Supporting chemistry teachers in implementing formative assessment of investigative practical work in Botswana

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Motswiri, Moipolai J.

Supporting chemistry teachers in implementing formative assessment of investigative practical work in Botswana.

Thesis University of Twente, Enschede – With refs. – With Dutch summary.
ISBN 90 365 2125 4

Layout: Sandra Schele
Press: PrintPartners Ipskamp - Enschede

SUPPORTING CHEMISTRY TEACHERS IN IMPLEMENTING FORMATIVE ASSESSMENT OF INVESTIGATIVE PRACTICAL WORK IN BOTSWANA

PROEFSCHRIFT

ter verkrijging van
de graad van doctor aan de Universiteit Twente,
op gezag van de rector magnificus,
prof. dr. F.A. van Vught,
volgens besluit van het College voor Promoties
in het openbaar te verdedigen
op donderdag 16 december 2004 om 15.00 uur

door

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geboren op 30 december 1955

te Manyana, Gaborone, Botswana

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Dr. A.M. Thijs

To my loving parents Ikanyeng and Phetwe

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Glossary

BGCSE	Botswana General Certificate of Secondary Education
UCLES	University of Cambridge Local Examinations Syndicate
COSC	Cambridge Overseas School Certificate
RNPE	Revised National Policy on Education
NCE	National Commission on Education
IPW	Investigative Practical Work
FA	Formative Assessment
LC	Learner-centred

ACKNOWLEDGEMENTS

Time has passed so swiftly from the conception of this study to its conclusion that it seems like only yesterday. Yet almost five years have elapsed and a lot has happened. In those years I became a stranger to many people including my family and my colleagues at work. The five years were spent on a study leave from work. In reality, I also took leave from my family responsibilities because I was not available to make any long-term plans with them. A sandwich PhD study trajectory meant that I spent time in both the Netherlands, at the University of Twente, and in Botswana. Most of my time in Botswana was invariably spent following the research activities in schools.

I realise this study could not have been possible without the assistance and moral support from many individuals and organizations. Space does not allow acknowledging all but a few notables.

- My supervision team led by the promotor Jan van den Akker also included Wilmad Kuiper and Annette Thijs, from whom I am privileged to have received guidance, stimulating discussions, and constant encouragement. A Setswana saying goes thus, 'mashi ke phepa gotswa thobeng selabi setla le motsaa kgamelo', meaning that you cannot fault the source of information (or advice) once it is being used. As I claim ownership of this work, so I am responsible for its strengths and shortcomings. I thank my promotor van den Akker for his generosity in giving me the opportunity to come and study at the University of Twente. Wilmad Kuiper has played both supervisory and pastoral roles. Major decisions on the study were made on his several visits either to Botswana or South Africa. Annette Thijs has been a supervisor and sister. Her research experience in Botswana made her the natural trouble-shooter.
- The Department of Mathematics and Science Education of the University of Botswana through the Training Department to give a leave of absence to realize this study. Professor A.A. Taiwo, my in country supervisor, who's guidance and support cannot be quantified.

- Leo de Feiter, Wout Ottevanger, and Wim Kouwenhoven for encouraging me to think less about my age and focus on what I can do. Sharing an office with Wim rekindled previous working relationships, the Calvinistic dedication and persistence to task that I learned to respect him for. His presence and eventual defence of his PhD thesis spurred me on. Wout continued to be a friend and peer on whom I could rely. Leo made the initial suggestions for my coming to Twente. That this work has been realised is testimony to his foresight and belief in human potential.
- The teachers who participated in various phases of the study. Their contributions were in both realising the quality of the curriculum materials and sacrificing in implementation despite tight commitments in their teaching timetables.
- The staff in the Department of Curriculum and at the International Office of the Faculty of Behavioural Sciences of the University of Twente for making me feel welcome and helping me maintain my sanity in the most trying five months of writing and producing this book. Sandra Schele for her help in accessing necessary office stationery resources and her part in the final production of this book. Kevin McKenney for his invaluable work of language proof reading and making recommendations for a better presentation of this book. Dionysia Loman who was incredibly helpful and for whom I am deeply indebted. Her colleagues Jan and Frances also deserve a mention.
- Marian Kuiper, Tineke Kouwenhoven, and Peter-Paul Verbeek, and their families respectively who feted me to a host of dinners for their generosity and helping me wind down and take a temporary leave from the scourge of writing.
- Last but not least my family for bearing with my leave of absence from their lives. My wife deserves acknowledgement for her strength and loyalty. Raising four children, and two of them hot-blooded teens, is no mean task. Thank you Shelia, Malebogo, Lesego, Keemenao, and Theophilus. My wife's strength came from our extended family system, especially my parents and my mother in-law.

I am indebted to your generosity.

Moipolai Joseph Motswiri
Enschede, December 2004

CHAPTER 1
About this study

This chapter introduces the study on supporting chemistry teachers to implement formative assessment of investigative practical work in senior secondary chemistry education in Botswana. The problems facing science teachers in curriculum reform and implementation in a Botswana context are discussed in section 1.1. Section 1.2 presents the aim of the study. The research approach is discussed in section 1.3, and section 1.4 presents an overview of the subsequent chapters.

1.1 PROBLEMS WITH SECONDARY SCIENCE CURRICULUM IMPLEMENTATION IN BOTSWANA

1.1.1 The BGCSE science curriculum

In line with many other countries, Botswana is implementing a learner-centred senior secondary science curriculum. The Botswana General Certificate of Secondary Education (BGCSE) curriculum, implemented first in 1998, encourages the learner to actively participate in the process of learning. The curriculum focuses on Forms 4 and 5, the last two years of the secondary school system. The BGCSE science curriculum intends to promote a learner-centred approach by the following:

- emphasising the development of science process skills and problem solving skills, and the acquisition of hands-on experience;
- catering to a wide range of abilities. For this purpose, the curriculum is divided into a core component with basic subject content to be done by all students, and an extended component with more challenging content aimed at high achievers;
- promoting a practical orientation and stressing the importance of local contexts to help learners develop practical skills to assist them in solving technological problems in everyday life situations;
- promoting school-based continuous assessment of students' acquisition of practical skills through practical work.

Among the first BGCSE curriculum subjects to be implemented from 1998 onwards was the pure chemistry syllabus. The chemistry syllabus included two major reforms by (i) emphasizing continuous coursework assessment of practical work at the school level, and (ii) encouraging teachers to use a learner-centred approach. Coursework assessment of practical work was intended to have both summative purposes in generating a mark for the examination grade and formative purposes in providing feedback for teaching and learning during classroom activities.

Based on the overall aim of the BGCSE curriculum to encourage learner-centred education, *formative assessment* was considered to be especially important. Emphasis was also put on *investigative practical work* in which 'minds on' rather than 'hands on' activities were emphasised. This study aimed at exploring how to support teachers with the implementation of a learner-centred approach in chemistry education, thereby focusing on the propagated formative assessment of investigative practical work.

