compare the student's present work with past observations of her performance on standard form. This test also required students to estimate values and write the solution to question C and F in standard form, as shown in Figure 10d.

Task	Problems
(i) Give an estimate of the sq. root	(c) 0.00012
(ii) Find the sq. root	
(iii) Write the solution to C and F in standard form	(f) 20478

Figure 10d. Sample of Square Root Test Items

From my notes, I concluded that student X1's performance had improved over time. Further,

> had I failed to observe her work then she might have been just another one of those students to go through the system with incomplete knowledge [understanding] of certain mathematical concepts. As teachers we need to look closely to what is happening in our classrooms and see where and how we could possibly reach each student. (TJ/R/13.11.96)

Observing students, I considered, can help us to (i) understand them, (ii) learn from what we see, and (iii) help students advance their thinking or performance. Hence, this assessment approach allowed us to focus attention on individual students and provided an opportunity for us as teachers to become acutely aware of certain behaviours that may have gone undetected. The information collected from the observation of students in action was used to inform our teaching and student learning.

Forming Descriptions of Students

Although teachers make inferences about student work every day, few of the teachers in this study were aware initially that observations provide support for such inferences or interpretations of student behaviour and/or performance. During the first few weeks, the teachers were very alert, constantly searching the classroom environment for information about their students. Sometimes their search led them to student readiness, student-student interactions, weaknesses and strengths. They assessed also (i) the degree to which the desired goals or criteria had been achieved, and (ii) student dispositions. In answer to the question 'What was there to see?' that indicated the students were learning, the teachers synthesised their assessment into general descriptions. For example,

> Several students failed to solve these problems correctly because of incorrect interpretations. I have a hunch that many of these students who are having this problem failed to listen. They seem to be a restless bunch and much instruction time is spent on getting them to settle ... However, they are a lovely group of students. They are now learning to accept other student contributions to class discussion. (TJ/F/4.11.96)

> Students' attitude was that they needed to catch up with the other forms. As a result of this, if the assessment task was not perceived as useful or applicable to real life some students became disinterested. This, I believe, affected their learning. (TJ/M/12.11.96)

> You can see some students are genuinely interested in assessing themselves, and this is important, but when it comes to the test they don't perform well. In looking at their progress you can see they have all the other skills and right attitude but something is blocking their knowledge entrance. (JI/F/13.9.96)

The above quotations provide rich and detailed descriptions of students. They present many different student characteristics, rely heavily on informal information, and convey many dimensions of student behaviour and/or performance.

Observation then is an integral component of the assessment process (Boehm & Weinberg, 1987); and while it may be regarded as just a special case of teachers' natural tendency to observe and assess students on the basis of what they see and hear about students in their daily interactions (Airasian, 1996), it could be given the same status, by teachers, as other assessments. As discussed above, observations also provided a frame of reference within which (i) social interaction and meaningful instruction took place, (ii) inferences were made, and (iii) hypotheses were checked. Thus, assessment of student learning based on observation took the form of a descriptive statement of what a student knows and can do. As Nix and Griffin (1991) and Webb (1993) concluded, such statements do not necessarily depend on tests, grades or scores.

10.5 SUMMARY AND DISCUSSION OF FINDINGS

The research findings generated from the data obtained on observation as an alternative form of assessment may be summarised as follows:

Implementation

- The teachers appeared to collect information through informal observation of students as they worked individually or in groups. The findings suggest that teachers collected information about student understanding almost continually and spontaneously (Section 10.2 to 10.4) and made adjustments to their teaching on the basis of their interpretation of the information (Section 10.4). However, the teachers were focussing on other alternative assessments and did not give it the same status as other assessment approaches (Section 10.2).
- When watching students, teachers simply looked for behaviours that provided evidence of student competence on certain criteria. There were no planned or structured observations. Good and Brophy (1994) noted that you can observe a lot by just watching, but it must be guided by knowledge or a frame of reference for as Wolf (1993) concluded, it is difficult to see if you do not know what you are looking for.

Teachers' Teaching

- Teachers observed critical incidents in the classroom, formulated hypotheses about the causes of those incidents, questioned students to test their hypotheses, interpreted student responses and adjusted their teaching (Section 10.3 and 10.4). In this process *the act of seeing gives way to the act of understanding* (Drummond, 1993, p.70). That is, the process of collecting evidence is followed by attempts to make the evidence meaningful.

- By focussing on individual students or on a particular group the teachers became acutely aware of certain behaviours that may have otherwise gone undetected. For example, X1's incomplete understanding of standard form was challenged and modified because her teacher observed the errors she was making and as a result was able to provide X1 with the feedback required to enhance her learning (Section 10.4). Hence, in assessing students, teachers positioned themselves alongside the learners. This enabled them to gain new insights into student learning, thought patterns and misconceptions.
- The data revealed that the teachers were required to deliver instruction while simultaneously assessing its success if they were to understand student learning and engage in informed practice. They therefore had a two-fold task to accomplish, a task that could be complicated (Sections 10.3 and 10.4). Time and again teachers were forced by their observations and analyses to reconsider and reconstruct their framework of meanings.

The findings reported above seem to confirm that observation may be used to assess student performance and dispositions with a view to enhancing their learning. Two characteristics of assessing students in this manner deserve attention. First, most of this information collected comes from informal observations of students. Such observations are (i) spontaneous, and (ii) reflect momentary unplanned happenings that teachers observe, mentally record, and interpret. Second, because the initial information is obtained largely by means of informal observations teachers are exposed to only a small sample of each student's behaviour. Since teachers can observe any given student only part of the time, it is inevitable that their informal observations will be incomplete and limited to what the students happened to be doing at a particular instant. Thus, observations have limitations. Although feelings and attitudes underlie many behaviours, it is often impossible to assess these dimensions through observation. Hence there is a need for other assessment approaches to tap these areas.

In the next chapter, the major research findings are summarised and discussed. Several conclusions and implications of these major findings are highlighted and recommendations are made for further research, curriculum development classroom-based alternative assessments and the general teaching and learning of mathematics.

CHAPTER 11

FINDINGS, LIMITATIONS, AND IMPLICATIONS FOR FURTHER RESEARCH

11.1 INTRODUCTION

Recent research indicates that the use of alternative assessments in mathematics classrooms enhances students' affective and cognitive outcomes. However, the focus of such research has been mainly children in primary schools or intermediate classrooms. Where there have been studies on the use of formative assessment in secondary schools, they have all been conducted in developed western countries with teachers who were experienced in the use of alternative assessments (see Chapters 3 & 4). In the few studies reported, teachers' perceptions of their own assessment practices have not been addressed. A literature search also revealed a striking paucity of published data on classroom assessment practices in the Caribbean. The few published studies focus on summative assessment but call for alternative assessment approaches in mathematics (Broomes & Halliday, 1993). As a consequence, this present study investigated teachers' views about and use of alternative assessments for formative purposes in mathematics. It also examined their impact on student mathematical learning.

In doing so, it sought to add to the body of knowledge about assessment practices by investigating and reporting on formative classroom-based assessment in high school mathematics in the context of one developing country in the West Indies, namely, St. Vincent and the Grenadines. The findings reported separately in the last four chapters, tend to mask the rich tapestry of teacher learning that occurred in the course of the research. This chapter summarises and discusses the main findings from the investigation. The remainder of the chapter is presented as follows:

11.2 Summary and Discussion of Findings

11.3 Broader Implications of Findings

11.4 Limitations of the Study

11.5 Implications for Further Research.

11.2 SUMMARY AND DISCUSSION OF FINDINGS

The main findings of this study can be considered under the following four categories: (i) secondary mathematics teachers' views of assessment, (ii) teachers' implementation of the alternative assessment strategies, (iii) changes in their teaching as a result of the use of the strategies, and (iv) the effect of the use of alternative assessments on student mathematical learning.

Secondary Mathematics Teachers' Views of Assessment

The results from the questionnaire showed that most of the 20 teachers perceived certain limitations in traditional assessment methods and a need to reconsider assessment practices in secondary schools in St. Vincent and the Grenadines, particularly in light of changes in teaching and learning approaches.

- Although all respondents felt that assessment should be reconsidered, two indicated that no change was needed. However, one of the latter argued that changes in assessment practices should be linked to changes in instruction practices.
- Ten respondents felt that present assessment practices did not allow consideration of the usefulness of mathematics or allow it to arise out of practical or real life situations. Fifteen respondents considered that the focus on right and wrong answers was too restricting and did not take account of students' procedures, logical thinking and reasoning. Three suggested the inclusion of other assessment approaches that could be used to provide opportunities for practical work, dialogue, continuous assessment, observations, and the inclusion of higher order thinking and creativity skills. Some teachers reported already using informal alternative assessment approaches, such as observations, quizzes and oral presentations. The use of debates, portfolios and journals

were not mentioned as applicable approaches for assessing students' mathematical understanding.

- Two main reasons given by these teachers for assessing student mathematical understanding were for informing students and informing pedagogy. Selection and qualification purposes of assessment were not suggested as reasons for assessing student learning but may have been taken for granted.

A focus on teachers' views of assessment is essential if classroom changes are to be effective since it is the teacher who is the key to the implementation of any such changes (Cobb, Wood & Yackel, 1990; Nolder, 1991; Prawat, 1992). Getting the teachers to identify what was problematic about their existing beliefs was an important step in the change process (Ernest, 1989; Fullan, 1993; Prawat, 1992). Most responses suggested a readiness by teachers to consider a broadening of assessment methods. This seems to contradict Fullan's (1993) view that teachers tend to be resistant to changes in traditional assessment practices.

Another interesting finding of this study that appears to contradict other research findings relates to the reasons suggested for assessing student learning. Although issues of *selection* and *qualification* are key aspects of summative assessment and have dominated testing in St. Vincent and the Grenadines for many years, the twenty teachers did not suggest these as reasons for assessing student learning. In fact, only one of the twenty teachers surveyed suggested using assessment for reporting purposes. This finding seems to suggest that, although the traditional objectives of testing may remain with us in St. Vincent and the Grenadines, many secondary school mathematics teachers are looking beyond this emphasis towards identifying students' actual mathematical understanding. This finding is supported by these teachers' calls for assessing students over a longer period using continuous school-based assessments (including observation) rather than a single terminal examination.

Teachers' Implementation of the Assessment Strategies

During the professional development sessions in the main study the teachers read, viewed, discussed and actively participated in simulation exercises before selecting the alternative assessment to be trialed. The three teachers involved in this phase of the study voluntarily committed themselves to trialing at least one assessment approach over twelve weeks. While Teacher J implemented self-assessment (Chapter 7), the two other teachers implemented journal and interview approaches concurrently (Chapters 8 and 9). Based on the research findings, a fourth assessment approach, observation, emerged as an approach that was integrated into the chosen approaches used by the three teachers.

Other research has suggested that workload and time can act as constraints, and indeed these were identified in this study. The teachers indicated that these two constraints inhibited their ability to effectively implement the assessment strategies. Two teachers were concerned about the increase in workload. Teaching loads, extra curricula activities and personal commitments limited a dedication to the assessment alternatives but provided the real-life school environment needed to check the feasibility of using the approaches.

The teachers felt that the timing of the trials may have affected the implementation. As discussed in Section 11.3, the shortage of teachers resulted in an increase in other teachers' workloads and hence less time for planning instruction and focussing on the use of the alternative assessment strategy. Such demands can discourage experimentation and transformation (Costa & Kallick, 1996; Wood, Cobb & Yackel, 1992). However, a combination of teacher dissatisfaction with the status quo and working together with others willing to support change enabled the three teachers to overcome these constraints and see the trial to its end. Indeed in Teacher J's case, she continued using the self-assessment approach with her students beyond the trial period. This teacher, although very busy and apparently burdened by the workload at the start of the trial, showed a developing ability to keep focussing on the aim of the intervention and her personal goal of implementing the self-assessment approach in her classroom. Also, she communicated the benefits of this assessment to others which resulted in one further teacher trialing the assessment. As pointed out by Kenny, Schloemer and Cain (1996), having trialed alternatives and being convinced of their benefits to teaching and learning, teachers should then communicate this information to others in the education community. In this study this occurred spontaneously.

Teacher J's priority was to enable her students to take more control of their learning so, although burdened by other impeding factors, she remained committed. Teacher B continued using journals and interviews for the remainder of that academic year, then left for a different profession. With respect to the class that I was teaching, the report from Teacher J suggests that some students were keeping journals during the second and third terms, even though there was no continuity in the use of this assessment approach with this class after the trial. Perhaps the usefulness of the assessment approach to the students themselves explains its continued use.

Teachers faced dilemmas since their new roles required them to act in ways that were in conflict with established traditional teaching and assessment practices. One teacher referred to the changes that occurred while implementing the assessment strategies as 'stalls and spurts'. Another was assailed occasionally by doubts. However, after considering the different roles, each teacher realised that others were facing the same or similar dilemmas. This helped them seek and value support from each other especially when faced with uncertainties in their progress or with the process. For example, Teacher J questioned the amount of control that should be given to students. Teacher B reported feelings of apprehension over what was perceived as no progress. I too experienced moments of uncertainty and apprehension, and questioned whether my role of researcher was affecting that of teacher. The support sessions helped the teachers to move forward or, as Teacher B described it, there was a spurt in enthusiasm and desire to carry out the intervention.

The different perceptions that the three teachers held about learning and assessment seemed to contribute to the progress that each made in implementing the alternative assessment approach. For example, Teacher J's perception of the learning process was to give students more responsibility for their learning whereas while Teacher B acknowledged the need for this, he saw learning as mainly being teacher-centred. Hence, Teacher B reverted to traditional assessment practices. These research findings support those of previous research that suggest that the impact of traditional assessment practices may hinder teachers' from implementing changes (Ginsburg et al, 1993; Romberg, Zarinnia & Collis, 1990).

Results Pertaining to the Effects of the Assessment Strategies

1. Teachers' Teaching

Research findings have indicated that the effect of alternative assessments on teachers' teaching can be positive or negative, and in some cases neutral (Wood et al, 1992). Data collected in the present study from teachers' interviews and journals, and field notes show that there was some change in the teachers' views of teaching and learning and also in their assessment practices. Changes in students' learning of mathematics were also evident. The findings are summarised in Tables 11.1 to 11.3. These show that the use of alternative assessments can improve teachers' teaching and enhance student learning. They consequently point to the need for an alignment of teaching, learning and assessment.

Table 11.1. Effects of the use of Three Alternative Assessment Approaches on Teachers' Teaching and Student Learning

Assessment Approach	Effects on teachers' teaching	Effects on student learning
Self-Assessment	Providing opportunities for students to engage in developing self-assessment skills: self-evaluation and self-awareness Respecting and encouraging students' opinions, insights and assessment of their performance Recognising and acknowledging differences in students' perceptions of criteria for good performance Encouraging students to establish their own criteria	Becoming responsible for their learning, assessing and/or verifying their own mathematical performance Grading their work and comparing their grades to their teachers' grade Establishing marking criteria, discussing and describing good and weak student assessments
Journals	Providing opportunities for and encouraging writing in mathematics Providing opportunities for students to establish marking criteria, research concepts and for shared learning Providing mathematical tasks problems or prompts that encouraged, elicited, engaged and challenged students' understanding Incorporating into their instruction what they learned from listening to students' explanations	Finding mathematics less stressful Becoming less dependent on their textbooks Promoting student learning through the provision of opportunities for students to: (i) express their thinking (ii) perform better, (iii) understand mathematics better, (iv) recall information better
Interviews	Seeking opportunities to attend to student thinking and to challenge and support their thinking Listening to and discussing students' ideas Probing students' thinking Creating classroom environments within which students felt confident and were able to express and discuss their views openly	Enabling them to (i) verbalise their thinking, (ii) understand better, (iii) identify mistakes, (iv) concentrate on and understand what they were doing, (v) challenge the limits of their thinking as they engage in discourse with the teacher, (vi) suggest other possible strategies for arriving at a solution, (vii) find mathematics more enjoyable and interesting

The alternative assessment approaches tried out in this study were conducted in an environment where assessment for summative purposes was dominant. These teachers trialed alternative assessments for formative purposes that by their nature required teachers to be responsive to the ideas and understandings of their students.

While it is clear that teachers' assessment data of student understanding may be collected from a variety of sources, it is also evident that classroom observations have considerable potential as a source. The data revealed that teachers' observations of critical incidents led them to formulate and test hypotheses about the causes of those incidents. The teachers looked at students while they worked individually and/or in group settings. In short, the use of observation as an alternative assessment approach is not a frivolous waste of time but an important dimension to the teaching, learning and assessment processes. For meaningful classroom assessment to be carried out it is imperative that teachers observe students' reactions, performance and interactions. Therefore, it is necessary that observation be viewed as applicable for assessment purposes and that it be accorded at least the equivalent status to that given of, say, the written test.

To understand the changes that occurred in the three teachers' practice, one needs to be able to compare them with what preceded the change itself. These changes are outlined in Table 11.2. The shift discussed in Chapter Two provides some key reference points for locating the changes in the teachers' teaching.

Table 11.2. Common Changes that occurred in Teachers' Teaching

From	Towards
Subject-centered classrooms	Student centered; focus on active participation by all students
Knower of right responses	Listener, facilitator, guide, negotiator, consultant
Classroom environments that restricted dialogue and where emphasis is on correct responses	Classroom environment where students were encouraged to explore ideas, ask questions, shared meanings, made mistakes
Summative assessment only	Inclusion of some formative assessment; modifying instruction and assessment during learning
Assessing to learn what students do not know	Assessing to learn what students understand, and can do; providing immediate feedback; refraining from providing answers
Weekly/mid-term/end of term tests	Ongoing assessment with student involvement.

The changes in teachers' roles concur with findings of others. Research shows that when teachers act upon their knowledge of student thinking, then their beliefs about learning and teaching, their classroom practices and, most importantly, their students' learning and beliefs can be affected profoundly (Nolder, 1991). Similar findings were noted by Cobb, Wood and Yackel (1990) who set out to understand students' learning processes in a constructivist classroom, and simultaneously analysed learning opportunities for the classroom teacher.