1.1.2 Problems with implementing the BGCSE science curriculum

Chemistry teachers who were involved in implementing the intended formative assessment of investigative practical work were uncertain of what was expected of them. Information from a number of national studies on science teaching (Motswiri, 2001; Rammung, 2000; Yandila, 1999) suggested that teachers had problems in successfully implementing the new reforms. While the learner-centred instructional approach advocated giving students space to actively construct their knowledge with the teacher in a facilitative role, classroom teaching in Botswana continues to be largely conducted in a more teacher-centred approach characterised by lecture methods in which 'chalk-and-talk' predominates (Kikstra, 1998; Prophet, 1995; Snyder & Ramatsui, 1990). The 'chalk-and-talk' approach is characterised by heavy teacher talk and passive students, who are either listening to the teacher or copying notes from the board.

The problems confronting teachers in Botswana when they attempt to implement innovative curriculum reforms are not unique. Such problems are common to most if not all educational systems of the world. Translating policy into practice has consistently proved to be a difficult undertaking and experience has shown that sustainable change is difficult to achieve at the classroom level (Fullan, 2001). In African countries, problems with curriculum change become even more magnified due to the unfavourable conditions under which implementation often takes place (de Feiter, Vonk & van den Akker, 1995). The bulk of the curriculum reforms are often imported and inconsistent with the objectives of the education policies they are intended to address. This makes it more difficult for the teachers to identify with the values on which the reforms were initially based. Second, as the rapid expansion of education has not been accompanied with a likewise growth in financial resources, the education systems have been operating under stressed conditions. This is mainly a result of an increase in the school going population and the drive to get as many students as possible through the school system to achieve an adequate supply of graduates for further education and the labour market. One result of these conditions has been poor quality education. In the developing world, improvement in quality of education is increasingly considered a priority, especially in science subjects because of their perceived potential to provide a foundation for scientific and technological developments. These are considered essential to address natural and social ills such as unemployment, poverty, and disease.

However, despite efforts to address the quality of education, many African countries and developing countries in general often have difficulties with providing satisfactory conditions for teaching science (Caillods, Göttelmann-Duret & Lewin, 1996; de Feiter et al., 1995; Ogunniyi, 1995). Schools lack material resources such as textbooks, laboratories, and equipment. Combined with high class sizes, this limits the possibilities for group work activities and practical work, two elements considered to be central to more learner-centred approaches in science education. The quality of science teaching is another major concern. Many teachers lack appropriate qualifications and backgrounds. Due to a rapid expansion of the education system, schools are often forced to employ teachers who are either unqualified or irrelevantly qualified in areas where the need is most. In the area of science, the number of expatriate staff on short contract is often considerable. Short contracts and teacher transfers contribute to high teacher turnover and lack of continuity in staffing. Other teachers move to administrative positions or find alternative employment in other areas of the economy.

The combined effect of the challenges posed by the conditions mentioned above widens the gap between the intended aims of the official curricula and the implemented curriculum in the classroom (cf. London, 1993; Ware, 1992). Because the teacher plays a key role in curriculum implementation, teacher support is crucial to facilitate curriculum change. In view of all the constraints regarding teaching conditions in developing countries, comprehensive teacher support programs are needed.

1.1.3 The role of materials in curriculum reform

From several studies (Ball & Cohen, 1996; van den Akker, 1988) it is known that curriculum materials can have great potential in supporting teachers with curriculum implementation. Especially during initial stages of implementation, curriculum materials can do the following (van den Akker, 1988):

- provide theoretical background information on the meaning of the change;
- demonstrate the practical meaning of the intended change;
- provide potential users with opportunity to experiment with exemplary activities, thereby gaining insight into the consequences of the change for their classroom practice;
- provide concrete resources that can serve as a frame of reference for the intended educational change and stimulate discussions among teachers who are using the materials.

To fulfil these functions the materials should contain a large amount of specific and concrete guidelines for the teacher on how to plan, organise, and conduct the lesson.

The use of curriculum materials with such guidelines has also been explored in the context of Southern Africa. Results of a study in Namibia (Ottevanger, 2001) show that exemplary curriculum materials can be a useful support tool for teachers during the initial implementation stages and can help them to organise and execute learner-centred lessons adequately. A study in Botswana (Thijs, 1999) found that exemplary curriculum materials could help teachers to overcome initial concerns and stimulate them to experiment with the use of a learner-centred approach in their lessons. As a result of using the materials, teachers also generated new ideas on ways to increase student involvement in their lessons. Because of these promising potentials, this study was initiated in 1999 to explore how exemplary curriculum materials could support teachers with the implementation of a formative assessment of investigative practical work in chemistry education.

1.2 AIM OF THE STUDY

The primary aim of this study was to develop insights into the characteristics of BGCSE-based exemplary curriculum materials (consisting of teacher and students' materials) that would support teachers to implement a more learner-centred approach emphasizing formative assessment of investigative practical work. The study involved the iterative design, development, and formative evaluation of prototypical materials. The exemplary materials were intended for supporting teachers in at least two distinct functions:

- First, the support included clarification of concepts involved in using a learner-centred instructional approach at the classroom level. This included clarification of learner-centeredness, formative assessment, and investigative practical work. This information aimed to provide teachers with a clear understanding of these concepts in terms of meaning and exemplification.

- Second, the exemplary materials aimed at providing teachers with prototypical experiences as a guide for use in practice.

With the assumption that exemplary curriculum materials have the potential to support teachers with implementing innovative curriculum practices, it becomes pertinent to ask questions about what such materials should look like and how they could be developed so that they could serve as a useful support tool for teachers. In line with this thinking, the main research question was formulated as the following:

> *How can exemplary curriculum materials support senior secondary chemistry teachers in Botswana with the implementation of formative assessment of students' investigative practical work?*

1.3 RESEARCH APPROACH

In this study a development research approach was followed. Van den Akker and Plomp (1993) argue that development research serves two purposes:
(i) optimising the development of prototypical products (including providing empirical evidence for their effectiveness);
(ii) generating methodological directions for the design and evaluation of such products.

In line with these purposes of development research, this study intended (i) to produce valid and practical chemistry curriculum materials aimed at supporting senior secondary science teachers to shift their classroom practice to a more learner-centred approach, exemplified by formative assessment of practical work and, (ii) to generate methodological guidelines for the design, development, and evaluation of such materials.

A prototyping approach was used in the design and development process, gradually specifying the characteristics of the materials (cf. Nieveen, 1999). Prototyping composes of the iterative process of development and extensive use of prototypes until the required quality product is attained. The development of prototypical products in the different stages of development research is guided by criteria of validity, practicality, and effectiveness (Nieveen, 1999). Formative evaluation pervades the entire process and provides information that feeds the cyclic process of development and research. The design and research activities involve high participation from the target group. According to van den Akker (1999) development research is often initiated for complex, innovative tasks for which only very few validated principles are available to structure and support the design and development activities. As indicated in the preceding sections, the implementation of the BGCSE curriculum is considered to be problematic. It was therefore considered that a development research approach could help to address some of the uncertainties experienced by teachers involved in the implementation process.

This study consisted of three related phases. The first phase consisted of an orientation study, aimed at articulating initial design specifications for the envisaged exemplary curriculum materials, followed by the design, development, and expert appraisal of a first prototype. As part of the orientation, a needs and context analysis of the current classroom practice was conducted (reported in chapter 2) and literature on curriculum implementation and the role of exemplary curriculum materials in supporting teachers in this process was reviewed (reported in chapter 3). The initial design specifications were appraised by a panel of experts for consistency with the insights developed from chapters 2 and 3. The design specifications were used as guide for the development of the first prototype of the exemplary curriculum materials (reported in chapter 4). The exemplary curriculum materials were based on the senior secondary pure chemistry topic of Acids, Bases, and Salts. The first prototype was appraised by both experts and teachers. The expert appraisal aimed at exploring the validity of the prototype in terms of its consistency with the design specifications and the subject syllabus objectives. Teachers appraised the first prototype for consistency with their usual practice.

The second phase consisted of the development and try out of a second prototype, which was based on recommendations derived from expert and teacher appraisal of the first prototype. A try out was carried out with lessons focusing on the practicality of the materials in terms of guiding teachers to support students' activities and also for students to be able to follow activities in ways that promoted learner-centred practice. The development activities included prototyping cycles in which the materials were iteratively improved (reported in chapter 5). The try out not only explored the practicality of the materials, but also provided an opportunity to test research instruments which would be used in the field test of a third prototype.

The third phase (described in chapter 6) involved the development and field test of a third prototype based on the results and insights learned from the try out phase. Research methods included lesson observations with use of a curriculum profile observation instrument, interviews for both teachers and students, and a logbook for teachers to reflect on their practice.

1.4 OVERVIEW OF THE FOLLOWING CHAPTERS

Chapter 2 discusses the context of Botswana and its education system. The education system is discussed in relation to the problems of curriculum reform in teaching and learning science. In chapter 3 the theoretical framework for implementing formative assessment of investigative practical work in a learner-centred setting is discussed. In chapter 4, the articulation of the initial design specifications and the development and the appraisal of the first prototype (exemplary teacher support curriculum materials including students materials) are described. Chapter 5 reports on the development and the try out of the second prototype with the aim of exploring its practicality in the classroom setting. In chapter 6, the development and the field test of the third prototype is reported. Chapter 7 presents the discussion on the outcomes and the conclusions of the study.

CHAPTER 2
The context of Botswana

In this chapter the context of the study is outlined. Section 2.1 describes the geography and the socio-economic status of Botswana. The general system of education is outlined in section 2.2. The teaching and learning of science is described in section 2.3, and the design and the results of the orientation study carried out to develop insights into the current status of Botwana's science curriculum reform is reported in 2.4. Section 2.5 describes the structures available for the professional development of teachers. Finally, section 2.6 discusses the main lessons learned from the context analysis.

2.1 COUNTRY BACKGROUND INFORMATION

2.1.1 The geography

Botswana is a semi-arid, land-locked country in Southern Africa with a surface area of about 600,000 square kilometres. The country shares long borders with South Africa, in the south; Namibia, to the north and west; and Zimbabwe and a 700 metres border with Zambia, to the northeast (see Figure 2.1). Most of the country (about 80%) is made up of the Kalahari Desert, which extends far beyond the borders of Botswana into South Africa, Namibia, and Angola. The most significant natural hazard is periodic long spells of droughts. The Botswana climate is subtropical. Botswana has a predominantly flat terrain punctuated occasionally by low hills, especially along the south-eastern boundary and far Northwest. In the Northwest, the Okavango delta system is fed by the Okavango River flowing from highlands of Angola to form a network of channels, lagoons, swamps, and islands. The north-eastern region of the Kalahari Basin contains the Makgadikgadi Pans—an extensive network of salt pans and ephemeral lakes.

Figure 2.1 Map of Botswana showing political boarders and major towns

2.1.2 Demographic data

Botswana was a British Protectorate of Bechuanaland from 1885 to 1966. On 30 September 1966, the country declared its independence as Botswana. Botswana has a population of about 1.7 million, with a population density of 2.8 persons per square area (2001 census). About 4/5 of the population is located in the eastern side of the country where they live in various settlements ranging from rural to urban centres. More than 50% of the population lives in urban areas in towns and cities while the rest of the population lives in settlements characterised as rural to semi-urban centres, often called villages. About 40% of the population is under the age of 15 years (The World Factbook, 2003). However, some of these figures are often downsized to about 1.6 million in international media. This is done to take into account the excess mortality rate due to AIDS (the infection prevalence rate is at 38.8%). The effects of AIDS infection and AIDS-related mortality are expected to result in lower life expectancy, higher infant mortality and death rates, lower population growth rates, and changes in the distribution of population by age and sex than otherwise would be expected (See The World Factbook, 2003 estimates). With this reasoning, the population growth is estimated at –0.55% (official ≈ 28%) with a life expectancy of about 32 years (official ≈ 56 years).

2.1.3 The economy

The economy of the country is mainly based on the mining industry and tourism. Botswana is blessed with natural resources such as minerals and wildlife. Mineral resources found in Botswana include diamonds, copper, nickel, and soda ash among others. Wildlife resources include large tracts of land and wild animals important for tourism. A major contributor to the economy is diamond mining, which accounts for more than 1/3 of the GDP. The GDP was estimated at US$ 12.4 billion in 2001, with about 6.9% allocated to education (The World Factbook, 2003). The source also notes that this allocation is ranked 10th in the world, which makes it one of the highest in Africa. Other key economic sectors are tourism, cattle rearing, and the beef industry. A major challenge for the economy is to diversify the industrial sectors and create more jobs for citizens. This challenge is made more daunting by the debilitating scourge of HIV/AIDS that threatens to reverse all economic and social gains to date. The prevalence of HIV/AIDS infection is felt intensely amongst the 15–49 age group, which is composed of the school going population and the able bodied family providers. These are some of the issues, which influenced the outcomes of the Revised National Policy of Education of 1994 (RNPE).

Education is seen as a potential medium through which change in attitudes (behaviour) and development of work related skills can be achieved to combat the scourge of HIV/AIDS and develop critical thinkers who are motivated to make decisions at higher levels. These aspirations are articulated in the country's 'Vision 2016,' presented in a booklet entitled 'A Framework for a Long Term Vision for Botswana,' intended as a national manifesto for the people of Botswana. It reflects the views of many different parts of the society. It is a statement of long term goals that identifies the challenges implied by those goals, and proposes a set of strategies that will meet them. Education forms an essential element of the vision. While striving to achieve the five national principles, which are Democracy, Development, Self-reliance, Unity, and Botho (Setswana word for respect, good manners), it is hoped that by the year 2016 Botswana will be an educated and informed nation. All people will be able to have good quality education that is adapted to the needs of the country (Republic of Botswana, 1997b). A major aspiration is to achieve enhanced prosperity, productivity, and innovativeness through hard work and discipline, and by diversification of the economy in the sectors of agriculture, industry, mining, and services.

2.2 THE EDUCATION SYSTEM

2.2.1 Structure of the education system

Education in Botswana is guided by the 'Education for Kagisano', Government policy paper No. 1 of 1977 (Republic of Botswana, 1977). *Kagisano* is a Setswana concept for living together in harmony. Social harmony was expected to be realised by highlighting the values in education guided by the national principles of democracy, development, self-reliance, and unity. A major objective for the education system was the aspiration to unite the nation by promoting these ideals.