The data from this research support the call for an alignment of assessment with teaching and learning (such as by Bazzini, 1993; Black 1995; Broadfoot, 1990; Clarke, 1997; Leder, 1992). Costa and Kallick (1996) postulated that there is a necessary disruption when we shift mental models. Although some researchers (e.g., Torrance, 1993; Pryor & Torrance, 1995) have argued that in practice there is no clear delineation between a behaviourist and a constructivist approach to what formative assessment may resemble, what was clear in this research is that the changes that occurred in the three teachers' teaching (highlighted in Table 11.2, page 219) were accompanied by a shift from a behaviourist approach to elements of a constructivist approach.

Thus, the teacher's role in the learning, teaching and assessment of mathematics appeared to be changing to facilitate student learning. This represents a gradual, yet, significant shift in the three teachers' traditional teaching and assessment practices. It may have been due to the alternative assessment procedures being grounded in constructivism.

In moving towards elements of assessment that fit with constructivism, the three teachers needed to attend to their own conceptual change as well as assessing the students. This was not always an easy task as the teachers had to move from a practice that appeared to be working, to one in which there was a degree of uncertainty. However, the risk was apparently worth taking; their willingness and commitment to the trial paid off for them and their students. Indeed, at the end of that academic year, one teacher from another subject area began trialing student self-assessment in her classroom. Further, the use of alternative assessments for formative purposes provided the three teachers with a window through which they could examine other aspects of student learning that were not previously possible. By opening up these windows, the teachers found that some form of change was inevitable. The data also indicated that the levels of change and reaction to changes varied from teacher to teacher, supporting the view that the implementation process is a personal process, a finding that supports similar claims reported by Fullan (1985).

It should be added that it took courage for the teachers to use elements of a constructivist approach in the classroom. The teachers found that some of their best students initially resisted the change in instruction and assessment even if they found the mathematics boring and not challenging. The teachers needed time to experience success with the alternative assessment approaches, and they needed guidance throughout the implementation process. It appears that any attempts at initiating changes in the classroom need to ensure that there is support, feedback, reflection and collaboration for those involved.

2. *Student Learning*

Researchers have agreed that students should become more involved in the assessment of their mathematical learning (Boud, 1995a, 1995b, 1995c; Falchikov, 1995; Mansfield, 1993). The findings reported in Table 11.1 show that most students in this study changed to some extent from being passive recipients to active learners through their involvement in the assessment process. While research has highlighted and endorsed the need for students to reflect on their learning (Boud, 1995a, 1995b, 1995c; Kenny & Silver, 1993; Stenmark, 1989; Tanner & Jones, 1994), it has not indicated the percentage of students who actually engage in reflecting on their learning as a result of self-assessment. This research shows that not all students reflected on their work. In fact about 46 % of the twenty-eight students claimed that they were either uncertain whether this happened or gave no response, suggesting that they did not reflect. Similarly, to date there has not been any research, in the region or in St. Vincent and the Grenadines, on other changes in students' learning as an outcome of their greater involvement in the assessment process in mathematics. Table 11.3 (overleaf) shows some common changes that occurred in student learning in this study.

Two of the five students who were initially hesitant remained the same at the end of the trial, mainly because they did not like talking about their work in the presence of other students. Generally, all students at some time during the trial became active seekers of knowledge, that is, they were researching topics, assessing themselves or explaining their understanding of a concept. The students constructed their own meanings and strategies and explained their strategies for solving mathematical tasks. This supports the contention that learning is a constructive process (Cobb et al, 1992; Wheatley et al, 1990). By explaining and reflecting on their work most students learned to verify their own mathematical knowledge, check for strengths, weaknesses or gaps in their understanding.

Table 11.3. Common Changes that occurred in Student Learning

From	Towards
Passive learners	Active participants; responsible for their learning; reviewing and reflecting on their work and progress
Focussing on products only	Focussing on processes as well as products
Working without sharing or discussing ideas	Being free to discuss, to share ideas and to make mistakes Explaining mathematical concepts; clarifying their thinking and reducing misconceptions; identifying mistakes or gaps in their understanding

An important finding was the value of the shared decision-making process involving teacher and students in establishing appropriate criteria, discussing performance and selecting strategies. These moments provided the students with opportunities to justify their answers or assess their performance based on the established criteria. Hence they took a more active role in their own learning. This situation is referred to by Harris and Bell (1990) as the redistribution of power to those being assessed.

Additionally, the use of assessment alternatives appeared to challenge aspects of the classroom subculture in each room. For some students, accepting this change was difficult as they saw no need to change: the previous classroom subculture served them well. This may explain why some high achievers were indifferent to trying, for example, journal writing. On the other hand, low achievers who resisted the self-assessment approach may have been wary of changes. With respect to interviewing, they tended to show a preference for private individual interviews rather than being interviewed in the presence of peers. Students also came to realise that teachers were genuinely interested in both correct and incorrect answers to tasks. Further, during the intervention some students voiced their concerns that it would detract from the time needed to complete the mathematics syllabus.

Thus, although (i) the changes that occurred in students' mathematical learning may be attributed to the use of the different assessment approaches, and (ii) the findings may indicate that students would favourably respond to formative assessment approaches in the mathematics classroom, one cannot conclude that students will perform better when traditional assessment practices are replaced. The purpose of this research was not to demonstrate that the assessment approaches worked for these students and for certain mathematical topics; rather it was to assess the feasibility of alternative assessments for formative purposes in the classroom, with the thought that they might enhance student mathematical learning.

11.3 BROADER IMPLICATIONS OF FINDINGS

The results indicate that the three teachers' involved in the trial all made changes in their teaching practices. There were noticeable changes in their pedagogical knowledge and views of the role of students in the learning and assessment processes. Other conclusions that may be drawn from the findings of the present study relate to teachers' views of assessment, formative assessment, and linking teaching, learning and assessment.

Teachers' View of Assessment

A crucial issue for those involved in any educational intervention is the expansion of assessment strategies to guide students as they examine and assess their individual roles in the learning process. Before this occurs, it will require that teachers be receptive to these alternative approaches to teaching and to assessing students' learning. With respect to secondary school mathematics teachers in St. Vincent and innovations in mathematics education the picture is far from being gloomy. Rather than being resistant to any change in the traditional manner of assessment, many teachers already seem to be exploring alternative forms. As was suggested by Fullan (1985), once teachers have examined their feelings and reflected upon their practices, many trials of new approaches will need to occur gradually to persuade them to adopt these approaches. Additionally, teachers will require support systems to assist them in the transition.

Formative Assessment

The findings in this study have indicated that it is possible to use alternative assessments for formative purposes in mathematics classrooms that traditionally have focussed on summative assessment. Formative assessments in this study were designed to explore student thinking as they solved mathematical tasks. This they did, but they did much more as well. By observing how students reacted to the assessment changes, the teachers learned much about the gulf that separates current assessment practices and emerging theories such as constructivism. We also learned that we are novices on how new forms of assessment will work in the classroom.

The data highlighted the need for assessment to occur along with the learning process. For example, regular student-teacher interviews are needed to understand how students are thinking about their work or progress. Such opportunities should be built into the daily classroom activities. As this study found, it may be necessary in secondary schools to interview at least four or five students per day, so that each student would be assured an opportunity to discuss her work with the teacher on a monthly basis. However, more decisive steps are needed for this interest to be translated into practice in order for students to benefit from the use of these assessment alternatives both in performance and satisfaction. One such step is for us to begin by aligning teaching, learning and assessment.

Linking teaching, learning and assessment

Although alternative assessments may be used by teachers to facilitate student learning, the role of instruction is to coordinate the alternatives and maximise learning. To this end, teaching, learning and formative assessment are inseparable. Teachers' instructional practices must be organised to enhance the opportunities for students to learn. As suggested in this research, to help students become active constructors of their mathematical knowledge requires the use of alternative assessment approaches that enable students to reflect on their learning, communicate their understanding either orally or in written form, and develop skills such as self-evaluation, self-awareness and research.

The experience at this secondary school has been that the use of alternative assessments can facilitate changes in student learning, even when there is no history of students and teachers being collaborators during the instructional and assessment processes. If, however, students are to modify their own behaviour as a result of newly learned knowledge then they must own the data. The findings have shown that change will not occur unless the students see the reason for change, believe that it is worthwhile, and see a way of integrating that change into already existing behaviours, attitudes and knowledge. The learning gains are not the sort that can be measured easily by using pre-and-post tests. The learning gain that has been identified in this study is to do with organising teaching, learning and assessment in ways that facilitate learning. If students participate actively in the teaching/learning and assessment processes, then such learning happens. How teachers determine whether a student is doing successful work should be a collaborative process. This is not the case in the traditional education setting of St. Vincent and the Grenadines, where assessment activities have been presented to the students as non-negotiable.

The data from this study show that when students are brought into a dialogue about establishing criteria for good work and for assessing their performance, ownership of the assessment data is possible; this constitutes an important aspect in student learning. It is therefore essential that students are exposed to assessment strategies wherein they become partners in the assessment process and consequently in the learning process. Self-assessment, journal, and interviews are powerful tools for achieving changes in student and teachers' roles in classroom mathematics.

Mathematics education is undergoing considerable change but teachers cannot accomplish it alone. Broad support from the educational community is needed to advance the shifts in teaching, learning and assessment practices needed. The rationale for changing mathematics teaching, learning and assessment and plans for implementing the changes should be known by all involved parties.

11.4 LIMITATIONS OF THE STUDY

The findings of this study should be treated with a certain degree of caution. Firstly, the sample for the trial came from just one single-sex girls school located in the capital of St. Vincent and the Grenadines; hence the results may not be applicable to students and teachers in schools in the deep rural areas of St. Vincent and the Grenadines nor in boys only or co-ed schools. Secondly, only three of the five third form classes were involved in the study (see Chapter 5). The results may have been different for the other two classes, especially the one with predominantly high ability students.

Thirdly, the lack of responses from three secondary schools in the Grenadines to the assessment questionnaire may raise reservations about the external validity of the findings to the population of secondary school mathematics teachers. However, responses from teachers in at least two schools perceived as 'hard areas' were obtained, so the 20 responses received from the 28 questionnaires that were distributed are probably reasonably representative of secondary school mathematics teachers in the country—despite some teachers being on strike.

Fourthly, the project coincided with a period of teachers' strikes in St. Vincent and the Grenadines. This meant that key teachers were absent for varying reasons. The absence of teachers resulted in additional work for those present. One teacher in the intervention claimed that this additional workload affected the successful implementation of the intervention. As a result of the shortage of teachers, I assumed the role of teacher/researcher for the twelve weeks of the trial. This was a role that I would have preferred to relinquish since valuable time was spent preparing work for students, and being at the school for an entire day for four days in each week. Again this was because of the timetabled mathematics schedule for third form classes and the other classes that I was helping. This role limited to some extent my being able to visit rural schools to collect the questionnaires. Most questionnaires were collected during the first week of the second term with the help of some school principals who arranged for me to come to the school and be on hand while teachers filled out the questionnaires. Thus, the help received and that given back showed reciprocity to be an important element of educational research.

Additionally, it was not always easy to persuade the two other teachers involved in the trial to keep records of student progress, date journal entries, or to make frequent journal entries. They appeared often to be sketchy in their depth of reflections and data gathering. They needed reminders and encouragement to do this. The only way to get them involved in the research side of the assessment intervention was during interviews and sharing sessions, where the necessary reflection time was built into the programme.

Fifthly, perceived lack of time was another consideration. This project required the mathematics teachers to give five full days to the professional development sessions before implementing the alternatives. The trialing of alternative assessments for formative purposes did not replace their summative assessment practices, but occurred alongside and complemented them. Not surprisingly, time available seemed related to the priority the teachers' gave to the trialing. For instance, Teacher J wanted her students to become active learners and went about achieving that goal. However, because the duration of the trial was only twelve weeks, it could be argued that at the end of the time, the teachers were just at the stage of beginning to move more fully into another stage after re-examining their traditional practice and taking a few steps in the implementation of alternatives. Further, my initial intentions were to carry out an action research project but due to the time and other unforeseen factors it was not possible to have a cyclic pattern, hence the linear approach (see Table 5.2, page 90).

Sixthly, the content area covered was Numbers and Number Theory. Other mathematics content areas may produce different results.

In any research one always wonders whether students and fellow teachers sometimes say what they think you (as researcher) want to hear, and one also wonders if the enthusiasm of being involved will remain after the researcher departs. Although this did not appear to be the case in this study, but the possibility cannot be discounted.

The Role of the Researcher

During the implementation of the intervention the demarcation line between researcher and teacher was very fuzzy at times. My role was not only that of researching the use of alternative assessments for formative purposes but I was also fully involved in teaching mathematics to a third form class. A unique relationship was developed within this small group of teachers as researchers, as my own experiences of being a teacher and a colleague assisted me to better understand the tensions, issues and successes experienced by the two other teachers.

My dilemma was in wanting to assist and model the alternative assessments and at the same time to be a critical friend of the teachers. I felt that it was important to work with the teachers in helping them to become independent of my role to a degree where they would continue with their assessment practices after the research was completed. During the initial stages of the trials I found it difficult not to judge the teachers' action with my researcher's eyes.

My own interest and over-riding goal was to implement this project for research purposes. The two teachers main interests and goals related specifically to their classroom teaching and assessment practices. Therefore, I placed greater emphasis on the research process. After initially trying to isolate the role of researcher on the one hand but on the other becoming immersed in the teaching, I came to realise that the role confusion no longer presented an issue when each teacher was regarded as a researcher. To a great degree, we were also researching the process. The two teachers were involved in setting the research directions and assisting in my reflections. A collaborative effort was demonstrated often as the teachers made suggestions and expressed what they wished to achieve with their students during our sharing sessions.

The experiences in this research contributed to my own professional development to a large extent through being open to changes in views of learning and the need to (i) probe student understanding of mathematics, (ii) encourage active student participation, and (iii) reduce the emphasis on summative assessment while increasing the use of formative assessment in mathematics classrooms. The changes that I experienced during the production of this thesis through reviewing literature on assessment practices and the need for reforms, discussions about assessment, and conference presentations on the use of alternative assessment for formative purposes meant that at the end of the study many earlier beliefs had been further developed.

Additionally, I have come to realise through the research that the use of alternative assessments has the capacity to put students in touch with their work in ways that enlarge their thinking and expand their knowledge of themselves as learners. Such involvement has been lacking in our education system where a premium is placed on summative assessment that retains a passive role for students.

The effectiveness of the approaches used in this study relate to the purpose of the assessment and the classroom goals. For teachers looking for ways to actively engage students in learning and assessment, the use of self-assessment and journals provides students with opportunities for owning their learning, and interviews provide both teacher and students with immediate feedback. However, when looking at student learning, observation as an alternative assessment offers a vehicle for providing the formative data necessary to identify gaps and errors in students' learning and disposition towards mathematics.

Notwithstanding these limitations, several implications for further research may be drawn from the findings of this study, and these are outlined and discussed in the final section.

11.5 IMPLICATIONS FOR FURTHER RESEARCH

Overall, the results of this study clearly indicate the need for assessment practices in mathematics in St. Vincent to be reconsidered. Well-documented research findings (Masters & Doig, 1992; Wood et al, 1992) have suggested changes in the direction of teaching, learning and assessment. These changes may incorporate aspects of a constructivist perspective that imply the use of alternative assessments for formative purposes such as those investigated in this research. The implications of the findings for teaching, learning and assessment, professional development for teachers, curricula developers and research are discussed in this section.

Teaching, Learning and Assessment

The findings suggest that social competence and intellectual development were facilitated by interaction during the learning and assessment process. As Brown, Campione, Webber and Mc Gilley (1992) and Campione et al (1988) pointed out, intellectual development depends on students adapting and adopting the intellectual tools as they engage in discourse with adults and peers, and as they interact with the environment and a variety of resources. The present research supports the contention that valuable information can be gathered about students' thought processes by analysing details of data collected from alternative assessment approaches. However, the question 'whether it is possible to directly assess the thinking processes a student uses in doing mathematics' remains unanswered. Trials such as those reported in this study need to be well documented if they are to serve as a source of vital information for changes *in* mathematics education. Further, it may be worthwhile to investigate whether it is assessment or opportunity for dialogue that plays the major part in changes that may occur in student mathematical learning.

Formative Assessment

While the debate over the place of tests continues, the need for more formative assessments in mathematics education, that is, the use of assessment approaches that fit the needs of student learning, should be considered. The use of interviews, journals, self-assessment and observation may provide teachers with a deeper understanding of the role of assessment alternatives in mathematical learning and teaching.

Professional Development for Teachers

There are certain implications of this present study for teacher development and changes in their teaching and assessment practices. These implications may be summarised as:

- Teachers need to recognise their role as guides, facilitators and/or initiators instead of transmitters of information.
- Teachers need to develop the sensitivity to know when to intervene to make appropriate suggestions and when to allow students to resolve conflicts, especially when using self-assessment.

- Teachers need to balance the tension between classroom learning and the conventions of the wider society.

This study indicated the importance of ongoing professional development for teachers. The approach used in this research was to provide a week of professional development sessions along with regular classroom-based inservice help in my role as researcher. Other forms of inservice support should be investigated to provide inservice training for mathematics teachers at all educational institutions in St. Vincent and the Grenadines to facilitate or strengthen the implementation of alternative assessments for formative purposes in mathematics classrooms. However, more professional development will not be effective unless teachers and educators actually use methods that model desired practice.

Teacher Pre-service Education

The Teacher Training college in St. Vincent and the Grenadines needs to develop teachers who will be able to confidently use new assessment approaches in their classrooms.

Examinations

The retention of externally controlled examinations continues to restrict the improvement of teachers' assessment practices in St. Vincent. As long as national examinations are externally controlled, the quality of assessment will continue to be directed by their standards and requirements, thus restricting the autonomy and development of teachers as professionals. One suggestion is to reduce the importance of external examinations thereby increasing teacher autonomy and encouraging more student-centred learning environments. While such steps are seen as acceptable in other subject areas (e.g., Science and Social Studies) as assessed by Caribbean Examination Council, the research identifies a need to extend this to mathematics and suggests for a reconsideration of secondary school assessment practices in mathematics in our region.

Curriculum Developers

Changes in emphasis of teaching, learning and assessment in mathematics education must include curriculum change. At present curriculum development does not emphasize formative assessment. Rather the assessment practices focus on summative assessment for qualification and certification purposes. Alongside this there is a need to revise resource materials and text books. These would have to be developed to incorporate aspects of (i) constructivism and its implications for teaching, learning and assessment, and (ii) the use of more formative assessments. Based on this study, it is suggested that some aspects of the Form 3 syllabus might be omitted to provide teachers with more time to utilise formative assessment approaches.

Future Research

The results of this study provided possible answers for the research questions but at the same time raised more questions. Further, fruitful lines of research stemming directly from this study would be to investigate:

- *[Nation-wide] teachers' perceptions of assessment and the use of alternatives for formative assessment purposes.*

The success of any change process will ultimately depend upon teachers. The teachers' views of and attitudes toward assessment, in particular the use of formative assessment in mathematics and other classrooms, need to be investigated more fully, including ways in which these can be developed.

- *The effect of alternative assessment for formative purposes on student learning focusing on relative achievement by diverse student populations in St. Vincent and the Grenadines.*
- *Secondary students' views about assessment.*

Most investigations have been done with elementary school children or with college students resulting in a gap in knowledge about students' thinking at the secondary level. Research efforts at this level are crucial to help teachers, curriculum developers and regional examination bodies such as Caribbean Examination Council.

- *The effectiveness of teachers' implementation of alternative forms of assessment in collaborative classroom research environments.*
- *The effectiveness of teachers as researchers in trialing alternative assessments for formative purposes.*

Lieberman (1995) promoted the idea of teachers as collaborators in classroom research innovations. That is, rather than using a direct teaching approach the shift is towards learning by doing. If reform plans are to be made operational –thus enabling teachers to make effective and long lasting changes – then teachers should not have innovations imposed upon them; rather, teachers should be active participants in the decision-making and implementation processes – discussing, thinking about, reflecting and sharing their thoughts and trying out new practices. Further, it is hoped that through these approaches teachers may recognise the need for widening their contact and hence locating broader support mechanisms, such as partnerships, that provide opportunities for learning and innovation that involve groups or individuals outside the school.

- *The feasibility of having continuous school-based assessment across all topics in all secondary schools in the region.*
- *The use of longitudinal and action research studies on the use of alternative assessments for formative purposes in a cross section of English speaking Caribbean Countries.*

It would be valuable to have similar studies done in other developing countries. This will help us to not only form a data base for the region but to increase our understanding of the need to match practice, theory and ideals of mathematics education with assessment practices.

Finally, in rethinking assessment to address the realities of the Caribbean classrooms at the threshold of a new century, assessment based on real-life experiences that empowers students in their mathematical learning is vital. Teachers must not lose sight of the fundamental value of assessing, namely, providing information so that students can be successful learners of mathematics. The use of alternative assessments is crucial to effective assessment and as such the information collected must be communicated to others. Hence, assessment innovations are imperative now, and would benefit from being research-based and democratically implemented.

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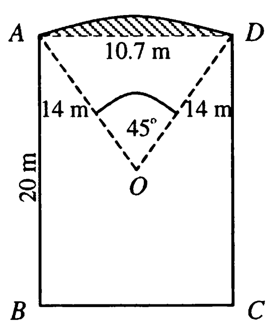
APPENDIX A

EXAMPLES OF CXC ASSESSMENT TASKS AT BASIC AND GENERAL PROFICIENCY LEVELS

Question 1: CXC Mathematics Basic Paper 2, June 1996

Question 6 part (a)

The figure below, not drawn to scale, represents a garden plot *ABCD*. *AOD* is the sector of a circle, centre *O*, with $<AOD = 45°$. $<ABC$ and $<BCD$ are right angles. (Use $\pi = {}^{22}/_{7}$)



Calculate:

(i) the length of arc AD

(ii) the perimeter of the garden plot

(iii) the area of the shaded portion, given that the area of the garden plot is $222m^2$.

(6 marks)

Question 2: CXC Mathematics General Paper 2, June 1996

Question 1 part (c)

(i) The basic wage rate for a technician for a 42 hour week is \$36.40 per hour. Calculate the technician's weekly wage.

(ii) For overtime work the technician is paid one and a half-times the basic hourly rate. Calculate the technician's total wage for 58 hours of work.

(iii) In a new wages agreement, the basic rate of payment is \$1490.00 for 36 hours of work. Calculate:

- the technician's hourly rate of pay
- the percentage increase in the hourly rate.

(7 marks)

Question 1 requires the student to decode the information in the diagram, access relevant information previous learnt about circles, the relation between circumference and arc and area of a circle and of a sector, recall equations, and find the perimeter of irregular shapes, in order to solve the problem.

Question 2 requires students to represent a real world problem in a form that is amenable to mathematical treatment to show the relationship between whole numbers, fractions, decimals and percentages, to do mathematical calculations and interpret the results of their calculations in the context of the problem. Thus a student demonstrates a variety of skills when solving the problem.

According to Broomes and Halliday (1993), these examination questions are designed to assess students abilities and skills. A student's performance is not simply determined in terms of marks, but in terms of students' abilities. Students' performance in the CXC mathematics examinations is described in two main ways, (i) as an overall grade, and (ii) as a profile grade. These are described in **Tables 1** and **2**.

Table 1. Description of an Overall Grade

Overall Grade	**Description**
1	A *comprehensive* knowledge of *all* aspects of the syllabus
2	A *working* knowledge of *most* aspects of the syllabus
3	A *working* knowledge of *some* aspects of the syllabus
4	A *limited* knowledge of *few* aspects of the syllabus
5	The student has not produced sufficient evidence on which to base a judgement

Table 2. Description of a Profile Grade

Profile Grade	**Description**
A	Above average
B	Average
C	Below average
NA	No assessment possible

(Adapted from Broomes and Halliday, 1993, p. 27)

APPENDIX B

ASSESSMENT APPROACHES
TO
ENHANCE LEARNING

A Teachers' Guide

by

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INTRODUCTION

PURPOSE OF THE BOOKLET

Why should we, as mathematics teachers, reconsider assessment? Mathematics learning and teaching has changed considerably in recent years. It is important that our assessment practices reflect these changes and do not undermine them. We would do our students a valuable service if we introduce forms of assessment that actually promote better learning. What are these forms?

This resource booklet outlines several assessment approaches that are in keeping with the latest ideas about learning and teaching in mathematics. They are designed to enhance the quality of learning in mathematics. These approaches differ on so many dimensions that any classification system will have some degree of arbitrariness. The boundaries are at best fuzzy but the categorisation facilitates discussion.

This booklet is a teachers' professional development guide written as a part of a collaborative-action research project. It will be introduced to, and used by, teachers in St. Vincent and the Grenadines. Each second-form mathematics teacher involved in this project will choose at least one from the eight distinct alternative assessment approaches described. Consideration will be given to how each appeoach applies to a Vincentian context.

THE NATURE OF LEARNING AND ASSESSMENT

Recent ideas about the nature of learning and the implications for assessment in mathematics are summarised below.

- **Changes from behavioural to cognitive views of learning**

  We used to think that we should convey various (pre-packaged) learnings to students piece by piece, and that they would absorb them passively. We now know from research that learning involves each student creating personal meaning from new information and prior knowledge. This in turn means that finding out students' prior ideas becomes an important part of assessment.

  Research has also shown that much important learning has a social dimension. It includes peer collaboration and whole class discussion. Students should therefore be given opportunities to explain and justify solutions, and listen and accept or refute the explanations of others.

These changes require assessment approaches that include self and peer assessments, assessment of group work and communication. Providing students with effective feedback is a sound way to better learning.

- **The active nature of learning**

Mathematics education is emphasising the doing of mathematics rather than merely studying the products of mathematicians. In other words, mathematics is an active process that includes questioning, investigating and reflecting. It also involves self-regulation, creativity and imagination in tackling problems.

In terms of assessment, this requires teachers to identify what students are thinking as they solve mathematical problems and what strategies or processes they are using to do so.

- **From paper-and-pencil to other assessments**

Research has shown that paper-and-pencil tests results can give a false impression about the mathematical understanding of many students.

As teachers, we should therefore use a variety of assessment approaches designed to assess both complex and lower-level knowledge. Further, the approaches should be used during meaningful learning tasks. In short, particular mathematical activities will serve the dual purpose of being learning *and* assessment tasks.

ARRANGEMENT OF THIS RESOURCE BOOKLET

The booklet is arranged in two sections.

- Section 1 considers why we need to assess in mathematics education, and then goes on to examine the differences between two forms of assessment: (i) assessment before and during learning (formative assessment) and (ii) assessment after learning (summative assessment).

- Section 2 comprises the following:
  (i) lists eight alternative assessment approaches,
  (ii) discusses their common characteristics.

- The coloured pages (i) provide exemplars of each alternative assessment approaches (ii) offer suggestions of how they can be used in the classroom, and (iii) gives a few advantages and disadvantages of each.

- Questions to consider.
  Several focus questions are given throughout each section and assessment approach. These are intended to encourage your participation through critical reflection and discussion.

SECTION 1

REASONS FOR ASSESSING

Assessment should do more than portray a learner's level of performance. It should help guide action to achieve better learning.

There are a number of reasons why teachers assess students. Six of these are:

- To compare students (this involves ranking rather than finding out how the student is thinking).
- Accountability (e.g., examination results).
- Communication of performance (informing students, reporting to parents, and possible employers).
- To enhance the learning process (e.g., help students become autonomous and self-monitoring).
- Diagnosis (to ascertain areas of students' strengths and weaknesses).

Focus Questions

- When you think about it, what are some of your reasons for assessing?

  ....

  ....

  ....

  ....
- Which reasons are most important? Why?

DEFINITIONS

Assessment is the process of determining students' knowledge, understanding, and intellectual strategies, and using this information to guide subsequent learning.

Two forms of assessment are described here:

(i) assessment before and during learning, and

(ii) assessment after learning.

Assessment Before and During Learning

What is it?

- It is initial and ongoing collection of data about students' ideas and strategies to assist in the improvement of their performance.
- It is a shift away from the more traditional assessment characterised by test scores.

Key features

- It is often informal and seen as part of the learning process.
- It is used to help teachers determine where best to direct their teaching efforts and how they might change their practices.
- It is used to inform students of their progress and indicate how they might improve or where to direct their future efforts.
- It involves a close relationship between teachers and students as they engage in assessment activities.

Uses

Assessment done before and during learning may be used to answer several questions. Three are given below. Please extend the list of questions in the space provided.

- What do students already know within this topic?
- What are they likely to learn next?
- What activities should be provided to foster this learning?

Assessment after learning

What is it?

- It is assessment undertaken when a topic or unit of work has been completed. It may occur at mid-term, end-of-term and end-of-year.
- Assessment after learning is used for reporting to students, their parents or caregivers, the school, and for award purposes.

Key Features

- The emphasis is on what students have learnt over time.
- Sometimes quite disparate data (e.g., practical and theoretical) may be added in arbitrary ways, if there is pressure to produce a single overall result.

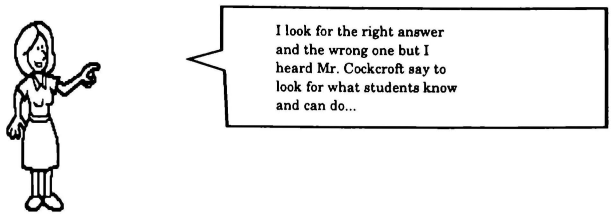
Uses

- To sum up achievement over time.
- To inform interested parties about performance.
- To make informed judgements about future performance, needs of students, and teaching.

Focus Questions

- What are your views of learning and teaching, and how do your ideas about assessment fit with these views?
- Cockcroft (1982) stated that assessment should enable students to demonstrate what they know and can do rather than what they do not know and cannot do. Do you agree with this? What might it mean in practice?
- How would you use the information gained from students' written work?

SECTION 2 DIFFERENT ASSESSMENT APPROACHES



As teachers we want to know what sense students are making of the mathematical experiences we are providing and of their world. There are different ways of finding this out.

The following eight assessment approaches are a selection that you may find applicable to your work.

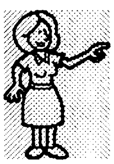
1. Concept maps
2. Interviews
3. Journals
4. Observations
5. Portfolios
6. Practical Work: Investigations
7. Practical Work: Projects
8. Students' self-assessments

These assessment approaches have some common characteristics.

Common Characteristics

1. They are approaches which can be carried out by teachers informally.
2. They may be used for assessment before, during and after learning.
3. They are alternatives to the usual testing involving multiple choice questions or other tests.
4. They assess students' performance in terms of mathematical creation, product and processes.
5. They can tap higher-level thinking and problem-solving skills.
6. They allow the teacher to recognise, value and reward appropriate multiple answers, strategies and invented processes.
7. They use tasks that are also meaningful instructional activities.

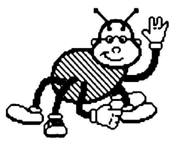
Focus Questions



- What do you understand at the moment by these eight approaches?
- Have you ever used any of them? Which ones? How successful do you think they were?
- Why would a range of assessment approaches be desirable?
- Are there assessment approaches that are more suited to certain topics in mathematics? What are they?
- If you were asked to suggest some approaches for assessing students' performance on the concepts of Number Theory, what would be your choices? Why?

Note: While the following eight alternative forms of assessment are each considered in isolation, they should all be seen in the long run as possibilities for a rich and interrelated assessment programme.

1. Concept Maps



"Forming links between the major ideas of a concept or the important concepts of a topic."

Have you ever used a concept map to assess your students' understanding of topics in mathematics? If the response is yes, then maybe you would like to share your ideas with the others in the group at this point. If no, then consider for a moment what some researchers have to say about this assessment approach.

A concept map is a diagram that shows how a student thinks about a topic. Concept maps may also be referred to as:

- Mind maps
- Thematic webs

In a concept map some terms are arranged on a piece of paper and each is connected by arrows to as many others as is sensibly possible.

Concept maps may be drawn *at the beginning* of a topic:

- This helps the teacher to spot students' misconceptions or gaps in their understanding.

When they are drawn *during* a topic:

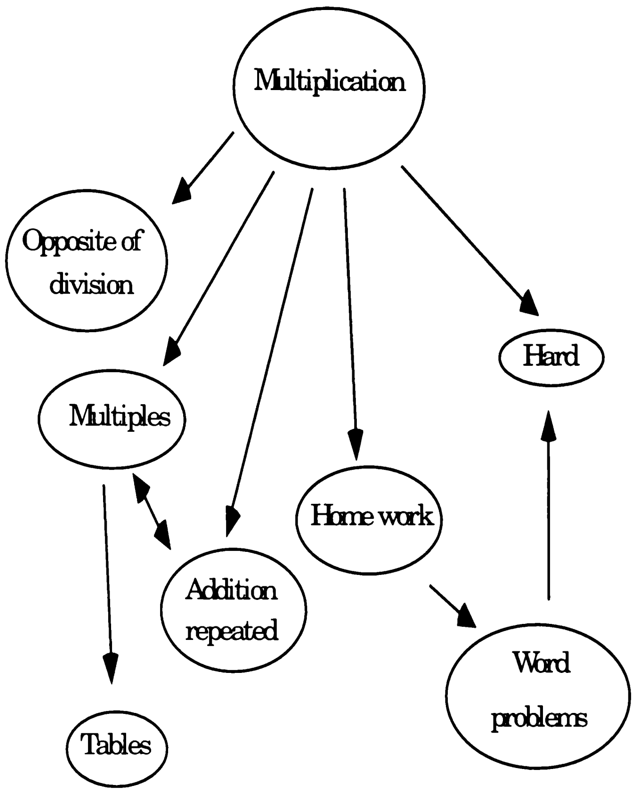
- The teacher gets to see how the students' ideas are coming together.
- They may also be modified during the lesson.

Concept maps may be drawn *at the end* of a lesson or unit of work to show understanding of how parts of a topic relate to each other.

Exemplar

The following concept map shows one student's ideas about multiplication. In this example, the relationships are not written on each arrow as is often the case. As you look at the example, consider

- The possible value of having connectors written on the arrows, and
- Other possible foci.



Focus Questions

- What are your thoughts about this concept map?
- In what Form would you use this assessment approach?
- If you were to give a mark for this concept map, discuss how you would do so. State your reasons for allocating any mark(s).
- If one focus of this type of assessment is to promote discussion, what are some other possible foci?

How to use it

Concept maps can be used to help students integrate a new idea into their thinking. Here are a few tips. Carefully examine each to see whether they are applicable or what changes are needed. You may want to list others in the space provided.

- Begin with a simple and familiar example. Use relatively few terms. A suitable well-known topic can often be from outside the topic you are teaching.
- It may be helpful to introduce concept maps by doing one yourself in front of the class. Let us look at the example above on multiplication.
- If students are working alone, then begin with only 4 to 6 ideas or concepts.
- Emphasise the need to:
  see a concept map as a hierarchy of ideas with a number of tiers,
  think about all possible links (also writing the nature of the links).

The list provided below does not represent all the possible advantages and disadvantages of this assessment approach. Can you think of others? You may write them in the space provided below.

Advantages

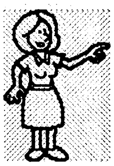
- Concept maps are useful in promoting learning.
- It is an approach that has flexibility and is relatively easy to administer.
- Concept maps also provide opportunities for probing, thus promoting discussion.

Disadvantages

- Initially, students may see the task as being difficult.
- Initially, analysis of the maps may be problematic.

Advantages	*Disadvantages*

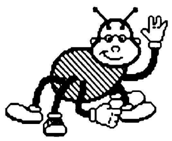
Focus Questions



- Think about some way that a simple concept map might be used in the unit of work on Number theory. What would you expect to get from it?
- Can you think of any situation where the use of concept maps may be useful to assess students' knowledge of a topic?