Twelve years of schooling should be completed before students can enter tertiary education. The first 10 years, which begin at the age of six are known as basic education and the last two years lead to the Botswana General Certificate in Secondary Education (BGCSE). Basic education is free and, although not compulsory, the majority of the children go to school. About 83% of the population aged 7-13 years enrol in the primary education school system with about 98.6% of them progressing to the junior secondary school system (Republic of Botswana, 1993). The education policy has been revised in government white paper No. 2 of 1994 (RNPE of 1994). The structure of the education system can be described as 7-3-2-4+ (see Figure 2.2). That is, basic education composing of 7 years of primary education and 3 years of junior secondary education; 2 years of the BGCSE; and a minimum of 4 years of university education for a degree programme. Apart from the university, education and training is also available in other institutions that offer tertiary level education such as the Institute of Health Sciences (IHS) for training medical professionals, including nurses. In addition, there are other vocational training institutions (VTCs) on various technical specialisations to absorb further intakes of qualifying senior secondary education graduates.

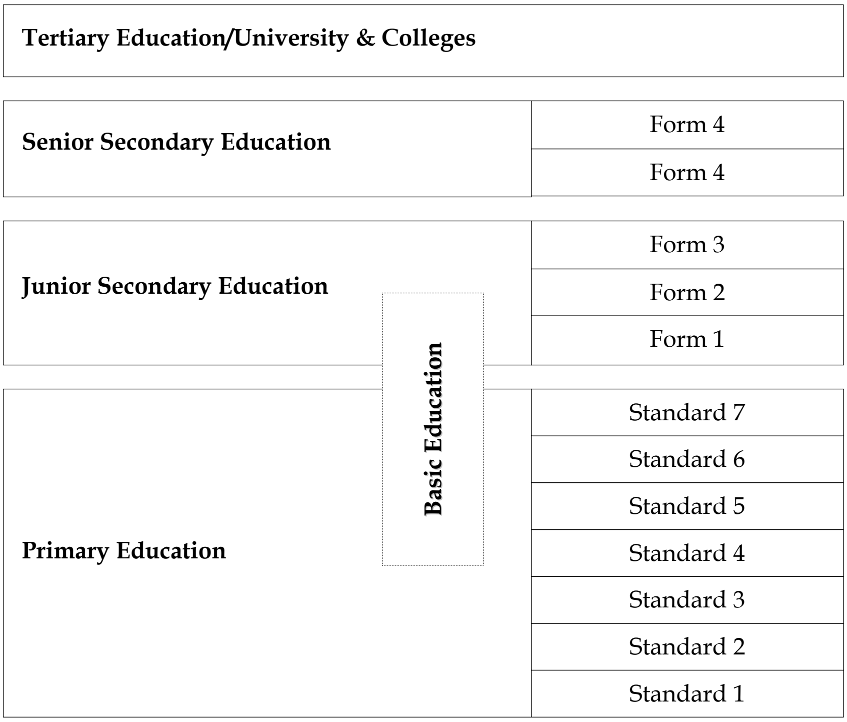

Figure 2.2 Botswana Education System

Basic education
The transition between the primary education and junior secondary education levels is almost 100% (96% in 1999). There are 703 government and grant-aided primary schools with an enrolment of 36,722 pupils and 58 private primary schools with an enrolment of 16,341 pupils (Republic of Botswana, 2003). Although progression is almost assured regardless of the outcome of the examination results at the end of primary education, league tables for examination results are published nationally, as they are seen as an incentive for both for the individual student and the school to do better. There are 205 Community Junior Secondary Schools to absorb the primary school leavers. The junior secondary education level curriculum offers science in an integrated form of combined biology, chemistry, and physics. All students do science as a subject. Progression to senior secondary education level is determined by success in competitive national Junior Certificate (JC) examinations in order to qualify for the limited places on offer.

Senior secondary school education
The transition rate from junior schools to senior schools stands at about 51% (Republic of Botswana, 2003). The senior secondary school curriculum offers a number of subjects as core (English, Setswana, and Mathematics) and the optional groups including the sciences (with biology, chemistry & physics), humanities and social sciences, creative technical and vocational, and the enrichment subjects. Table 2.1 presents the complete list of subjects offered by the BGCSE.

Table 2.1 BGCSE subject groupings (BGCSE Curriculum blueprint, 1998)

	Options			
Core	*Humanities and social sciences*	*Sciences*	*Creative, technical and vocational*	*Enrichment*
English	History	Single science	Design & Technology Agriculture	Third language
Setswana	Geography	Double science	Art Food & Nutrition	Physical education
Mathematics	Social studies	Pure chemistry	Computer studies Fashion & Fabrics	Music
	Development studies	Pure physics	Business studies Home management	Religious education
	Literature in English	Pure biology		Moral education
		Human & Social Biology (only for private candidates)		

The core subjects are a group which is compulsory for all students while options are electives from which students have to choose a minimum of one subject for each of the humanities & social sciences, sciences, and enrichment (see Table 2.1).

From creative, technical & vocational a minimum of two subjects may be chosen, making a minimum of eight subjects per student. Students have to choose at least of the subjects from the cluster of optional science subjects. Students who are more inclined to do science choose the separate (pure) science curriculum composing of biology, chemistry, and physics while humanities and social sciences inclined students can choose between the double award science syllabus and single award science syllabus. The senior secondary education is the last phase of secondary education and serves as both a platform for tertiary education for the few and preparation for the field of work for most. Quality in the graduates at this level is motivated by demands from both the University of Botswana and the employment sector for high levels of performance.

2.2.2 Senior secondary schools and science teachers

Schools

There are 27 government and government-aided senior secondary schools, scattered all over the country with a high concentration on the eastern side of the country where the majority of the population resides. Education is free, although there is talk about sharing costs and introducing school fees in the near future. Senior secondary schools in Botswana have an average enrolment of 1,200 students, composing both Form 4 and Form 5 classes. Official class sizes are 35 students per class (Republic of Botswana, 1994). A number of private schools offer either the BGCSE curriculum or other syllabi such as the IGCSE, equivalent of the O-level. All government and government-aided schools offer the BGCSE science syllabi. The Ministry of Education is responsible for and provides adequate resources for teaching and learning science in government schools and government aided schools. The prescribed equipment list often provides adequate coverage for the science subjects offered. However, the quantities of the prescribed equipment are often not adequate for different schools.

Science teachers

Botswana school science departments are large with an average of 21 teachers of which 7 belong to the chemistry section. The science department staff is made up of both citizens and expatriates. According to 1997 official figures, 65% of science and mathematics teachers were expatriates. However, in chemistry, 81% of teachers were expatriates. The government has since then accelerated the localisation of positions in both mathematics and science at the secondary level. The current figures may thus be a bit more in balance. Science teachers are qualified with a minimum of first college or university degrees, such as Bachelor of Education in science (B.Ed.-Biology, Physics or Chemistry) or Bachelor of Science and Post Graduate Diploma in

Education (B.Sc. + PGDE). Science teachers are at various levels of experience in terms of the number of years they have been teaching. Generally expatriates are recruited based on their long teaching experience. However, in some cases the teaching experience held by an expatriate may not be relevant to the level of senior secondary education, rendering him or her inexperienced as well. Teacher transfers are a source of insecurity among teachers and may work against teacher commitment to engage in reforms. While it could be hoped that new teachers bring vigour and new ideas to the department, the institutionalised department cultures often prove too dominant for newcomers, tending to maintain the status quo and making reform in classroom practice difficult to initiate and maintain.