Other Comments:

2. Interviews



Take a moment to "talk and listen"

There are moments in the teaching/learning situations when, as teachers, we need to probe and investigate students' responses and working strategies. One assessment approach that offers such an opportunity is interviewing which may be formal or informal.

Interviews may be viewed as:

- One-to-one interactions, or one-to-group probing conversations
- Oral communication
- Conferences
- Or they may be modified by the teacher to suit specific purposes.

We may interview students for varying reasons. One reason is suggested below. Please feel free to suggest others in the space provided.

- To find the students' ability to apply mathematical knowledge in unfamiliar contexts such as problem solving.

Interviews can take different forms. For example, they may be structured, semi-structured or unstructured.

Structured interviews:

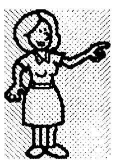
- Use a set schedule of questions which are asked of all students interviewed in the same order.
- May centre around a mathematical task.
- Seek to establish students' mathematical thinking.
- Tend not to probe or follow up interesting and/or important leads during the interview.

Semi-structured interviews (sometimes thought of as conferencing):

- Are similar to structured interviews, but the schedule of questions is considered as a guide only.
- Usually include further probing to follow up leads, or to check seeming inconsistencies.

Unstructured interviews (also known as concurrent interviews) are usually used informally with a student or a group as part of normal teaching to probe students' responses in depth in a flexible manner.

Focus Question



- **Have you ever used interviews as an approach to collect assessment data? How was it done? What do you feel were the advantages and disadvantages?**

Exemplar

The following is an excerpt of a teacher's interview with a student as she worked on a task involving prime numbers. The goal of the interview was to ascertain the student's understanding of the concept of prime numbers.

Teacher: What are your reasons for saying that 1, 2, 3, 5, 7, 9 are prime numbers between 1 and 10?

Student: They all have two factors. See ... [she pulls out her scrapbook and points to the working].

The working revealed the following (dots indicate the presence of other factors):

Number	*Factors*	*No. different factors*
1	1, 1	2
2	1, 2	2
3	1, 3	2
4	1, 2, 4	3
5	1, 5	2
6	1, 2..	4
7	1, 7	2
8	1, 2 ..	4
9	1, 3	2

Focus Questions

- Without interviewing this student, how would you account for her response?
- If you were the teacher, what might you wish to probe further?

How to use it

Let us consider for a moment some of the things that should be done in each phase of the interview. Starters are given and space is provided for you to share your views.

Before the Interview	*During the Interview*	*After the Interview*
Prepare a few questions and tasks	Mention again that you are really interested in the students' own ideas	Summarise results
Plan to make notes or tape-record students' responses	Have follow up questions to check consistency of ideas	
Put students at ease		

Advantages

Using interviews provides a rich source of information regarding students' thoughts, understandings and attitudes towards mathematics. Here are a few advantages for both teacher and students:

For Teachers:

- Awareness of students' personal constructions and how these may differ;
- Delve deeply into students' thinking and reasoning;
- Diagnose (mis)conceptions and missing connections;

For Students:

- Provide opportunities for students who find it easier to communicate orally about what they have done or are doing;
- Allow them to become more aware of their thinking processes;

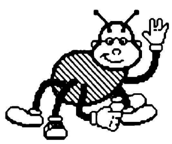
Disadvantages

What do you think might be some of the disadvantages of this assessment approach? Think of ways in which their effects could be minimised.

Focus Questions

- Would group interviews be more efficient than individual interviews?
- How could interviewing be used to assess students' understanding of integers? What are some of the questions that you would ask?

3. Journals



"Writing-to-learn"

Individual records or logs in which students describe their experiences of part or a whole unit of work.

Many would agree that females are good at keeping diaries. What do you think? Have you ever kept a diary or a journal? How would you describe a journal?

Students may keep journals (or diaries or learning logs) in which they record their daily experiences in mathematics class. A simple notebook, doubled-line exercise book, or some loose leaves in a folder may be used. Nothing fanciful or expensive is needed.

Journal writing is different from an essay or a report in that it:

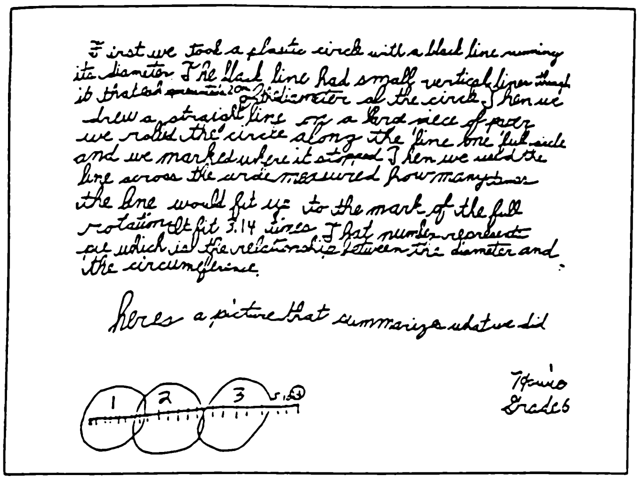
- Focuses on the process of learning rather than the outcome;
- Tends to be informal in style and structure.

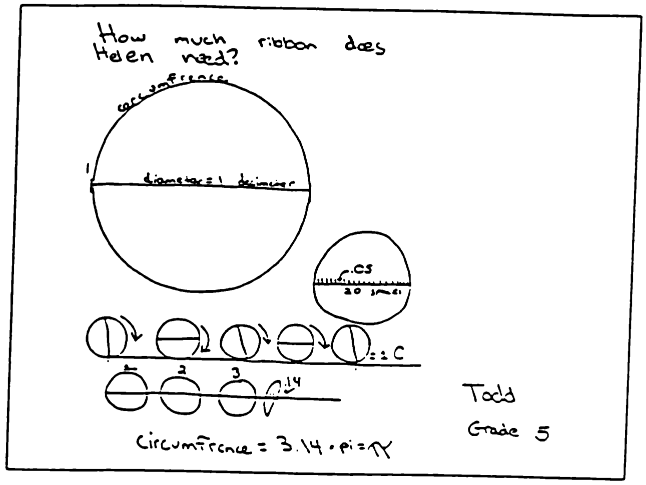
Focus Questions

- Are journals used in any other subjects in the school? If so, could they be extended to include mathematics?
- How would you use the information collected from this assessment approach?
- One use of journals may be to get students to summarise key topics. What do you perceive as the purposes for students' keeping a journal?

Exemplar

Have a look at the journal assessment example below. It was taken from Stix, A. (1994). Pic-Jour Math. *Arithmetic Teacher,* 41(5), 264–268.





Assessment Form

Name: Howie   Topic: Pi
Evaluator: Diane   Date: 2/12/92

A. Application

	Words	Pictures	Numbers
1. diameter ÷ into 20 parts	✓	—	—
2. rolled out circumference	✓	✓	—
3. measured amount of diameters	✓	✓	✓
4. answer = 3.14	✓	✓	✓
5. 3.14 = relationship of d + c	✓	—	—
6.	—	—	—
7.	—	—	—

B. Central idea

1. Offers logical evidence to support every major point: •Clear logical order •Good squence ability •Smooth transition between steps	1	2	3	4	5-
2. Manipulates diagrams or materials	1	2	3	4	5
3. Coordinates pictures, numbers, or words	1	2	3	4+	5
4. Exhibits a level of understanding	1	2	3	4	5

C. Comments

The written explanation is clear and easy to follow. In the number/picture section, Howie used an arrow to prove .14. I needed to refer to the diagrams to recognize that Howie knew that each 20th of the diameter equalled .05

D. Overall rating

nonexistent	marginal	adequate	above average	excellent
1	2	3	4	5-

Assessment Form

Name: Todd   Topic: Pi
Evaluator: Sue   Date: 4/12/92

A. Application

	Words	Pictures	Numbers
1. diameter = 1 decimeter	—	✓	—
2. each of 20 sections = .05	—	✓	✓
3. rolled circumference rotation	—	✓	✓
4. finds 3 whole diameters	—	✓	✓
5. finds .14	—	✓	✓
6. answer 3.14 = pi	—	✓	✓
7.	—	—	—

B. Central idea

1. Offers logical evidence to support every major point: •Clear logical order •Good squence ability •Smooth transition between steps	1	2	3	4	5
2. Manipulates diagrams or materials	1	2	3	4	5
3. Coordinates pictures, numbers, or words	1	2	3	4	5
4. Exhibits a level of understanding	1	2	3	4	5

C. Comments

Student relies on pictures & numbers to [illegible] concepts. Uses words only as labels. Needs more of an explanation & relationship [illegible] circumference does not equal pi. [illegible] student for verbal/written clarification [illegible] integration of concept.

D. Overall rating

nonexistent	marginal	adequate	above average	excellent
1	2	3	4+	5

On the basis of your observations of the given example, what other features would you like to be assessed?

How to use it

Here are a few hints:

- Think about introducing this approach at the beginning of the school year rather than during it so that students may feel at ease and ready to tackle this new process.
- One researcher suggested that you may trial this approach by getting one member of the class to write the diary episode each week. Then distribute a copy to each student so that they finish with a group record.
- Another suggestion is to begin writing with "feeling" questions in students' journals. These are perceived as less threatening since there are no right or wrong answers. Teachers can use this information to explore students' conceptual understanding. Some examples are:

  "The thing I liked most about .... is ...."
  "The thing I found hardest was ...."
  "My feelings about ...."
  "My Junior 5 mathematics experience was ...."
  "Today's mathematics lesson was about ...."

Others:

Focus Questions

- What do you think about these suggestions? Are they applicable to your form?
- What approach(es) would you take to prepare students for journal writing?
- Originality of work may be one criterion for assessing students' work. What other criteria may be applicable?
- Would you attempt to formally assess journal entries, or would you see them as a means of communication (that you might even reply to) that enable you to understand something of the students' thinking and feelings?

Advantages

Journals, which make use of students' everyday language, can provide a link between everyday thinking and mathematical literacy. Other advantages are:

- They encourage students to sort out logically and to assess their ideas or thinking, thus making concepts meaningful for themselves;
- They help in the identification of gaps in students' knowledge and skills;

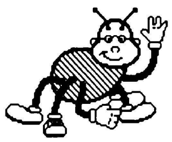
Disadvantages

- Students are initially hesitant to write in mathematics class;
- Not all students may readily want to expose their thoughts or feelings in this manner;

Focus Questions

- What do you consider are the practicalities of using journal writing as an assessment approach?
- Do you consider the students' workbook as a journal?
- How would you use journals as an assessment approach in mathematics?
- Some people may say that while students are writing in their journals teachers should be doing likewise? What do you think?

4. Observations



"Seeing is believing"

Some people have described observation as the process of listening and noticing the important elements of a performance, for the purpose of increasing the effectiveness of teaching and learning. Others regard observation as the gathering of examples of 'work in progress' which indicate that desirable learning is occurring.

Focus Questions

- Does either of these represent the way you think about observation? What do you think about these views?
- When would you use this type of assessment?

Exemplar

A checklist may be a handy tool to assist your observations of students' disposition toward learning mathematics. The checklist over the page was used in the following scenario:

Scenario: While students were involved in group work, the teacher walked from group to group using a checklist to assess the individual student's participation in the group and attitude towards their work. Each group was assessed twice.

Observations: Nicole, an above average student did not participate in the group's activity today. She was slow to get on task and seemed to be easily distracted. She did not support others nor shared her ideas. Although assigned the role of a checker, she rarely assumed that responsibility.

In contrast Andrena, a slow student seemed to function well in the same group. She got on task quickly, contributed to the group's discussion, supported other members and persisted in completing the task. She assumed the role of checker.

Comments: *Nicole*: needs to take advantage of the opportunity; role-playing as checker needed; will ask group member(s) to have a chat with her; need to chat with her.

Andrena: needs continued support and encouragement.

Sample Checklist

Behaviour	*Checked if observed*		*Comments*
	Nicole	Andrena	
Communication			
Follows instructions			
Teacher explanations needed			
Contributes to group discussions	?	*	
Personal			
Supports others ideas	?	*	
participates in group	?	*	
settles to work quickly		*	
easily distracted	?		
Mathematical Skills			
Accurately recalls basic facts			
Masters new task quickly			
Gaps in conceptual understanding			

* = positive attribute ? = required immediate follow up

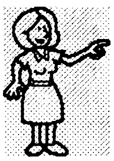
How to use it

Everyone will agree that this is one assessment activity that all teachers use every day to assess some aspects of students' thinking, behaviour or attitude. However, our approaches may differ. As teachers you may want to look at students':

- Individual learning styles
- Explanations
- Ways of communicating
- Cooperation patterns

List in the space provided any other aspect that teachers may wish to include in their observations.

Focus Questions



- How are your classroom observations conducted?
- A checklist was used in the above exemplar. Do you think this was needed? Why?
- How would you use the data/ comments that are recorded?
- Would having this knowledge change your subsequent teaching of the students or the lesson?

Some Observation-recording Techniques

Recording our observations helps to ensure that we make the most use of the data obtained, and helps reduce wastage of time. There are different recording techniques.

Four recording techniques are suggested here as examples:

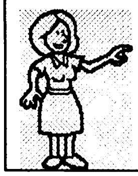
(i) Diary description.
Entries are made occasionally rather than systematically.

(ii) Running record: This provides a description of one student's behaviour over a period of time, in a particular setting.

(iv) Interval Recording:
The teacher focuses on one person or a number of categories of behaviour. The responses to the questions are either "yes or no". For example, *one may observe for 10 seconds, look for any behaviour fitting one or more categories. There is a 5 seconds interval for making the check marks, followed immediately by the next 10-seconds observation period.*

(v) Event Recording: Here the focus is on an event rather than on time intervals.

Focus Question



- What would you consider to be an advantage and a weakness of each recording format?

Advantages

As an assessment approach, observation is useful in obtaining data on

- time spent on task;
- students' participation in group activity and class discussion;

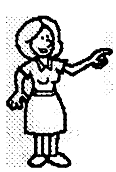
Disadvantages

Most often you may hear the comment that:

- If students are aware that they are being observed they may behave unnaturally.

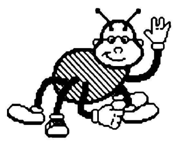
What are other possible disadvantages when using this assessment approach?

Focus Questions



- Should the information obtained from observations be used when reporting to parents?
- Can the use of this assessment approach find out what learners know?
- What questions do you have about the use of observation as an assessment approach in mathematics?

5. Portfolios

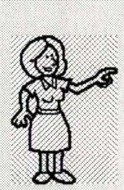


"Students' collection of a wide sample of their 'best' work which shows their mathematical thinking and growth over time."

Portfolios are for Art students, right? Well ... not exclusively. Portfolios can be used for assessment in all subjects. It is an approach that gives students more responsibility for the assessment process.

As in the artist's portfolio, the mathematics portfolio consists of a collection of a student's mathematical work. This collection may represent work in progress and illustrate the development of an idea, and "show pieces".

Focus Questions



- An individual's portfolio is said to show a wide sample of the student's work. What would you like to see a student's portfolio contain?
- What will happen to the portfolios at the end of the term?

Students may be required to indicate what they regard as their "best" work to be assessed. This involvement may require them to:

- Collect pieces of work
- Evaluate or critique their work
- Select the pieces that go together to make the best portfolio
- Reflect and see their own developmental progress

Although there are other ways with which you may feel more comfortable, the following exemplar is one indication of what you may require.

Exemplar

Requirement: 4–8 pieces of work on the unit Number Theory.

Interim Dates: Week 5, 8, 10

Final Date: Week 13

The pieces should cover a wide range of aspects of the unit of work and demonstrate some kind of coherence.

For example,

- Select a sample of work that you feel needs improvement. If you were to do this work again what changes would you make?
- Explain what you learned from taking the test on...
- What would you do differently if you were to take the test today?

How to use it

It could be used as follows:

- First decide who chooses what might go into the portfolio.
- Inform students of the mathematics goal of the unit, and the grading criteria (if grading is necessary) at the time the portfolio is introduced.
- Have students reflect on their best work. Read and comment on students' reflections.

Others are:

One area that needs consideration is that of managing the portfolios. Consider the following suggestions and add your suggestions to this list.

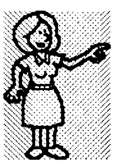
- Agree upon a general format for the portfolio.
- Consider how portfolios can be kept and stored.
- Select a range of a student's work for the portfolio.
- Have students include work that has already been reviewed, graded and also revised.

Another suggestion for managing portfolios is to put in it at the beginning of the academic year one piece of the student's work from each mathematics topic covered. At the end of the first term include the student's best work from each topic again. This is repeated in the second term, except that term one's work is removed. The same pattern is repeated in term three.

What are the practicalities of this suggestion?

One area that may require consideration is whether to grade portfolios.

Focus Questions



- Rather than assigning a grade to each portfolio, it is suggested that the completed portfolio be a requirement for a recommendation for graduation. What are some possible implications of this suggestion?
- If a grade is deemed necessary, how would you assess a student's portfolio?

Advantages

It is generally believed that portfolio assessment helps teachers to assess all areas of students' learning.

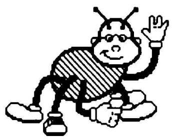
- Some areas of students' learning that could be assessed are

- Some possible learning benefits resulting from students' selection of items for inclusion are

Disadvantages

What may be some of the pitfalls that teachers need to be aware of when using this assessment approach?

6. Investigations



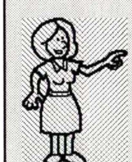
"I don't know for sure, but I will find out."

This approach may be loosely defined as the use of mathematics in novel situations. Investigations are usually open-ended. Some may even have more than one valid answer, solution or set of results.

An investigation as an assessment approach:

- Is viewed as inquiry learning
- Usually has a written component

Focus Questions



- What does mathematical investigation mean to you?
- What would be required of both teacher and students if this approach is used?

Exemplar

Here is a short investigative task.

Choose a number [e.g., 31], find the sum of the square of each digit [$3^2 + 1^2 = 10$].
Follow this pattern, [$1^2 + 0^2 = 1$].
A result of 1 indicates that the original number is a "Happy Number".

- Given the set of whole numbers from 1 to 100, investigate all possible "Happy Numbers".

After you have experimented for a while, explain your thinking in writing using examples to illustrate your understanding.

Focus Questions

- **Having looked at the exemplar, what would be your assessment criteria?**
- **What would you suggest as possible investigations that could be carried out for Number Theory?**

How to use it

The following suggestions are given as discussion starters. Examine each, then in the space provided write your comments and other possible suggestions.

- Students would carry out investigations either individually or in groups.
- The task may include various steps, some of them corresponding to work in the classroom. For example, definition of the problem, discussion of strategies, and group work/discussions.
- Assessment and feedback should be continuous.
- Allow students to investigate aspects of mathematics that interest them personally.

Advantages

It is believed that investigations encourage students to use mathematics in ways that are not part of the curriculum. What do you think? What are some of these 'ways'?

Additionally, investigations may be useful for:

- Ascertaining whether a student can identify and define a problem; their existing knowledge; their organising and interpreting strategies; and their ability to produce a quality report.
- Affording students opportunities to display their mathematical thinking, reasoning, problem solving and communication skills.

Other:

Disadvantages

Several disadvantages are suggested, and there may be others that you may add to these.

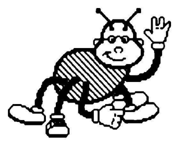
- It is often difficult to assess the processes and skills involved in investigations rather than the end product;
- Difficulty in agreeing on assessment criteria for investigational skills may occur;
- If the task is done as a group, individual weaknesses may be covered up by the strengths of other group members;

•..

Focus Questions

- It is suggested that assessment of the task be ongoing rather than at the end of the task. What would be some of the benefits of continuous assessment?
- How do you feel about assessment activities being done in groups? Are the results still useful?
- Will this type of assessment focus on processes and strategies or only on the solutions and results of the investigation?
- How could the use of this assessment help to enhance students' learning?

7. Projects



"A long-term task submitted by a student for assessment."

Many subjects offered by the Caribbean Examinations Council (CXC) have a school-based assessment (SBA) component in the form of a project. This is assessed internally by the subject teacher.

If you are not aware of what subjects have SBA, then now is a good time to find out from your colleagues. You may also want to find out:

- What is required of both teacher and students?
- How are projects assessed in other subject areas?

Project work is usually open-ended. This assessment approach:

- Is likely to include a written component
- Is viewed as learning by doing
- Moves students away from guessing what the teacher wants and also from the notion of finding the one right solution to the problem

Exemplar

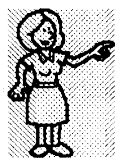
The following example represents one attempt to develop criteria and a scoring system to assess project work.

A penalty system was developed by the teacher and students of Form 1N to guide the allocation of marks for each group member. Students opted to work in groups of five on a given task. On completion of the project, a set of penalties was submitted (having been signed by each member) by each group leader for the project. The task was awarded a maximum of 50 points.

One group's project received 36 points. Based on the penalty system below, each member received the following scores:
Nyla: 26 Jo: 23 Sam: 36 Tan: 16 Di: 19

	Contribution		
	Major	Some	Little
Leadership and direction	0	-1	-2
Organisation and management	0	-1	-2
Ideas and suggestions	0	-1	-2
Data collection	0	-2	-4
Data analysis	0	-2	-4
Report writing	0	-3	-6

Focus Questions



- **Using the penalty system, how would you account for a student having a score of 19 and another a score of 23?**
- **How can peer assessment of each other's contribution to group work help to reduce a teacher's workload?**
- **Do you think students should be allowed to distribute between themselves marks that reflect each member's contributions to the task?**
- **What are some points to consider when allocating differing marks to individuals of a group?**

How to use it

Here are a few guidelines:

- Begin with a briefing session at which the mathematical purposes of the activity are made clear either by the teacher or by direct negotiation.
- Develop a plan of action.
- Check to ensure originality of each student's or group's work.

Since testing is part of your assessment process, you may want to include tests or examination items about project work.

Another suggestion may be that students could be assessed on the basis of:

- An oral examination,
- An interview
- A seminar presentation of the project
- A poster display of the project.

Advantages

Project work as an assessment approach is useful in

- checking students' ability to apply mathematics and to use the symbolism and language of mathematics;
- developing cooperative learning, leadership or responsibility roles;
- affording students opportunities to display their mathematical thinking, reasoning, problem solving and communication skills; and
- facilitating teacher-student interaction and communication in the classroom.

Another advantage of this assessment approach is developing students' familiarity with research skills. Some research skills are:

Disadvantages

What do you consider to be some disadvantages in using projects as an alternative assessment approach?

Focus Questions

- Who chooses the type of project to be carried out?
- Would all students work on the same project, or would projects vary? If they vary, then what would be the criteria for assessing each project?
- How would you keep track of students' work to ensure the work belongs to the student?
- Do you think students should be allowed to distribute between themselves marks that reflect each member's contributions to the task?

8. Students' self-assessment

"Students monitoring their own progress."

How much do we, as teachers, involve our students in the assessment process? Here is an assessment approach that offers a great opportunity to encourage students' involvement –Students' self-assessment.

This assessment approach requires students to monitor their own progress in learning and understanding mathematics. Two components of self-assessment are:

- Self-awareness
- Self-evaluation

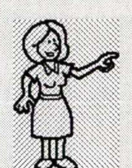
These two components should occur in tandem. By engaging in activities that involve these two components students can:

- Enhance their strengths
- Reduce their weaknesses

Students' assessment may take the form of:

- Guided self-assessment:
- Self-assessment
- Peer assessment

Focus Questions



- Do you think that students should be involved in the assessment of their mathematics progress? Why?
- Can you see yourself adopting such an approach to assessment in mathematics? Why?
- What would your role be in all of this?

Exemplars

Here is an exemplar of a student's self-appraisal of one incident in a mathematics session.

> Today I worked with Zoe. She helped me to reflect on what I had done. I was trying to solve a word problem about integers but wasn't sure about my answer. While I was explaining to Zoe how I solved the problem, I suddenly realised that my interpretation of the question was incorrect.
>
> I think that having someone to whom I may explain my solutions was a good motivator. It helped me to reflect on my thinking and to successfully complete the problem.

Another exemplar is a guided self-assessment approach. Here, the teacher gives a few questions as assessment guides.

Consider these two questions, then make your additions.

- What is the most important thing you have learned this week in mathematics?
- What is your biggest worry about your work in mathematics at present?

How to use it

It is believed that assessment which includes *students' active participation* provides the teacher with data to make judgements, and students with the opportunity to help shape instruction.

Focus Questions

- How does this view fit with your beliefs of assessment?
- Describe in detail what opportunities you would provide to facilitate and enhance students' self-assessment?

Here are a few hints that may prove useful.

Begin by developing a framework to help students become self-assessors. For example, you may try using:

- A systematic approach.
  Begin by emphasising structure and providing guidance. This may be followed by a gradual weaning of your input (e.g., less guidance), ending with students setting their own structure.

- A checklist.
  This technique gives students the responsibility for their learning by getting them to identify more than one person's view.

This checklist may be used to encourage students to assess their own performance, then compare their self-assessment with that of the teacher. The idea is to achieve comparability. You are encouraged to comment on each item and suggest other items.

Areas to be addressed	*Possible Marks* *Student*	*Teacher*	*Comment*
Did I answer all questions?			
Did I include all important things?			
Is my work organised and tidy?			
Is my computation done carefully?			
Did I read all the questions carefully?			
Did I spend enough time on each task?			
Did I do my best work?			

Focus Questions

- How could the use of this checklist by students promote learning?

- What marking schedule could be used with the above checklist?

Advantages

What do you see as some possible benefits of this mode of assessment for both teachers and students?

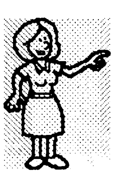
Teachers

Students

Disadvantages

- Students may allocate themselves higher marks than their work warrants;
- The introductory stage may be time consuming (e.g., students will require time to practise assessing);

Focus Questions



- What is the role of self-assessment in helping students learn-to-learn?
- How can you build opportunities for self-assessment into your programme?
- If you were asked to build a framework for developing students competencies in self-assessment for your unit of work or over one term, what would be some of its features?

APPENDIX C

FORMAL INTERVIEW QUESTIONS

Other mathematics education individuals

- What learning theories influenced our teaching and assessment practices in the 1960s and 70s? What changes, if any, have we made? Where do we stand and where should we go? (Participant: Teachers' College Lecturer)
- What views of learning have, and are, impacting on the way we teach children?
- What changes (if any) have occurred over the past in our assessment practices?
- Is there a need for us to reconsider our assessment practices of students' understanding of mathematics?
- In 1990 the Teachers' Training College introduced the use of projects in mathematics. This is now extended to include portfolios and journals. What are your views about the use of other assessment approaches in mathematics?
- Apart from written tests, what other forms of assessment could be used in mathematics classrooms?
- Considering the Caribbean Examination Council (CXC) examinations, can you see a place for other forms of assessment?
- The Caribbean Examination Council assesses mathematics on three areas: computation, comprehension and reasoning. Do you think that these skills are being developed and assessed in the classroom?
- Can we say 'constructivist' ideas will work in St. Vincent and the Grenadines?
- Do you agree that the way mathematics is taught should be matched to our societal needs?

Teachers

(i) Before the trial

- Should we only assess students' written work? Why/why not?
- What might be some possible alternatives to written tests?
- Have you ever used any other assessment approach? Which ones?
- What are your reasons for selecting your chosen assessment approach?
- How can we encourage more student involvement?

(ii) During the trial

- What strategies can be used for managing/making the chosen approach(es) more effective in enhancing students' mathematical understanding?
- How are your students reacting to the use of these approach (es)?
- What did you do to check students' understanding of the information (given in their journals)?
- How can we encourage more student involvement?

(iii) After the trial

- Looking back at the way you have been assessing students' mathematical understanding, what changes have you seen?
- What are you thinking and doing differently in assessment of student mathematical understanding?
- How can we encourage more student involvement?
- What suggestions can you give to others who might trial these approach(es)?

APPENDIX D

CORE CURRICULUM OUTLINE: FORM 3
NUMBERS AND NUMBER THEORY

1.0 INTEGERS AND RATIONAL NUMBERS

Content

1.1 Four operations (+, -, x, ÷).
1.2 The set of Integers as a subset of the set of Rational numbers.
1.3 Applications (e.g. temperature, banking and measurements).

Skills

Students should be able to:

1. Perform calculations involving the four operations on integers.
2. Perform the four basic operations using rational numbers (positive and negative whole numbers, fractions, decimals).
3. Solve real-life problems involving integers and rational numbers.

Attitudes and Values

1. Demonstrate an awareness that numbers are either positive or negative.
2. Be sensitive to the fact that certain phenomena in real-life operate like integers.

2.0 COMPUTATIONS OF FRACTIONS, DECIMALS AND PERCENTAGES

Content

2.1 Fractions

Skills

1. Apply the order of operations to problems involving fractions with two or more operations.
2. Solve word problems depending on order of operations of two or more operations. (These problems must be well formulated to actually check the students' appreciation of the order of operations.)

Attitudes and Values

Show appreciation of the importance of systematic problem solving by using an organized approach when solving problems.

2.2 Decimals

Skills

1. Round off decimals to a specific number of decimal places.
2. Round off numbers (e.g. measurement) to a whole number of a specific unit.
3. Estimate the answer to operations (+, -, x, ÷).
4. Use of calculators to check answers.
5. Multiply and divide decimals by decimals.
6. Use a calculator to multiply and divide decimals by decimals, and then round off answers to a specific number of decimal places.

Attitudes and Values

1. Show appreciation for estimates by comparing estimates with final answers within a given limit as specified by the teacher.
2. Show a willingness to use estimates as guidelines by using estimates to check work whenever possible.

2.3 Percentages

Skills

1. Find the value of a quantity given a percentage increase or decrease.
2. Find the original quantity given the final result and percentage increase or decrease.
3. Find the profit or loss percent given the cost price and selling prices.
4. Calculate the discount on an item given the discount rate.
5. Find the new selling price given percent discount.
6. Express discount as a percent.
7. Calculate annual simple interest and compound interest.
8. Calculate total earnings given percent commission.

Attitudes and Values

1. Show awareness of the use of percentages in business by giving examples of how percentages are used.
2. Show appreciation for how a bank uses percentages by identifying to whom the interest is paid.

3.0 NUMBER BASES

Content

3.1 Review place value in base 10 (whole numbers and decimals).
3.2 bases other than 10 e.g. 2,3,4,5,8.
3.3 Conversions.
3.4 Addition, subtraction, and multiplication.

Skills

1. Convert numbers written in base 10 to other bases and vice versa.
2. Add, subtract and multiply numbers given in the same base.
3. Add, subtract and multiply numbers given in different bases.
4. (Optional) To use the calculator in performing operations.

Attitudes and Values

1. Showing awareness of the use of the binary system in computers and calculators.
2. Better understanding of the base 10 system through working with other bases.

4.0 RATIO/PROPORTIONS

Content

4.1 Concept of ration and proportion.
4.2 Notation.
4.3 Ratio between two quantities; same units; different units.
4.4 Applications e.g. – scale drawing
map reading
unit pricing
recipes
mixtures
currency conversion.

Skills

Students should be able to:

1. Demonstrate an understanding of ratio as a comparison of two numbers, using the notation 'a' to 'b', a:b or $\frac{a}{b}$
2. Solve problems involving applications of ration and proportions in real-life.
3. Use the calculator as a tool in solving problems involving ratio and proportions.

Attitudes and Values

Develop an awareness of applications of ratio and proportions in real-life, eg.
mixing concrete
cooking
architecture
foreign exchange
(generally sharing experiences).

5.0 SQUARES AND SQUARE ROOTS

Content

5.1 Computations.
5.2 Use of tables.
5.3 Estimations.
5.4 Use of a calculator.

Skills

1. Calculate by multiplication the squares of whole numbers.
2. Demonstrate an understanding of the relationship between square and square roots.
3. Find the square and square root of any natural number using:
   (a) 3 figure tables.
   (b) a calculator.
4. Estimate the square and square root of a natural number.

Attitudes and Values

1. Appreciation of how the use of a calculator greatly simplifies computation involving squares and square roots.
2. Demonstrate a willingness to use estimation as a means of checking computation.

6.0 NUMBER THEORY

Content

6.1 Indices

Review positive indices.
Negative indices (whole numbers as bases).
Reciprocals.
Multiplication and division.

Skills

1. Write the reciprocal of a number.
2. Multiply or divide numbers with negative indices but the same base, e.g. $3^{-2} \times 3^{-5}$
3. Multiply or divide whole numbers with negative indices but with different base, e.g. $3^{-2} \times 4^{-3}$

6.2 Significant Figures

Review decimal places.
Comparison: decimal places vs. significant figures.
Rules for determining significant figures (whole numbers and decimals).

Skills

1. Approximate any number to any number of significant figures.
2. Apply the concept of significant figures to numbers written in standard form.

Attitudes and Values

Develop a sensitivity to the importance of approximations e.g. estimating large crowds, audiences from seating capacity.

6.3 Standard Form (Scientific Notation)

Multiplication and division.
Estimation, rounding off.
Use of a calculator.

Skills

1. Rewrite a given number in scientific notation and vice versa.
2. Multiply or divide two numbers using scientific notation, e.g.
$$3.5 \times 10^2 \times 2.4 \times 10^5$$
3. Apply scientific notation and rounding off to estimate the products or quotients of very large or very small numbers, e.g.
$$\frac{14002 \times 0.00057}{0.000563}$$
4. Use a calculator to verify answers.

Attitudes and Values

1. Show appreciation for the importance of scientific notation in simplifying computations involving large numbers.
2. Suggest real-life situations in which scientific notation may be useful.
3. Show appreciation for the use of the calculator as a computational tool.

(Source: Ministry of Education (1992). St. Vincent and the Grenadines curriculum guide in mathematics for third forms. Kingstown, St. Vincent and the Grenadines: Ministry of Education.)

APPENDIX E

QUESTIONNAIRE: SECONDARY TEACHERS' VIEWS OF ASSESSMENT

Dear Friends,

I am in the process of conducting research in the area of assessment in mathematics. Your participation is greatly appreciated. Please note that your views and opinions will be valuable contributions to this study and that all responses are confidential.

Yours truly

Sandra Trotman

TEACHERS' VIEWS OF ASSESSMENT

Please answer either by ticking the appropriate column or by writing in the spaces provided.

- Are you happy with the assessment method(s) currently being used in your school? Give reason(s) for your response.
- In your opinion, what are the three most important reasons for assessing mathematical learning? Give reasons to support your responses.
- Should we, as mathematics teachers, reconsider assessment? Why/why not?

- How often do you use the following approaches when assessing students? Indicate your response with a tick.

Assessment Approach	Daily	Weekly	Monthly	Not Applicable
Interviews/Conferencing				
Debates				
Quizzes				
Oral presentation				
Projects				
Investigations				
Students self-assessment				
Peer assessment				
Written tests				
Portfolios				
Journals				
Observation				

- When you think of assessment what words come to mind?

- What changes, if any, would you make to the present system of assessment? Give reasons for your response.