2.3 TEACHING AND LEARNING SCIENCE IN BOTSWANA

2.3.1 Science curriculum reform in Botswana

In Botswana the BGCSE curriculum is the main preparation for tertiary education for some students, while it is the preparation for the world of work and probably the end of formal schooling for most of them. It is therefore the general intention of curriculum to serve the dual purpose of providing students with relevant knowledge and skills as foundation for tertiary education, and with problem-solving skills useful in the world of work. In line with these policy aspirations, recent science education reforms aim at improving the quality of the teaching and learning of science. To initiate reform in line with the recommendations of the RNPE of 1994 policy, task forces were set up to address various levels to develop relevant curricula. A major focus of policy translation into curricula was localisation of the examination system and contextualisation of the subject syllabuses to reflect more local content (Republic of Botswana, 1997a). Previously, the examination was run externally by the University of Cambridge Local Examination Syndicate (UCLES) in Britain. The examination format was based on the Cambridge Overseas School Certificate (COSC) curriculum.

The COSC was abandoned because it did not fit well with the intentions of the RNPE of 1994. It was believed to cater to only the top 25% ability group in an ever increasing ability student population, as the transition rate between the junior secondary and senior secondary levels improved. These changes had major implications for the science syllabus content, the teaching and the structure of the examinations. The new curriculum was first introduced in schools through a number of subject syllabuses in 1998. The BGCSE chemistry (pure science) syllabus was one of the first reforms to be implemented. The chemistry curriculum is offered through three syllabuses: Pure Chemistry (Separate Sciences) Syllabus

Award, Single Science Syllabus Award, and the Double Science Syllabus Award. The corresponding syllabuses offered through COSC science curriculum were 'Pure chemistry,' 'Physical Science Chemistry,' and 'Combined Science'. This uncanny resemblance in nomenclature has made the transition from the COSC to BGCSE teaching approaches to be perceived as unchanged to most teachers (Motswiri, 2001). However, there are fundamental differences between the BGCSE and COSC chemistry syllabuses. In contrast with the COSC curriculum, the BGCSE pure chemistry syllabus distinguishes between core content for all students and extended content for the top 20% of ability groups. Second, while there is a clear reduction in the cognitive demand from pure chemistry through physical science to the combined science in the COSC syllabuses, this is not the case in the BGCSE curriculum. The results of a study on the cognitive demands of the new curriculum has indicated a mismatch between the intended outcomes and the actual cognitive development levels of senior secondary school students in Botswana (Prophet & Vlaardingerbroek, 2003). Third, differences are also clearly visible in the amount of time allocated in relation to the amount of topics covered in COSC and BGCSE syllabuses. That is, in comparison there has been less time allocated to cover the same number of topics in the BGCSE science curriculum than was the case in the COSC science curriculum. There is less time in the BGCSE science curriculum because other subjects were included in the senior secondary curriculum, such as vocational subjects, and time had to be distributed equitably among all subjects. The time allocation for both COSC and BGCSE chemistry syllabuses are presented in Table 2.2.

Table 2.2 Teaching time allocation per week for each syllabus (Curriculum Blueprint)

Subjects	**Number of Periods per week**	
	BGCSE	*COSC*
Single Science Award	**4**	**3**
Double Science Award	4+ 4 = **8**	(3+3+3) = **9**
Pure Chemistry	4+ 4 + 4 = **12**	6 + 6 + 6 = **18**

Table 2.2 shows that, especially for pure science subjects, the teaching time has decreased by 1/3 (from 18 to 12). This has been one of the major sources of discontent among science teachers with the timetabling in the BGCSE science lessons. Teachers perceive the time allocated in the BGCSE chemistry syllabuses not to be enough to support learner-centred teaching approaches.

2.3.2 The BGCSE chemistry syllabus

In line with the aims of the BGCSE science curriculum the chemistry syllabus intends to promote a more learner-centred approach in teaching and learning (Republic of Botswana, 1998), with, among others an emphasis on: (a) *process skills, problem solving skills*, and *hands-on experience;* and (b) *school-based continuous assessment* of students' practical work skills. School-based continuous assessment has been used interchangeably with coursework assessment. Throughout this book the term coursework assessment has been preferred.

The chemistry curriculum at senior secondary level is guided by the following general aims:

1. to acquire a systematic body of scientific knowledge and develop an understanding of chemistry including its strengths and limitations;
2. to develop an understanding of key concepts and principles of Chemistry as they relate to everyday life experiences;
3. to develop abilities and skills that are relevant to the study of Chemistry to help them to be productive and adaptive to cope in a changing world;
4. to develop positive attitudes towards Chemistry;
5. to develop desirable attitudes and behavioural patterns in interacting with the environment in a manner that is protective, preserving, developmental and nurturing.

The structure of the syllabus

The BGCSE chemistry syllabuses are presented in core and extended content. The core syllabus content is the main syllabus, while the extended content is meant to cater to fast learners. In this way the syllabus is able to guide the teacher in addressing the range of abilities found in science classes. The syllabus content is presented in the form of specific learning objectives. An example of how the core and extended syllabus content of the topic used in this study is presented in Table 2.3.

Experience has shown that this distinction between core and extended syllabus content rarely happens in class lessons. Teachers often aim at the average student and consequently avoid using a mixed-ability approach intended by the syllabus structuring.

Table 2.3 The core and extended syllabus content of the BGCSE chemistry

Acids, Bases and Salts		
General learning objectives	*Core syllabus content*	*Extended syllabus content*
Students should be able to: ▪ acquire information about acids, bases, and salts and investigate their properties	*Students should be able to*: ▪ define an acid as a hydrogen ion, H^+, donor ▪ define a base as a hydrogen, H^+, acceptor ▪ describe the meaning of weak and strong acids and alkalis ▪ investigate the properties of strong acids ▪ investigate the properties of strong alkalis ▪ explain the difference between strength and concentration ▪ investigate the effect of acids and alkalis on indicators such as methyl orange, litmus, and screened methyl orange ▪ describe pH as a measure of the degree of acidity or alkalinity of a solution ▪ determine the pH of a solution using universal indicator ▪ investigate the characteristic properties of acids in reactions with metals and bases (including alkalis and carbonates) ▪ test for and identify hydrogen and carbon dioxide ▪ investigate the characteristic properties of bases in reactions with ammonium salts ▪ give applications of acid/base reactions in daily life, e.g., treatment of indigestion, acidic soils, care of teeth with using toothpaste	*Students should be able to*: ▪ conduct tests for the following ions: I^-, NO_3^-, Ca^{2+}, and Al^{3+}.

2.3.3 The role of practical work and its assessment

All students taking the BGCSE chemistry (and any other science) syllabus are required to learn and be assessed for knowledge acquisition and practical and problem-solving skills. The assessment of science practical and problem-solving skills development is achieved through continuous coursework assessment of practical work. Coursework assessment is intended to be both formative and summative (see section 2.3.5). However, the reality at the classroom level is that the use of coursework assessment has been geared more towards summative purposes than formative assessment (FA). Coursework assessment is mainly used to generate a more representative grade of students' performance. That is, coursework assessment has become more of an alternative assessment to the national examination than formative assessment. Although it is possible to use coursework assessment in a formative way, this has been very difficult to achieve in the context of Botswana. The tension between formative purposes of assessment and summative purposes of assessment is striking. Teachers are often under pressure to prepare students for external examinations, which have high-stake purposes. At the same time teachers are expected to employ teaching approaches which are learner-centred. Preparation for examinations under pressure of time invariably forces teachers to encourage rote learning as students are drilled through more content in less time to cover the length and breadth of the syllabus. This situation makes the learner-centred teaching approaches challenging, especially the formative assessment part because teachers and students would need sufficient time to implement it.

2.3.4 Learner-centred chemistry education in the BGCSE curriculum

Learner-centred philosophy and practice is expressed at different curriculum levels in Botswana. At the level of the intended curriculum (policy), a learner-centred approach is reflected in the goals and overall philosophy of education (Republic of Botswana, 1994), stressing the following:

- relevance of education to the country's needs;
- importance of providing relevant learning experiences to all students;
- promoting active learning through a variety of methods such as group discussions, project work, investigations, and problem solving exercises.

These policy aims on learner-centeredness of curriculum and classroom practices are further expanded at the level of the formal curriculum. The broader aims of the formal curriculum reflect intentions to promote acquisition of knowledge with skills and attitudes (Republic of Botswana, 1997a). These can be grouped into at least into five areas indicating that at the end of the BGCSE curriculum students are expected to have achieved the following:

1. developed the ability to assess personal achievement and capabilities realistically in pursuit of appropriate career/employment opportunities and/or further education;
2. developed desirable attitudes and behavioural patterns in interacting with the environment in a manner that is protective, preserving, developmental, and nurturing;
3. acquired knowledge, attitudes, and practices that will promote good family life and health including awareness and management of epidemics such as HIV/AIDS ;
4. developed abilities and skills that are relevant to the study, safe practice and application of science (such as experimenting and investigating);
5. developed problem solving, critical thinking, communication, inquiry, and teamwork/interpersonal skills to help them be productive and adaptive to cope in a changing environment.

Read as a whole, the BGCSE science general aims are geared towards addressing both the process of science and attitudes towards science while learning science content. In encouraging the promotion of critical thinking and reflection, it intends to address lifelong learning skills that are essential in the work world.

At the level of the formal curriculum (chemistry syllabus) the objectives are made more specific on what purposes the general aims must serve. These include emphases on the following (Republic of Botswana, 1998):

- The development of science process skills and problem solving skills, and acquisition of hands-on experience.
- Catering to a wide range of abilities. For this purpose, it is divided into a core component, with basic subject content to be done by all students, and an extended component with more challenging content aimed at higher achievers.
- Curriculum that has a practical orientation and stresses the importance of local contexts. Learners should develop skills to assist them in solving technological problems in everyday life situations.
- Curriculum content that is assessed through school-based continuous assessment of students' acquisition of practical skills through practical work.

The list of objectives may lead to the intended change or not. In this regard it is necessary to temper optimism with contextual reality. Ample research in the context of Botswana indicates that change in the direction of a learner-centred teaching approach face constraints and take a long time to be accomplished. A useful summary of research knowledge about the context of science teaching in relation to promoting a more learner-centred teaching approach has been highlighted by Thijs (1999). Major findings on classroom practice from a number of studies (Chapman, Snyder & Burchfield, 1993; Kikstra, 1998; Prophet, 1995; Ramatsui, 1990; Snyder & Ramatsui, 1990) included the following:

- Instruction is teacher-centred with an emphasis on lecturing, questioning and answer exchange, written exercises, notes, and tests.
- Teacher questions focus on factual information and are frequently of the sentence completion types, with students answering individually or in chorus. Incorrect answers are largely ignored.
- Student involvement is minimal with more teacher-talk, while students listen, copy notes, answer when called upon, and silently work on whole-class assignments. Students rarely ask questions.
- Emphasis in learning is on memorisation and recall rather than on problem solving and creativity.

In relation to these findings, the studies also showed that there was only a little difference between citizen staff and expatriate staff, shifting the causes more to external factors than the background of individual teachers.

Thijs (1999) notes that various explanations can be given for these findings, including the following (see Kikstra, 1998; Ogunniyi, 1995; Ramatsui, 1990):

- Teachers' lack of confidence and mastery of subject matter content and basic teaching skills.

- Lack of material facilities and large class sizes. According to Ogunniyi (1995), the major areas of concern include the limited number of classrooms, laboratories, equipment, and lack of laboratory assistants.
- Language problems for both teachers and students (Prophet & Rowell, 1993). English, the medium of instruction, is not native to the students while teachers in science education come from varied language backgrounds.
- Examinations often do not reflect the innovative curricular aims.
- Examinations have a dominant influence on classroom instruction. Teachers often consider examinations success the top priority in teaching, and perceive teaching methods as dysfunctional when they are not directly related to the passing of examinations (Rowell, 1990; Rowell & Prophet, 1990; Tabulawa, 1997).
- Tension between African culture (traditions, values) and life outside the school environment and the culture of inquiry required in the classroom in view of more meaningful science education. Consequently, a good teacher is perceived to be authoritarian in controlling the class lesson activities. According to Prophet (1995), students appear to have the same perceptions of participation and authority in the classroom, and tend to prefer the security of silent and individual deskwork.

Although most of these studies had their focus on junior secondary science curriculum implementation rather than the senior secondary curriculum, the conclusion by Fuller and Snyder (1990) that, "for whatever reason, the scripts that teachers follow in Botswana have little to do with the age or developmental character of the children they face" (p. 69), seems also applicable even at the level of senior secondary school science curriculum practice. This brief review can only underline the conclusion by Thijs (1999) that, "…there appears to be a large gap between the ideals of learner-centred education, as set forth in Botswana's national education policy…, and the actual curriculum in the classroom" (p. 44). Therefore, it is clear that for a more learner-centred teaching approach to be realised, the practice and context of teaching would need to be changed to be aligned with the intended teaching approaches.

2.3.5 Formative assessment of practical work in the BGCSE chemistry syllabus

Within the general aim of striving for learner-centred education, the BGCSE curriculum emphasises the role of formative continuous assessment of science knowledge and practical skills. Routinely, teachers are expected to carry out formative assessment of students' scientific knowledge and practical skills as part of coursework assessment during the two years of senior secondary education (Forms 4 and 5). In the science curriculum, coursework assessment is intended to have both formative and summative purposes. For formative purposes, information gathered through this assessment of practical work is intended to help teachers modify their teaching program with the aim of making it more effective by helping students acquire scientific knowledge and practical skills. For the summative purposes, the assessment is used to generate a summative mark that contributes to the final examination grade at the end of the two-year senior secondary school BGCSE chemistry syllabus. The two purposes of assessment are therefore, expected to be carried out in tandem. The task of accomplishing a balance between the two is difficult and may need specific skills on pedagogy and external support.

However, most of the work has to be carried out by teachers in their school environment with little external help. For that to happen the curriculum documents have to be more specific about what type of activities teachers are expected to engage in and the sorts of materials that would support such actions. It is possible that teachers' actions towards more summative purposes of coursework assessment already have foundation in their experience with the previous COSC curriculum practices. Help needed in this area may be more procedural than conceptual. However, with formative assessment purposes, teachers would need procedural and conceptual support. The procedural support is already partly being supported by the coursework assessment manual provided to teachers by the department of Curriculum Development and Evaluation (CD&E). The coursework assessment manual contains a set of exemplar practical work activities that teachers may use to carry out continuous practical work assessment. The manual also contains teacher advice about how to assess students' observed practical work, individual actions, and reported work by assigning marks against a set of practical skills' criteria. These marks are mainly accrued for summative purposes. However, despite this level of support, the conceptual frameworks for formative assessment purposes remain weak in the content of the manual. As a result, science teachers are faced with several challenges in carrying out the requirements of the new curriculum innovation. A new set of knowledge and skills is needed to teach and assess practical science skills. To be able to develop these new competencies, teachers need continuous support.