Personal Background

Gender: Male ☐ Number of years teaching experience

Female ☐ 0 - 4 ☐ 5 - 9 ☐ 9 – 15 ☐ 15+ ☐

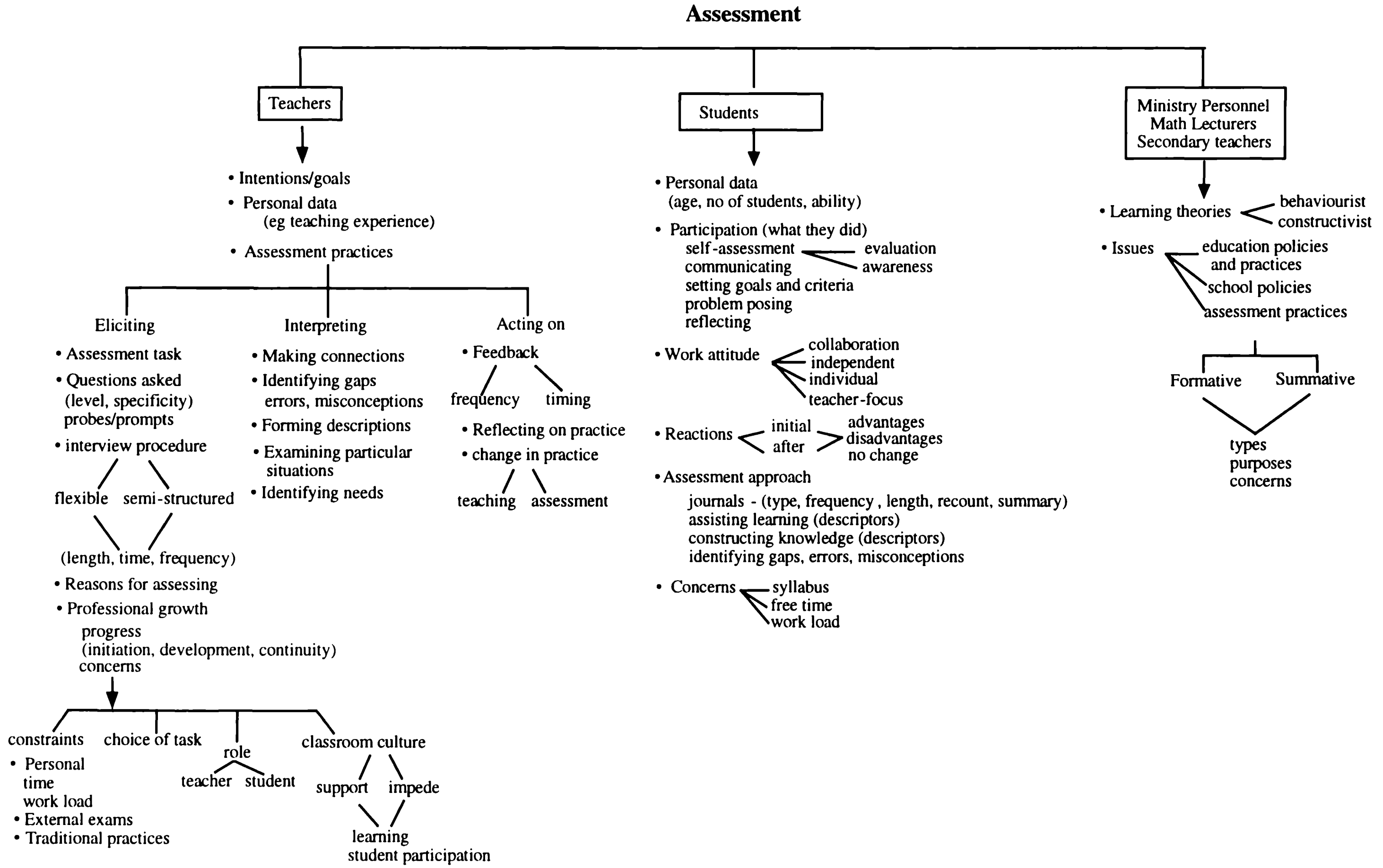
Name of School...

Thank you for your cooperation.

APPENDIX F

DATA ANALYSIS CATEGORIES

A Schematic Overview of the Categories for Data Reduction & Analysis



REFERENCES

Adams, C., & King, K. (1995). Towards a framework for student self-assessment. *Innovation in Education and Training International*, 32(4), 336–343.

Airasian, P. W. (1996). *Assessment in the classroom.* New York: McGraw-Hill.

Angelo, T. (1995). *Reassessing and defining assessment. AAHE Bulletin.*

Angelo, T., & Cross, P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). San Francisco: Jossey-Bass Inc.

Archbald, D. A., & Newmann, F. M. (1988). *Beyond standardized testing: Assessing authentic achievement in secondary school.* Reston, VA: National Association of Secondary Principals.

Arnove, A. K., & Arnove, R. F. (1997). A reassessment of education, language and cultural imperialism: British colonialism in India and Africa. In W. K. Cummings & N. F. McGinn (Eds.), *International handbook of education and development: Preparing schools, students and nations for the twenty-first century* (pp. 87–101). Oxford: Pergamon.

Arnove, R. F., & Graff, H. J. (1992). National literacy campaigns in historical and comparative perspective: Legacies, lessons and Issues. In R. F. Arnove, P. G. Altbach & G. P. Kelly (Eds.), *Emergent issues in education: Comparative perspectives*(pp. 283–294). Albany, NY: State University of New York Press.

Atwater, M. M. (1996). Social constructivism: Infusion into the multicultural science education agenda. *Journal of Research in Science Education*, 33(8), 821–838.

Bachor, D. G., Anderson, J. O., Walsh, J., & Muir, W. (1994). Classroom assessment and the relationship to representativeness, accuracy and consistency. *Alberta Journal of Educational Research*, 11(2), 247–262.

Baird, J. R., & Mitchell, I. J. (1986). *Improving the quality of teaching and learning: An Australian case study—The PEEL Project.* Melbourne: Monash University.

Banister, P., Burman, E., Parker, I., Taylor, M., & Tindall C. (1995). *Qualitative methods in psychology: A research guide.* Buckingham: Open University Press.

Baroody, A. (1987). *Children's mathematical thinking. A developmental framework for preschool, primary and special education teachers.* New York: Teachers College Press.

Bazzini, L. (1993). The teaching/learning process and assessment practices: Two intertwined sides of mathematics education. In M. Niss (Ed.), *Cases of assessment in mathematics education. An International Commission on Mathematical Instruction study* (pp. 99–106). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Begg, A. (1991). *Assessment and constructivism.* Paper presented at the International Commission on Mathematical Instruction study conference on Assessment in Mathematics Education and its effects. Calonge, Spain.

Begg, A. (1993a). Communication and assessment in mathematics education. In M. Stephens, A. Waywood, D. Clarke & J. Izard (Eds.), *Communicating mathematics: perspectives from classroom practice and current research* (pp. 283–290). Hawthorn: Australian Council for Educational Research.

Begg, A. (Ed.). (1993b). *MATHSassessment.* Unpublished draft teachers' guide submitted to the New Zealand Ministry of Education.

Begg, A. (1995). Constructivism in the classroom. *New Zealand Mathematics Magazine*, 33(1), 3–17.

Begg, A. (1998). *Assessment and school mathematics.* A discussion paper for the Education Review Office, New Zealand.

Bell, B. (1993). *Taking into account students' thinking: A teacher development guide.* Hamilton, New Zealand: University of Waikato.

Bell, B., & Cowie, B. (1997). *Formative assessment and science education. Research report of the learning in Science Project (Assessment).* Hamilton, New Zealand: University of Waikato.

Bell, B., & Gilbert, J. (1996). *Teacher development: a model from science education.* London: Falmer Press.

Bell, B., Osborne, R., & Tasker, R. (1985). Finding out what children think. In R. Osborne & P. Freyberg (Eds.), *Learning in science: The implications of children's science* (151–165). Auckland: Heinemann.

Bell, J. (1995). *Doing your research project: A guide for first-time researchers in education and social science* (2nd ed.). Buckingham: Open University Press.

Benaim, D. (1995). *Constructivism as an educational philosophy (A thumbnail sketch).* Paper presented to the Dalton School's Education Policy Committee.[Online] available URL:http://www.dalton.org/groups/ NLTL /area11/benaim01.html

Bentt, V. Bynoe, S., Goldberg, N., Singh, M. P., Wardle, M. E., & Weeks, C. J. (1996). *Oxford Mathematics for the Caribbean Book 3* (rev. ed.). London: Oxford University Press.

Berenson, S. B., & Carter, G. S. (1995). Changing assessment practices in science and mathematics. *School Science and Mathematics*, 95(4), 182–186.

Berlak, H. (1992). The need for a new science of school assessment. In H. Berlak, F. M. Newmann, E. Adams, D. A. Archbald, T. Burgess, J. Raven, & T. A. Romberg (Eds.), *Toward a new science of educational testing and assessment* (pp. 1–21). Albany, NY: State University of New York Press.

Best, J. W., & Kahn, J. V. (1993). *Research in education* (7th ed.). Boston: Allyn & Bacon.

Beyer, A. (1993). Assessing students' performance using observations, reflections and other methods. In N. L. Webb & A. P. Coxford (Eds.), *Assessment in the mathematics classrooms.* NCTM 1993 Yearbook (pp. 111–120). Reston, VA: National Council of Teachers of Mathematics.

Biddulph, F. (1993). A teacher reflects on evaluation in primary school mathematics. In A. Begg (Ed.), *MATHSassessment* (pp. 10–14). Unpublished papers. A draft teachers' guide submitted to the New Zealand Ministry of Education.

Biddulph, F., Bell, B., & Carr, M. (1989). Constructivist assessment: submission to the *Assessment for Better Learning Project*. Hamilton, New Zealand: University of Waikato.

Biggs, J. B. (1995). Assessing for learning: Some dimensions underlying new approaches to educational assessment. *The Alberta Journal of Educational Research*, 41(1), 117.

Biggs, J. B., & Moore, P. J. (1993). *The process of learning*. Sydney: Prentice-Hall.

Bishop, G. (1989). *Alternative strategies for education*. London: Macmillan.

Black, P. (1993). Formative and summative assessment by teachers. *Studies in Science Education*, 21, 49–97.

Black, P. (1995). Can teachers use assessment to improve learning? *British Journal of Curriculum & Assessment,* 5(2), 7–11.

Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. Final draft. To be published in *Assessment in Education,* 5(1), March 1998.

Blais, D. M. (1988). Constructivism: a theoretical revolution for algebra. *Mathematics Teacher*, 81(8), 624–633.

Blane, D. (1992). Curriculum planning, assessment and student learning in mathematics: A top-down approach. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 290–304). Victoria, Australia: Australian Council for Educational Research.

Blaxter, L., & Tight, M. (1993). "I'm only doing it to get a black gown": Dream and reality for adults in part-time higher education. *Journal of Further and Higher Education*, 17(1), 13–21.

Boehm, A. E., & Weinberg, R. A. (1987). *The classroom observer: Developing observation skills in early childhood settings*. (2nd ed.). New York: Teachers College Press.

Bogdan, R., & Biklen, S. (1982). *Qualitative research for education: An introduction to theory and methods*. London: Allyn and Bacon.

Bolam, R. (1987). *What is effective INSET? In Professional Development and INSET: Proceedings of the 1987 NFER Members Conference* (pp. 38–53). England: National Foundation for Educational Research.

Boud, D. (1990). Assessment and the promotion of academic values. *Studies in Higher Education,* 15(1), 101–111.

Boud, D. (1995a). Assessment and learning: Contradictory or complementary? In P. Knight (Ed.), *Assessment for learning in higher education* (pp. 35–48). London: Kogan Page.

Boud, D. (1995b). *Workshop report: Developing effective student self assessment.* Oxford: Worcester College.

Boud, D. (1995c). *Enhancing learning through self assessmen*t. London: Kogan Page.

Boud, D., & Feletti, G. (1991). *The challenge of problem-based learning*. London: Kogan Page.

Bray, M., & Packer, Steve. (1993). Curriculum, examinations and certification. In M. Bray & S. Packer (Eds.), *Education in small states: Concepts, challenges and strategies* (pp. 93–105). Oxford: Pergamon Press.

Brew, A. (1995). Self assessment, learning and assessment. In D. Boud (Ed.), *Enhancing learning through self assessment* (pp.11–62). London: Kogan Page.

Broadfoot, P. (1990). Towards curssment: The symbiotic relationship between curriculum and assessment. In N. Entwistle (Ed.), *Handbook of Educational Ideas and Practices* (pp. 647–657). London: Routledge.

Broadfoot, P. (1996). *Assessing assessment: Education, assessment and society. A sociological analysis.* Buckingham: Open University Press.

Brock, C. (1982). The legacy of colonialism in West Indian Education. In K. Watson (Ed.), *Education in the third world* (pp. 119–140). London: Croom Helm.

Broomes, D. R., & Cumberbatch, G. (1991). *Developing a primary school mathematics programme.* Buckinghamshire, England: Ginn and Company Ltd.

Broomes, D. R., & Halliday, J. A. (1993). Major issues in assessing mathematics performance at 16+ level: A Caribbean perspective. In M. Niss (Ed.), *Cases of assessment in mathematics education.* An ICMI study (pp. 21–33). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Brown, A. (1987). Metacognition and other mechanisms. In F. E. Weinert & R. H. (Eds.), *Metacognition, motivation and understanding* (pp. 65–116). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brown, A. L., Campione, J. C., Webber, L. S., & Mc Gilley, K. (1992). Interactive learning environments. A new look at assessment and instruction. In B. R. Gifford & M. C. O'Connor (Eds.), *Changing assessments: Alternative views of aptitude, achievement, and instruction* (pp. 121–211). Norwell, MA: Kluwer Academic Publishers.

Brown, S. (1990a). Criterion-referenced assessment. In N. Entwistle (Ed.), *Handbook of Educational Ideas and Practices* (pp. 865–874). London: Routledge.

Brown, S. (1990b). Assessment: A changing practice. In T. Horton (Ed.), *Assessment debates* (pp. 5–11). London: Hodder and Stoughton.

Brown, S., & Knight, P. (1994). *Assessing learners in higher education.* London: Kogan Page.

Buchert, L. (1995). *Recent trends in education aid: Towards a classification of policies.* Paris: International Institute for Educational Planning. UNESCO.

Burgess, R. G. (1985). *Strategies of educational research: Qualitative methods.* London: Falmer Press.

Burns, R. B. (1994). *Introduction to research methods* (2nd ed.). Melbourne: Longman.

Burton, L. (1992). Who assesses whom and to what purpose? In M. Stephens & J. Izard (Eds.), *Reshaping assessment practices: Assessment in mathematics and sciences under challenge* (pp. 1–18). Geelong, Victoria: Australian Council for Educational Research.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research*, 65(3), 245–281.

Butler, J., & Beasley, W. (1987). The impact of assessment changes in the science curriculum: A descriptive account. *Research in Science Education,* 17, 236–243.

Campione, J. C., Brown, A. L., & Connell, M. L. (1988). Metacognition: On the importance of understanding what you are doing. In R. Charles & E. Silver (Eds.), *The teaching and assessing of mathematical problem solving* (pp. 93–114). Reston, VA: National Council of Teachers of Mathematics.

Caribbean Examinations Council. (1985). *Secondary education certificate mathematics.* Cave Hill Campus, Barbados: Caribbean Examinations Council.

Caribbean Examinations Council. (1990). *Secondary education certificate mathematics.* Cave Hill Campus, Barbados: Caribbean Examinations Council.

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C. P., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal*, 26(4), 499–531.

Carr, K. (1994). Assessment and evaluation in primary school mathematics. In J. Neyland (Ed.), *Mathematics education: A handbook for teachers Volume 1.* Wellington: Wellington College of Education.

Carter, P. L., Ogle, P. K., & Royer, L. B. (1993). Learning logs: What are they and how do we use them? In N. L. Webb & A. F. Coxford (Eds.), *Assessment in mathematics classroom* (pp. 87–96). Reston, VA: National Council of Teachers of Mathematics.

Chambers, D. L. (1995). Improving instruction by listening to children. *Teaching Children Mathematics*, 1(6), 378–380.

Charles, R. (1985). The role of problem solving. *Arithmetic Teacher*, 32(6), 48–50.

Chittenden, E. (1991). Authentic assessment, evaluation and documentation. In V. Perrone (Ed.), *Expanding student assessment* (pp. 22–31). Alexandria, VA: Association for Supervision and Curriculum Development.

Clarke, D. J. (1992). The role of assessment in determining mathematics performance. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 145-168). Victoria, Australia: Australian Council for Educational Research.

Clarke, D. J. (1996). Assessment. In A. J. Bishop, K. Clements, C. Keitel, J. Kilpatrick & C. Laborde (Eds.), *International handbook of mathematics education. Part 1* (pp. 327–370). Dordrecht, The Netherlands: Kluwer, Academic Publishers.

Clarke, D. J. (1997). Teaching, learning and assessment: A symbiotic relationship. Paper presented at New Zealand Association of Mathematics Teachers 5 Conference, *'Get in the know'*. Palmerston North.

Clarke, D. J., Clarke, D. M., & Lovitt, C. J. (1990). Changes in mathematics teaching call for assessment alternatives. In T. J. Cooney & C. R. Hirsch (Eds.), *Teaching and learning mathematics in the 1990s* (pp. 118–129). Reston, VA: National Council of Teachers of Mathematics.

Clarke, D. J., Waywood, A., & Stephens, M. (1993). Probing the structure of mathematical writing. *Educational Studies in Mathematics*, 25(3), 235–250.

Clarke, D. M. (1997). The changing role of the mathematics teacher. *Journal for Research in Mathematics Education*, 28(3), 278–308.

Clarke, S. (1995). Assessing significant achievement in the primary classroom. *British Journal of Curriculum & Assessment,* 5(3), 12–15.

Classroom Compass. (1995). Building an understanding of constructivism. *Classroom Compass,* 1(3). [Online] available URL:http://diogenes.sedl.org/scimath/compass/vol 1no3/welcome.html.

Clements, M. A. (Ken)., & Thomas, J. (1996). Politics of mathematics education: Australian perspectives. In B. Atweh, K. Owens & P. Sullivan (Eds.), *Research in mathematics education in Australasia 1992–1995* (pp. 89–117). Campbelltown, Australia: Mathematics Education Research Group of Australia.

Cobb, P. (1990). Multiple perspectives. In L. P. Steefe & T. Wood (Ed.), *Transforming children's mathematics education: International perspectives* (pp. 200–215). Hillsdales, NJ: Lawrence Erlbaum Associates.