2.4 ORIENTATION STUDY

In addition to the context literature review presented above, an orientation study was conducted as part of the context analysis. The study sought to explore the perceptions of Education Officers and teachers about the feasibility of implementing the BGCSE science curriculum reform. The study asked about their (i) understanding of the process of learner-centeredness in relation to formative assessment and investigative practical work, (ii) view on the adequacy of equipment (relevant apparatus), and (iii) view on the adequacy of their knowledge and skills to make the intended implementation possible. The study involved 27 science teachers and seven Education Officers. Teachers were randomly selected while Education Officers were selected based on their close involvement with the BGCSE science curriculum reform and implementation. The seven Education Officers included three from the Department of Secondary Education; two from Teacher Training and Development, and two from Curriculum Development and Evaluation. Data were collected through document analysis, interviews, and lesson observations. Analysis was carried out through pattern coding (see Miles & Huberman, 1994).

Findings from document analysis showed consistency between the policy (ideal curriculum) and the curriculum blueprint and the syllabuses (formal curriculum). However, it was evident that while the amount of content remained substantially high, the time allocated for teaching the pure science subject had decreased from six lessons to four lessons per week, mainly due to the expansion of the school curriculum in including vocational and technical subjects to enrich students' experiences. From interviews it was also evident that teachers and education officers were conversant with the policy documents and the formal curriculum. However, their conceptual knowledge about learner-centred practice including both investigative practical work and formative assessment was less specific. Learner-centred teaching approaches were perceived to represent hands-on experience. However, there were differences in perceptions about the feasibility of implementing learner-centred teaching between teachers and education officers. Teachers tended to be more pessimistic, citing contextual constraints such as lack of time and resources and the nature of the national examination. In contrast, education officers perceived that teachers were unwilling to initiate change in their classrooms because they did not have adequate knowledge about the intended learner-centred teaching approaches. The perceived teachers' lack of necessary knowledge was often attributed to perceived 'inadequate' pre-service education.

The study resulted in the following findings:

- All teachers were relevantly trained in the area of their teaching with at least a first professional college degree in chemistry education.
- Instruction was largely teacher-centred with much time spent on lecturing, often with closed question and answer exchanges, emphasising memorisation and recall rather than on problem solving and creativity.
- Resources in terms of equipment in most of the senior secondary school laboratories were often adequate for implementation of practical work

investigations in groups. However, laboratory space facilities were not often conducive to group activity.

- Group work activities were used routinely as a strategy to achieve equity in the use of equipment rather than as a social group to encourage effective learning that would encourage learner-centred practice
- Students' involvement in the practical work was relatively high but was often nullified by a lack of reflection on the process and product.
- Teachers believed that the practical work activities, which were mostly 'hands-on' rather than 'minds-on', and characterised by ready-made, step-by-step experiment procedures that did not require much thinking, were learner-centred and represented investigative practical work. That is, the procedure (given by teacher), experimenting (with apparatus and set-up already revealed), collection of results (in a manner pre-indicated to students), analysis of data (also in a manner pre-revealed to students).
- Most teachers believed that they achieved practice of formative assessment merely by engaging students in question-answer activities carried out as part of lesson introduction and lesson conclusion. They also believed their strategies to be effective as was evidenced by the consistent good students' results in the national examinations.

The findings of the orientation study confirmed the picture as described in section 2.3.4. First, in relation to resources in terms of science apparatus, the findings indicated that the labs were generally inadequately resourced. However, basic equipment was available in quantities that could support the initiation and promotion of a learner-centred teaching approach albeit with some potential challenges. A major resource limitation that was identified included lab space. The amount of work space and spatial arrangements of furniture made the application of learning environments such as group work difficult to implement. A complete list of challenges presented by the context of implementation of science innovation in Botswana included the following (cf. Ogunniyi, 1995; Prophet, 1995):

- large classes of students (official 35) of varying abilities;
- limited laboratory preparation and working space;
- limited or non-existent laboratory technical personnel;
- high teacher turnover with a loss of experienced staff each year;
- teacher-centred approach to teaching characterised by chalk and talk;
- inadequate preparation of teachers in terms of educational philosophy behind the reforms and the expected changes and the knowledge and skills to effect change;
- ad hoc decisions in reforming the high stakes assessment procedures.

Opportunity to participate in lab activities is an important element that enhances students' learning and promotes learner-centred practice (van den Berg & Giddings, 1992). Second, teacher classroom practice indicating a more teacher dominant role and promoting more hands-on experience than minds-on needs some reorientation. One area that needs attention in this respect is how teachers used their questions. Questioning strategies that encourage reflection on the part of the students could enhance the facilitative role of the teacher, which is believed to serve two purposes in promoting learner-centeredness (Black, 2001):

- to help individual students to develop their own models of learning;
- to develop the capacity of the class as a whole to function as a community of learners.

The finding that teachers equated their lecture dominated lessons and recipe-type practical work activities as one aspect of learner-centred practice indicates why it is often difficult to initiate change in the direction of learner-centeredness. When teachers do not experience any cognitive conflict between their teacher-centred practice and the intended learner-centred practice, opportunities to change their practice are diminished. Beliefs are not easy to change (Fullan, 2001). However, providing teachers with relevant pedagogical content knowledge is regarded as being crucial to promoting teacher change (Shulman, 1986). Such experiences are essential to demonstrate what is intended while making the gap created by the teachers' actual knowledge and level of practice against the desired knowledge or skill level more visible. When teachers are aware of their expectations, uncertainty is reduced and change may occur because they would be able to tell when they have changed their practice.

In view of the needs identified through the study findings, in the areas of teacher practice and teacher beliefs, it is clear that an articulation of what is meant by learner-centeredness and how it could be exemplified and supported was necessary. Exemplifying the intervention might reduce teachers' uncertainty. Opportunities to experience cognitive conflict would be enhanced with the advent of a fully implemented BGCSE curriculum reform, including relevant examination procedures, which would motivate teachers to change most of their practice. With examinations acting as the cutting edge of practice of many teachers, change in that area would likely create an immediate need to change their practice accordingly. In this next section we discuss briefly the possible role of the in-service education in the professional development of the teacher as part of curriculum reform.

2.5 PROFESSIONAL DEVELOPMENT OF TEACHERS

In this section we describe structures for professional development of teachers in Botswana. First, we look at pre-service education programmes for senior secondary science teachers. Second, we will look at both induction and in-service professional education under the in-service training programmes provided by the University of Botswana in partnership with the Ministry of Education in Botswana.