Cobb, P. (Ed.). (1994). *Learning mathematics: Constructivist and interactionist theories of mathematical development.* Boston: Kluwer Academic Publishers.

Cobb, P., & Wood, T. (1990). Experience, problem solving and discourse as central aspects of constructivism. *Arithmetic Teacher*, 38(4), 34–35.

Cobb, P., Wood, T., & Yackel, E. (1990). Classrooms as learning environments for teachers and researchers. *Journal for Research in Mathematics Education,* 4, 125–146.

Cobb, P., Yackel, E., & Wood, T. (1992). A constructivist perspective to the representational view of the mind in mathematics education. *Journal for Research in Mathematics Education,* 23(1), 2–33.

Cockcroft, W. H. (1982). *Mathematics counts : Report of the committee of inquiry into the teaching of mathematics in schools.* London: Her Majesty's Stationery Office.

Cohen, L., & Manion, L. (1994). *Research methods in education* (4th ed). London: Routledge.

Cole, A. L. (1989). Researchers and teacher: Partners in theory building. *Journal of Education for Teaching*, 15(3), 225–237.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing and mathematics. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Hillsdale, NJ: Lawrence Erlbaum Associates.

Confrey, J. (1990). What constructivism implies for teaching. *Journal for Research in Mathematics Education, Monograph 4* (pp. 107–122). Reston, VA: National Council of Teachers of Mathematics.

Connell, M. L., & Peck, D. M. (1993). Report of a conceptual change intervention in elementary mathematics. *Journal of Mathematical Behaviour*, 12, 329–350.

Connor, C. (1991). *Assessment and testing in the primary schools.* London: Falmer Press.

Costa, A. L. (1991). *Developing minds: A resource book for teaching thinking.* Alexandria, VA: Association for Supervision and Curriculum Development.

Costa, A. L., & Kallick, B. (1995). *Assessment in the learning organization: Shifting the paradigm.* Alexandria, VA: Association for Supervision and Curriculum Development.

Countryman, J. (1992). *Writing to learn mathematics.* Portsmouth, NH: Heinemann Educational Books.

Crooks, T. J. (1988). The impact of classroom evaluation practices on students. *Review of Educational Research,* 58(4), 438–481.

Crooks, T. J. (1993). Principles to guide assessment practise. Paper presented to *Assessment and Learning in New Zealand: Challenges and choice.* Palmerston North, New Zealand.

Cross, L., & Hynes, Michael. C. (1994). Assessing mathematical learning for students with learning differences. *Arithmetic Teacher,* 41(7), 371–377.

D' Ambrosio, U. (1990). The role of mathematics in building up a democratic society and the civilizatory mission of the European powers since the discoveries. In R. N. Noss, P. Dowling, P. Drake, M. Harris, C. Hoyles & S. Mellin-Olsen (Eds.), *Political dimensions of mathematics education: Action critique* (pp. 13–21). Proceedings of the First International Conference (Rev. ed.). London: Department of Mathematics, Statistics & Computing, Institute of Education, University of London.

Darling-Hammond, L. (1993). Reframing the school agenda: Developing capacity for school transformation. *Phi Delta Kappan,* 1(6), 753–755.

Davis, R. B., Maher, C., & Noddings, N. (1990). Suggestions for the improvement of mathematics education. *Journal for Research in Mathematics Education, Monograph* 4 (pp. 187–191). Reston, VA: National Council of Teachers of Mathematics.

Davison, D., & Pearce, D. (1990). Perspectives on writing activities in the mathematics classroom. *Mathematics Education Research Journal,* 2(1), 15–22.

Dengate, B., & Lerman, S. (1995). Learning theory in mathematics education: Using the wider angle lens and not just the microscope. *Mathematics Education Research Journal,* 7(1), 26–36.

Denvir, B. (1988). What are we assessing in mathematics and what are we assessing for? In D. Pimm (Ed.), *Mathematics, teachers and children* (pp. 129–140). London: Hodder & Stoughton

Desforges, C. (1989). Classroom processes and mathematical discussions: A cautionary note. In P. Ernest (Ed.), *Mathematics teaching: The state of the art* (pp.143–150). Barcombe, East Sussex: Falmer Press.

Dick, W. (1991). An instructional designer's view of constructivism. *Educational Technology,* 5, 41–44.

Dickson, L., Brown, M., & Gibson, O. (1984). *Children learning mathematics: A teacher's guide to recent research.* London: Cassell.

Dirks, M. (1997). Developing an appropriate assessment strategy: Research and guidance for practice. [Online] available URL:http://www.fsu.edu/garnet /acns.html

Dougherty, B. J. (1996). The write way: A look at journal writing in first-year algebra. *Mathematics Teacher,* 89(7), 556–560.

Driscoll, M., & Cuevas, G. (1993). (Eds.). *Reaching all students with mathematics.* Reston, VA: National Council of Teachers of Mathematics.

Drummond, M. J. (1993). *Assessing children's learning*. London: David Fulton Publishers.

Ellerton, N. F., & Clements, M. A. (1996). Researching language factors in mathematics education: The Australia contribution. In P. Sullivan, K. Owens & B. Atweh (Eds.), *Review of mathematics education in Australasia 1992–1995* (pp. 191–236). Campbelltown, Australia: Mathematics Education Research Group of Australasia.

Ellerton, N. F., Clements, M. A., & Skehan, S. (1989). Action research the ownership of change: A case study. In N. F. Ellerton & M. A. Clements (Eds.), *School mathematics; the challenge to change* (pp. 284–302). Australia: Deakin University.

Ellerton, N. F., Cowan, E., & Clements, M. A. (1992). Some pluses and some minuses of radical constructivism in mathematics education. *Mathematics Education Research Journal,* 4(2), 1–22.

Entwistle, N. (1990). Introduction: Changing conceptions of learning and teaching. In N. Entwistle (Ed.), *Handbook of Educational Ideas and Practices* (pp. 662–667). London: Routledge.

Ernest, P. (1989). The knowledge, beliefs and attitudes of the mathematics teacher: A model. *Journal of Education for Teaching*, 15(1), 13 - 33.

Ernest, P. (1994). Varieties of constructivism: Other metaphors, epistemologies and pedagogical implications. *Hiroshima Journal of Mathematics Education,* 2, 1–14.

Fairbrother, R. W., Black, P. J., & Gill, P. (Eds.). (1995). *Teachers assessing pupils: Lessons from science classrooms*. Hatfield, UK: Association for Science Education.

Fairbrother, R. W., Dillon, J., & Gill, P. (1995). Assessment in science: Teachers' attitudes and practices. *Australian Science Journal*, 41(4), 30–36.

Faire, M., & Yates, R. (1994). Assessing and evaluating student learning. In C. Mc Gee and D. Fraser (Eds.), *The professional practice of teaching; an introduction to teaching, learning and curriculum* (pp. 109–130). Palmerston North: Dunmore Press.

Falchikov, N. (1995). Improving feedback to and from students. In P. Knight (Ed.), *Assessment for learning in higher education* (pp. 157–166). London: Kogan Page.

Fergus, H. (1991). Relevance and scale in educational development in some micro-states of the Eastern Caribbean. Paper presented at the *Annual Conference of the Comparative and International Society*, Pittsburgh.

Frankfort–Nachmias, C., & Nachmias, D. (1996*). Research methods in the social sciences* (5th ed.). New York: St. Martin's Press.

Freire, P. (1985). *Education for critical consciousness*. London: Sheed & Ward.

Fullan, M. (1985). Change process and strategies at the local level. *Elementary School Journal*, 85(3), 391–421.

Fullan, M. (1993). *Change forces: Probing the depths of educational reform.* NY: Falmer Press.

Gagne, R. M. (1967). Instructions and conditions of learning. In L. Siegel (Ed.), *Instruction: Some contemporary viewpoints* (pp. 291–313). San Francisco: Chandler.

Galbraith, P. L. (1993). Paradigms, problems and assessment: Some ideological implications. In M. Niss (Ed.), *Investigations into assessment in mathematics education. An International Commission on Mathematics Instruction study* (pp.73–86). Dordrecht, Netherlands: Kluwer Academic Publishers.

Gardner, H. (1992). Assessment in context: The alternative to standardized testing. In B. R. Gifford & M. C. O'Connor (Eds.), *Changing assessments: Alternative views of aptitude, achievement, and instruction* (pp. 77–119). Norwell, MA: Kluwer Academic Publishers.

Ginsburg, H. P., Jacobs, S. F. and Lopez, L. S. (1993). Assessing mathematical thinking and learning potential. In R. B. Davis & C. A. Maher (Eds.), *Schools, mathematics, and the world of reality* (pp. 237–262). Boston: Allyn and Bacon.

Gipps, C. (1990). *Assessment: A teachers' guide to the issues.* London: Hodder & Stoughton.

Gipps, C. (1994). Quality in teacher assessment. In W. Harlen (Ed.), *Enhancing quality in assessment* (pp. 71–86). London: Paul Chapman Publishing.

Gipps, C., Brown, M., Mc Callum, B., & Mc Alister, S. (1995). *Intuition or evidence? Teachers and national assessment of seven-year olds.* Buckingham: Open University Press.

Goldin, G. A. (1993). Towards an assessment framework for school mathematics. In R. B. Davis & C. A. Maher (Eds.), *Schools, mathematics, and the world of reality* (pp. 63–72). Boston: Allyn and Bacon.

Good, T. L., & Brophy, J. E. (1994). *Looking in classrooms* (6th ed.). New York: Harper Collins College Publishers.

Gooding, A., & Stacey, K. (1993a). How children help each other learn in groups. In M. Stephens, A, Waywood, & D. Clarke (Eds.), *Communicating mathematics: Perspectives from classroom practice and current research* (pp. 41–50). Hawthorn, Victoria: Australian Council for Educational Research.

Gooding, A., & Stacey, K. (1993b). Characteristics of small group discussion reducing misconceptions. *Mathematics Education Research Journal*, 5(1), 60–73.

Gopen, G. D., & Smith, D. A. (1990). What's an assignment like you doing in a course like this? Writing to learn mathematics. *The College Mathematics Journal*, 21(1).

Greenwood, J. J. (1993). On the nature of teaching and assessing mathematical power and mathematical thinking. *Arithmetic Teacher*, 41(3), 144–151.

Grennon Brooks, J. G. & Brooks, M. G. (1993). *In search of understanding: The case for constructivist classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development.

Grouws, D. A., & Meier, S. L. (1992). Teaching and assessment relationships in mathematics instruction. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 83–106). Hawthorn: Australian Council for Educational Research.

Guba, E. G., & Lincoln, Y. S. (1985). *Naturalistic inquiry.* Beverly Hills: Sage Publications.

Hammond, M., & Collins, R. (1991). Self-directed learning: Critical practice. London: Kogan Page.

Hancock, J. (1992). Side-by-side: Responsive evaluation in a year five classroom. In C. Bouffler (Ed.), *Literacy evaluation: Issues and practicalities* (pp. 85–98). Sydney: Primary English Teaching Association.

Hanley, S. (1994). *On constructivism.* College Park, MD: Maryland Collaborative for Teacher Preparation.

Harding, S. (Ed.). (1993). *The racial economy of science: Toward a democratic future.* Bloomington: Indiana University Press.

Harlen, W. (1994). Issues and approaches to quality assurance and quality control in assessment. In W. Harlen (Ed.), *Enhancing quality in assessment.*(pp. 11–25). London: Paul Chapman Publishing Ltd.

Harlen, W. (1995). To the rescue of formative assessment. *Primary Science Review,* 37 April, 14–16.

Harlen, W., Gipps, C., Broadfoot, P., & Nuttall, D. (1992). Assessment and the improvement of education. *The Curriculum Journal,* 3(3), 215–230.

Harris, D., & Bell, C. (1990). *Evaluating and assessing learning.* London: Kogan Page.

Heath, P. (1994). *Alternative assessment for college mathematics.* ERIC document Reproduction Service, ED 376208.

Hergenhahn, B. R. (1988). *An introduction to theories of learning* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Herman, J. L. (1997). Assessing new assessments: How do they measure up? *Theory into Practice,* 36(4), 196–204.

Herman, J. L., Aschbacher, P. R., & Winters, L. (1992). *A practical guide to alternative assessment.* Alexandria, VA: Association for Supervision and Curriculum Development.

Hiebert, J., & Carpenter, T. P. (1992). Learning and teaching with understanding. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics* (pp. 65–97). New York: MacMillan.

Holly, M. L. (1987). *Keeping a personal-professional journal.* Geelong, Vic: Deakin University Press.

Holly, M. L., & Mcloughlin, C. (1988). Professional development and journal writing. In M. L.Holly & C. Mcloughlin (Eds.), *Perspectives on professional development.* London: Falmer Press.

Hopkins, D. (1993). *A teacher's guide to classroom research* (2nd ed.). Bristol, PA: Open University Press.

Horton, T. (1990). TGAT: A report. Purposes and principles. In T. Horton (Ed.), *Assessment debates* (pp. 37–47). London: Hodder & Stoughton. (TGAT = Task Group on Assessment and Testing)

Hughes, I., & Large, B. (1993). Assessment of students' oral communication skills by staff and peer groups. *The New Academic,* Summer, 10–12.

Huinker, D. M. (1993). Interviews: A window to students' conceptual knowledge of the operations. In N. L. Webb & A. P. Coxford (Eds.), *Assessment in mathematics classrooms.* NCTM 1993 Yearbook (pp. 80–86). Reston, VA: National Council of Teachers of Mathematics.

Hunting, R., & Doig, B. (1991). Development of a clinical tool for initial assessment of a student's mathematics learning. In M. Stephen and J. Izard (Eds.), *Reshaping assessment practices: Assessment in the mathematical sciences under challenge* (pp. 201–217). Proceedings from the First National Conference on Assessment in the Mathematical Sciences at Geelong. Hawthorn, Vic: Australian Council for Educational Research.

Jaworski, B. (1988). "Is" versus "seeing as": Constructivism and the mathematics classroom. In D. Pimm (Ed.), *Mathematics, teachers and children* (pp. 287–296). London: Hodder & Stoughton.

Jennings, Z. (1994). Innovations in Caribbean School Systems: Why some have become institutionalised and others have not. *Curriculum Studies,* 2(3), 309–331.

Jinkins, D., & Bobrow, J. (1997). *St. Vincent and the Grenadines: A plural country.* Stockbridge, MA: Concepts Publishing.

Joffe, L. S. (1990). Evaluating assessment: Examining alternatives. In S. Willis (Ed.), Being numerate: What counts? (pp. 138–161). Hawthorn: Australian Council for Educational Research.

Joffe, L. S. (1992). The English experience of a national curriculum and assessments. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 190–222). Hawthorn, Vic: Australian Council for Educational Research.

Johnson, D. W., & Johnson, R. T. (1991). *Learning together and alone: Cooperative, competitive and individualistic learning* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Jonassen, D. H. (1991). Objectivism versus Constructivism: Do we need a new philosophical paradigm? *Journal of Educational Research,* 39(3), 5–14.

Joyce B., & Showers, B. (1980). Improving in-service training: the messages of research. *Educational Leadership,* 37(5), 379–385.

Joyce, B., & Showers, B. (1988). *Student achievement through staff development.* New York: Longman.

Joyce, B., & Weil, M. (1992). *Models of teaching* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Joyner, J. (1996). Implementing the assessment standards for school mathematics: Look! How I am growing. *Teaching Children Mathematics,* 2(7), 404–407.

Kenny, P. A., Schloemer, G. C., & Cain, R. W. (1996). Communicating all about assessment beyond the classroom. In P. C. Elliot & M. J. Kenny (Eds.), *Communication in mathematics K-12* (pp. 187–196). Reston, VA: National Council of Teachers of Mathematics.

Kenny, P. A., & Silver, E. A. (1993). Student self-assessment in mathematics. In N. L. Webb and A. P. Coxford (Eds.), *Assessment in mathematics classrooms.* NCTM 1993 Yearbook (pp. 229–238). Reston, VA: National Council of Teachers of Mathematics.

King, A. (1989). Verbal interaction and problem-solving within computer-assisted cooperative learning groups. *Journal of Educational Computing Research,* 5(1), 1–15.

King, K. (1990). Introduction: Education in contrasting societies. In N. Entwistle (Ed.), *Handbook of educational ideas and practices* (pp. 140–142). London: Routledge.

King, K. (1991). *Aid and education in the developed world.* Harlow: Longman..

King, W. (1991). School-based assessment in science: A Caribbean perspective. *School Science Review*, 72(261), 127–131.

Kirk, G. (1990). Introduction: Techniques of teaching and assessment. In N. Entwistle (Ed.), *Handbook of educational ideas and practices*(pp. 782–784). London: Routledge.

Kolstad, R., Briggs, L. D., & Hughes, S. (1993). Assessment in mathematics: Three alternative strategies. *Education*, 14(2), 297–301.

Kroll, D. L. (1989). Connections between psychological learning theories and the elementary mathematics curriculum. In P. Trafton, & A. Shulte (Eds.), *New directions for elementary school mathematics* (pp. 199–211). Reston, VA: National Council of Teachers of Mathematics.

Kuhs, T. (1992). *A viewer's guide. Mathematics assessment : Alternative approaches. Video tape and guide book.* Reston, VA: National Council of Teachers of Mathematics.

Kulm, G. (Ed.). (1990). *Assessing higher order thinking in mathematics.* Washington, DC: American Association for the Advancement of Science.

Kumar, R. (1996). *Research methodology: A step-by-step guide for beginners.* Melbourne, Australia: Addison-Wesley Longman.

Lamming, G. (1994). The Caribbean intellectual and Western education. In A. Cobley (Ed.), *Crossroads of empire: The Europe-Caribbean connection 1492–1992* (pp. 78–93). Barbados: University of the West Indies.

Leder, G. C. (1992). Curriculum planning + assessment = learning. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 330–346). Hawthorn, Vic: Australian Council for Educational Research.

Leder, G. C., & Forgasz. H. J. (1992). Perspectives on learning, teaching and assessment. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 1–23). Hawthorn, Vic: Australian Council for Educational Research.

LeGree, A. (1991). Collaboration and writing in the mathematics classroom. *Mathematics Teacher*, 84(3), 166–170.

Lerman, S. (1989). Constructivism, mathematics and mathematics education. *Educational Studies in Mathematics*, 20(2), 211–223.

Lieberman, A. (1995). Practices that support teacher development: Transforming conceptions of professional learning. *Phi Delta Kappan*, 76(8), 591–596.

Liedkte, W. (1988). Diagnosis in mathematics: The advantages of an interview. *Arithmetic Teacher*, 36(3), 26–29.

Linn, M. M. (1987). *Effects of journal writing on the thinking skills of high school geometry students.* Unpublished M.Sc. Thesis, University of Florida.

Linn, R. L. (1989). Current perspectives and future directions. In R. Linn (Ed.), *Educational measurement* (3rd ed.) (pp. 1–10). London: Collier MacMillan.

Lloyd-Jones, R., Bray, E., Johnson, G., & Currie, R. (1986). *Assessment: From principles to action.* London: MacMillan.

Long, M. J., & Ben-Hur, M. (1991). Informing learning through the clinical interview. *Arithmetic Teacher*, 38(6), 44–46.

Lovitt, C., Stephens, M., Clarke, D., & Romberg, T. A. (1990). Mathematics teachers reconceptualizing their roles. In T. J. Cooney & C. R. Hirsch (Eds.), *Teaching and learning in the 1990s. NCTM 1990 Yearbook* (pp. 229–236). Reston, VA: National Council of Teachers of Mathematics.

Lythcott, J., & Duschl, R. (1990). Qualitative research: From methods to conclusions. *Science Education*, 74(4), 445–460.

Macmillan, Primary Direct. (1997). *Solve the puzzle of maths assessment with jigsaw ideas for assessment in mathematics.* Albany, Auckland: Macmillan.

Mansfield, H. (1993). Process? Product? *The Australian Mathematics Teacher*, 49(4), 20–23.

Mason, J. (1991). Tensions. In D. Pimm (Ed.), *Mathematics, teachers and children* (pp. 164–169). London: Hodder & Stoughton.

Masqud, M., & Pillai, C. M. (1991). Effect of self-scoring on subsequent performances in academic achievement tests. *Educational Research*, 33(2), 151–154.

Masters, G. N. & Doig, B. A. (1992). Understanding children's mathematics; some assessment tools. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 249–268). Hawthorn, Vic: ACER.

Maykut, P., & Morehouse, R. (1994). *Beginning qualitative research: A philosophical and practical guide*. London: Falmer Press.

Mc Intosh, A. (1979). When will they ever learn? *Mathematics Teaching*, 86, i–iv.

Mc Intosh, M. E. (1991). No time for writing in your class? *Mathematics Teacher*, 84(6), 423–432.

McGaw, B. (1988). Overview of issues in school assessment. *SET*, 2(11), 1–4.

Meier, S. L. (1992). Evaluating problem-solving processes. *Mathematics Teacher*, 85(8), 664–666.

Meltzer, L. (1994). New directions in the assessment of students with special needs: The shift toward a constructivist perspective. *Journal of Special Education*, 28(3), 338–355.

Merriam, S. B. (1988). *Case study research in education. A qualitative approach.* San Francisco: Jossey-Boss.

Messick, S. J. (1989). Meaning and values in test validation: The science and ethics of assessment. *Educational Researcher*, 18(2), 5–11.

Messick, S. J. (1994). The interplay of evidence and consequences in validation of performance assessments. *Educational Researcher,* 23(2), 13–23.

Miller, D. L. (1991). Writing to learn mathematics. *Mathematics Teacher*, 84(7), 516–521.

Miller, D. L. (1992). Teacher benefits from using impromptu writing prompts in algebra classes. *Journal for Research in Mathematics Education*, 23(4), 329–340.

Ministry of Education. (1992). *St. Vincent and the Grenadines curriculum guide in mathematics for third forms*. Kingstown, St. Vincent and the Grenadines: Ministry of Education.

Ministry of Education. (1996). *Education policies*. Kingstown, St. Vincent and the Grenadines: Ministry of Education.

Ministry of Education, New Zealand. (1994). *Assessment: Policy into Practice.* Wellington: Learning Media.

Morgan, D. (1981). Men, masculinity and the process of sociological enquiry. In, H. Roberts (Ed.), *Doing feminist research* (pp. 83–113). London: Routledge and Kegan Paul.

Mousley, J. (1996). *Evaluating mathematics learning and teaching.* (Draft version). Geelong: Deakin University.

Mousley, J. A., Clements, M. A. K., & Ellerton, N. F. (1992). Teachers' interpretations of their roles in mathematics classroom. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 107–144). Hawthorn, Vic: Australian Council for Educational Research.

Mousley, J. A., Lean, G., & Zevenbergen, R. (1993). *Constructivism: The intersection of disciplines.* Geelong: Deakin University Press.

Murphy, P. (1990). TGAT: A conflict of purpose. In T. Horton (Ed.), *Assessment debates* (pp. 37–47). London: Hodder & Stoughton.

Murphy, R., & Torrance, H. (1988). *The changing face of educational assessment.* Milton Keynes: Open University.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1993). *Assessment in the mathematics classroom.* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1994). *Mathematics assessment: Alternative approaches. Videotape and discussion guide.* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics.* Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (1996). *Communication in mathematics K-12.* Reston, VA: National Council of Teachers of Mathematics.

New Living Translation (NLT). (1996). *Life application study Bible.* Wheaton, IL: Tyndale House Publishers.

Nicholson, D. J., & Anderson, J. O. (1993). A time and place for observations: Talking with primary teachers about classroom assessment. *The Alberta Journal of Educational Research*, 39(3), 363–374.

Niss, M. (Ed.). (1993a). *Investigations into assessment in mathematics education. An International Commission on Mathematics Instruction study.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Niss, M. (Ed.). (1993b). *Cases of assessment in mathematics education. An An International Commission on Mathematics Instruction study.* Dordrecht, The Netherlands: Kluwer Academic Publishers.

Nix, P., & Griffin, P. (1991). *Educational assessment and reporting: A new approach.* Sydney: Harcourt Brace Jovanovich.

Noddings, N. (1988). Preparing teachers to teach mathematical problem solving. In R. Charles & E. A. Silver (Eds.), *The teaching and assessing of mathematical problem solving* (pp. 244–258). Reston, VA: National Council of Teachers of Mathematics.

Nolder, R. (1991). Responding to change. In D. Pimm (Ed.), *Mathematics, teachers and children* (pp. 156–163). London: Hodder & Stoughton.

Nolder, R. (1992). Towards a model of accelerated professional development. *British Journal of In-Service Education*, 18(1), 35–41.

Novak, J. D., & Gowin, B. D. (1984). *Learning to learn.* New York: Cambridge University Press.

OECS Education Reform Strategy. (1996). *The Vincentian*, Friday October 18, 89(42), 8. (OECS = Organisation for Eastern Caribbean States).

Oliver, B. (1980). Action Research for inservice training. *Educational Leadership,* 37(5), 394–395.

Pateman, N. A., & Johnson, D. C. (1990). Curriculum and constructivism in early childhood mathematics: Sources of tension and possible resolutions. In L. P. Steffe & T. Wood (Eds.), *Transforming children's mathematics education: International perspectives* (pp. 346–356). Hillsdale, NJ: Lawrence Erlbaum Associates.

Peck, D. M., Jencks, S. M., & Connell, M. L. (1989). Improving instruction through brief interviews. *Arithmetic Teacher*, 37(3), 15–17.

Perrone, V. (Ed.). (1991). *Expanding student assessment.* Alexandria, VA: Association for Supervision and Curriculum Development.

Prawat, R. S. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education,* 100(3), 354–395.

Pryor, J., & Torrance, H. (1995). *Teacher-pupil interaction in formative assessment: Assessing the work or protecting the child?* Unpublished paper, University of Surrey.

Raymond, A. M. (1994). Assessment in mathematics education: What are some of the alternatives in alternative assessment? *Contemporary Education,* 66(1), 13–17.

Reinharz, S. (1992). *Feminist methods in social research.* New York: Oxford University Press.

Resnick, L. B., & Ford, W. W. (1981). *The psychology of mathematics for instruction*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Resnick, L. B., & Resnick, D. P. (1991). Assessing the thinking curriculum: New tools for education reform. In B. R. Gifford & M. C. O'Connor (Eds.), *Changing assessments: Alternative views of aptitude, achievement and instruction* (pp. 37–75). Boston: Kluwer Academic Publishers.

Romberg, T. A. (1993). How one comes to know: Models and theories of the learning of mathematics. In M. Niss (Ed.), *Investigations into assessment in mathematics education. An International Commission on Mathematics Instruction study* (pp. 97–111). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Romberg, T. A., Zarinnia, E. A., & Collis, K. V. (1990). A new world view of assessment in mathematics. In G. Kulm (Ed.), *Assessing higher order thinking in mathematics* (pp. 21–38). Washington DC: American Association for the Advancement of Science.

Rowntree, D. (1987). *Assessing students: How shall we know them?*(2nd ed.). London: Harper & Row.

Sadler, R. (1989). Formative assessment and the design of instructional systems. *Instructional Science*, 18, 119–144.

Said, E. W. (1993). *Culture and Imperialism*. New York: Alfred. A Knopf Inc.

Sam, C. A. (1992). *Looking at the Vincentian Garifuna*. Paper presented at the *Preservation of the Garifuna Culture Society Conference,* Los Angeles.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning. A project* *of the National Council of Teachers of Mathematics* (pp. 334–370). New York: MacMillan.

Schoenfeld, W. N. (1993). The necessity of behaviourism. *Educational Technology*, 33(10), 5–7.

Schroeder, T. L., & Lester, F. K. (1989). Developing understanding in mathematics via problem solving. In P. R. Trafton & A. P. Shulte (Eds.), *Directions for elementary school mathematics* (pp.31–42). Reston, VA: National Council of Teachers of Mathematics.

Scriven, M. (1988). Duty-based teacher evaluation. *Journal of Personnel Evaluation in Education*, 1(4), 319–334.

SEDLetter. (1996). The practice and implications of constructivism. *SEDLetter*, 9(3), 1–2.

Shepard, L. A. (1989). Why we need better assessments. *Educational Leadership*, 46(7), 4–9.

Shepard, L. A. (1993). Evaluating test validity. *Review of Research in Education*, 19, 405–450.

Shepard, L. A. (1994). The challenges of assessing young children appropriately. *Phi Delta Kappan*, 76(3), 206–212.

Shield, M., & Swinson, K. (1997). Encouraging learning in mathematics through writing. *The Australian Mathematics Teacher*, 53(1), 4–8.

Siemon, D. (1989). Teachers as agents of change in mathematics education. In N.F. Ellerton & M.A.C. Clements (Eds.), *School mathematics: The challenge to change*. Geelong: Deakin University Press.

Skinner, B. F. (1953). *Science and human behavior*. New York: MacMillan.

Smith, B. O. (1987). Assessment. In M. J. Dunkin (Ed.), *The international encyclopedia of teaching and teacher education* (pp.11–15). Oxford: Pergamon Press.

Steffe, L. P., & D' Ambrosio, B. S. (1995). Toward a working model of constructivist teaching: A reaction to Simon. *Journal for Research in Mathematics Education*, 26(2), 146–159.

Stenmark, J. K. (1989). *Assessment alternatives in mathematics: An overview of assessment techniques that promote learning*. Berkley, CA: EQUALS.

Stenmark, J. K. (Ed.). (1991). *Mathematics assessment: Myths, models, good questions, and practical suggestions*. Reston, VA: National Council of Teachers of Mathematics.

Stephens, M., & Izard, J. (Eds.). (1992). *Reshaping assessment practices: Assessment in the mathematial sciences under challenge*. Hawthorn, Vic: Australian Council for Educational Research.

Stiggins, R. J. (1988). Revitalising classroom assessment: The highest instructional priority. *Phi Delta Kappan*, 65(3), 363–368.

Stiggins, R. J. (1992). In teacher's hands: investigating the practices of classroom assessment. Albany, New York: State University Press.

Stix, A. (1994). Pic-Jour math: Pictorial journal writing in mathematics. *Arithmetic Teacher*, 41(5), 264–269.

Sutton, R. (1995). *Assessment for learning*. Salford, England: RS Publications.

Tanner, H., & Jones, S. (1994). Using peer and self-assessment to develop modelling skills with students aged 11–16: A socio-constructive view. *Educational Studies in Mathematics*, 27, 413–431.

Thomas, J. (1992). Politics of mathematics education in Australia. In B. Atweh & J. Watson (Eds.), *Research in mathematics education in Australasia 1988–1991* (pp. 26–42). Brisbane: Mathematics Education Research Group of Australasia.

Thompson, A. G. (1985). Teachers' conceptions of mathematics and the teaching of problem solving. In E. Silver (Ed.), *Teaching and learning mathematical problem solving: Multiple research perspectives* (pp. 281–294). Hillsdale, NJ: Lawrence Erlbaum Associates.

Thorndike, E. L. (1922). *The psychology of arithmetic.* New York: MacMillan.

Torrance, H. (1993). Formative assessment: Some theoretical problems and empirical questions. *Cambridge Journal of Education*, 23(3), 333–342.

Torrance, H. (1995). Teacher involvement in new approaches to assessment. In H. Torrance (Ed.), *Evaluating authentic assessment: Problems and possibilities in new approaches to assessment* (pp. 44–56). Buckingham: Open Press.

Torrance, H., & Pryor, J. (1995). Investigating teacher assessment in infant classrooms: Methodological problems and emerging issues. *Assessment in Education,* 2(3), 305–320.

United Nations Development Programme. (1994). *Human development report.* NY: Oxford University Press.

Van de Walle, J. A. (1995). *Elementary school mathematics: Teaching developmentally.* White Plains, NY: Longman.

von Glasersfeld, E. (1990). An exposition of constructivism: Why some like it radical. *Journal for Research in Mathematics Education,* Monograph Number 4, 19–29.

Vygotsky, L. S. (1978). *Mind in society: The development of higher pyschological processes.* M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds. and Trans.). Cambridge; MA: Harvard University Press.

Walker, R. (1993). *Applied qualitative research.* Aldershot, England: Dartsmouth.

Watson, K. (Ed.). (1982). Colonialism and educational development. In K. Watson (Ed.), *Education in the third world* (pp. 1–46). London: Croom Helm.

Waywood, A. (1992). *Journal writing and learning mathematics.* Christ Campus, Victoria: Australian Catholic University.

Webb, N. (1992). Testing a theoretical model of student interaction and learning in small groups. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interaction in cooperative groups: The theoretical anatomy of group learning* (pp. 102–119). Cambridge, UK: Cambridge University Press.

Webb, N. (1993). Assessment for the mathematics classroom. In N. L. Webb & A. P. Coxford (Eds.), *Assessment in mathematics classrooms.* NCTM 1993 Yearbook (pp. 1–6). Reston, VA: National Council of Teachers of Mathematics.

Webb, N., & Briars, D. J. (1990). Assessment in mathematics classrooms K-8. In T. J. Cooney & C. R. Hirsch (Eds.), *Teaching and learning mathematics in the 1990s* (pp. 108-129). Reston, VA: National Council of Teachers of Mathematics.

Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education,* 75(1), 9–21.

Wheatley, G. H., Clements, D. H. & Battista, M. T. (1990). Calculators and constructivism. *Arithmetic Teacher*, 83(6), 276–279.

White, R., & Gunstone, R. (1992). *Probing understanding*. London: Falmer Press.

Wiggins, G. (1989). A true test: Toward more authentic and equitable assessment. *Phi Delta Kappan*, 79, 703–713.

Wiggins, G. (1990). *The case for authentic assessment*. American Institute for Research, Washington, DC. [Online] available URL:http.www.gopher// vmsgopher.cua.edu;70/00gopher-root-eric-ae%3A%5B-alt%5D/issues.txt

Wiliam, D. (1992). Some technical issues in assessment: A user's guide. *British Journal for Curriculum and Assessment*, 2(3), 11–20.

Wilson, B., Teslow, J., & Osman-Jouchoux, R. (1995). The impact of constructivism (and postmodernism) on ID Fundamentals. In B. B. Seels (Ed.), *Instructional Design Fundamentals: A review and reconsideration* (pp. 137–157). Englewood Cliffs, NJ: Educational Technology Publications.

Wilson, L. D. (1994). *A theoretical framework linking beliefs with assessment practices in school mathematics: Assessment reforms in search of a theory*. Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA. ED 377215.

Wolf, K. P. (1993). From informal to informed assessment: Recognizing the role of the classroom teacher. *Journal of Reading*, 36(7), 518–522.

Wood, T., Cobb, P., & Yackel, E. (1992). Change in teaching mathematics: A case study. *American Educational Research Journal*, 28(3), 587–616.

Woodruffe, K. E. (1992). *Journal writing in a third form mathematics class*. Unpublished M.Sc. Thesis, University of Waikato, Hamilton, New Zealand.

Yackel, E., Cobb, P., & Wood, T. (1992). Instructional development and assessment from a socio-constructivist perspective. In G. Leder (Ed.), *Assessment and learning of mathematics* (pp. 63–82). Hawthorn, Vic: Australian Council for Educational Research.

Yackel, E., Cobb, P., Wood, T., Wheatley, G., & Merkel, G. (1990). The importance of social interactions in children's construction of mathematical knowledge. In T. Cooney (Ed.), *Teaching and learning mathematics in the 1990s* (pp.12–21). Reston, VA: National Council of Teachers of Mathematics.

Yin, R. (1989). *Case study research: Design and methods*. Beverly Hills, CA: Sage.

Zevenbergen, R. (1991). Constructivism in the classroom. In J. O'Reilly & S. Wettenhall (Eds.), *Mathematics ideas: Inclusive, dynamic, exciting, active and stimulating* (pp. 15–18). Parkville, Vic: The Mathematical Association of Victoria.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: The emergence of a social cognitive perspective. *Educational Psychology Review*, 2, 173–201.