Pre-service science teachers

The training of senior secondary science teachers in Botswana is the responsibility of the Faculty of Education's (FoE) Department of Mathematics and Science Education (DMSE) at the University of Botswana. This training is carried out in collaboration with the university's Faculty of Science (FoS). Trainee teachers learn more on specific content in the Departments of Biology, Chemistry, and Physics. Concurrently, trainee teachers also take some courses from the DMSE in line with their specific discipline. These courses focus on pedagogical content knowledge (cf. Shulman, 1986). That is, knowledge about how to teach the specific subject matter to a specific level of students. The DMSE provides under-graduate and post-graduate courses. The Bachelor of Education (science) and the Bachelor of Education (secondary) are undergraduate programs leading to a university degree qualification. The department also offers a post-graduate program, the Post-Graduate Diploma in Education (PGDE) with emphasis on Science, for candidates who already possess the Bachelor of Science degree (BSc).

In-service training programmes

Both the induction program and the in-service programs are in-service responsibilities of the DMSE. Induction programs are intended to bridge short in-service courses for teachers who have just entered the service and may be experiencing challenges of being beginners in a new community of professionals with new values and expectations. The purpose for induction meetings or workshops is to provide beginning teachers with a forum and opportunity to share their experiences with classroom teaching and their colleagues. The feedback from such meetings could also provide valuable information to the pre-service programs for preparation of future candidates. In addressing the challenges of the beginning teachers at school sites, the system of mentoring is intended as an option to guide the beginning teacher through the expertise of an experienced colleague in the school assigned by the head of department. The induction programs are expected to dovetail into the general in-service professional training program. However, although some efforts have been made towards realising these intentions, the structures for making effective impact are still not well established. Some of the activities described have been tried and the results from evaluation of participants experiences have shown promise (see Chakalisa, Motswiri & Yandila, 1995).

The Ministry of Education (MoE) is responsible for all in-service training (primary, junior secondary, senior secondary) in teacher education through the in-service unit of the department of Teacher Training and Development (TT&D). At the senior secondary school level, the TT&D INSET unit cooperates with the University of Botswana's Department of Mathematics and Science Education (DMSE) INSET unit to run in-service training for mathematics and science teachers. Together with the TT&D INSET unit, the DMSE-INSET has the main responsibility of running short period in-service professional training courses for senior secondary school science and mathematics teachers. The training programs designed for science teachers at the senior secondary school level have been the main vehicles for orienting teachers to the new education reform ushered by the RNPE of 1994 in the form of the BGCSE science curriculum. In the foreseeable future the DMSE-INSET may continue playing this role in cooperation with the TT&D-INSET unit. The DMSE-INSET develops and delivers its INSET programs for teachers based on relevant and up-to-date research on professional development of teachers. The basic delivery structure is based on the Joyce and Showers (1988) INSET approach of combining (a) theory, (b) demonstration, (c) practice, (d) feedback, and (e) coaching. Conceptualisation of the approach as perceived and adapted into the DMSE-INSET approach is represented in Figure 2.3.

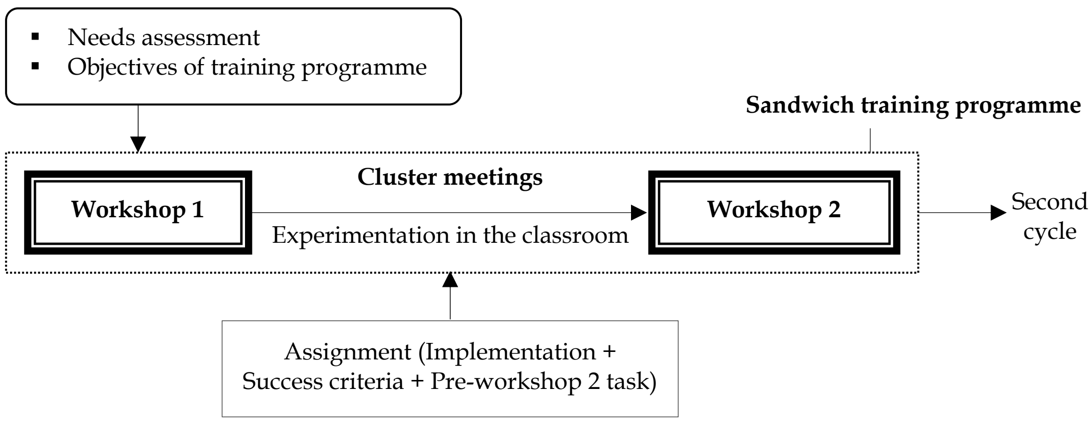

Figure 2.3 The DMSE-INSET approach

The main training programme is enclosed by the dotted structure. The programme is generated by sequencing several workshop activities *sandwiched* by experimentation activities, with a progress review at various points and times. Each workshop training is preceded by a pre-workshop task, helping teachers to reflect on past knowledge and experience to make the transition to the new knowledge and training in the following workshop. The pre-workshop assignment includes experimentation with the intended practice at the classroom level. Cluster meetings provide opportunities for sharing ideas and formatively evaluate the intervention against its objectives and set of success criteria. The rationale for this approach is that its focus is on implementation in the school, especially the classroom, which offers teachers the opportunity to experiment with the intervention in their lessons with students.

2.6 LESSONS LEARNED

Discussion of the context so far indicates that current curriculum reform in Botswana has been motivated by political, socio-economic and education imperatives. At the level of politics, educational policy reforms endeavoured to perpetuate the 'Education for Kagisano' ideology of building a foundation for social harmony for Botswana around the four national principles of democracy, development, self-reliance, and unity. At the socio-economic level the drive was mainly to address the complaints by the industrial sector and further education training institutions about the quality of graduates churned out by the education system (see Republic of Botswana, 1993). The low quality of achievement standards of achievements was blamed on the widening of the ability ranges due to the expanded intake in the school system. The mixed ability ranges presented new challenges that could not be dealt with in the COSC curriculum that catered mostly to only 20% of the school population at the senior secondary level. These concerns motivated the introduction of a more inclusive curriculum such as the Botswana General Certificate of Secondary Education (BGCSE) curriculum in which all students may develop according to their abilities. Regarding the characteristics of this curriculum and its implications for classroom practice, the following conclusions can be drawn from the context analysis presented in this chapter:

- The BGCSE curriculum has high aspirations in emphasizing the importance of learner-centred education and continuous assessment, and by including a lot of content.
- There is a large gap between these ambitions and classroom realities.
- There many obstacles hindering the implementation of learner-centred education in general, and of formative assessment and investigative practical work in specific.

- There is a need to support teachers with the implementation of formative assessment and investigative practical work. Teachers specifically need support in the following areas: (i) subject-specific knowledge on practical science skills in chemistry education; (ii) skills on how to organise investigative practical work activities that fit with syllabus content, (iii) skills and knowledge on how to organise formative assessment of student performance in investigative practical work activities and how to use the outcomes of the formative assessment to improve the teaching and learning processs.
- There is a need for concrete materials to support teachers with the use of formative assessment of investigative practical work in classroom practice. There is a coursework assessment manual, but it does not focus on formative assessment. There are textbooks with examples of practical work and the syllabus also provides suggestions for practical work, but not in regard to investigative practical work activities.

The overall conclusion that emerges from the context analysis is that teachers are uncertain about their role in the ambitious aspiration of the new curriculum to use a learner-centred approach with a specific emphasis on formative assessment and investigative practical work. There is a need for comprehensive teacher support strategies that help teachers to understand what it means to use a learner-centred approach and guide them in organising formative assessment and investigative practical work activities within existing constraints at the school level. The next chapter discusses the potential of curriculum materials to support teachers in this process.

CHAPTER 3
Implementing formative assessment of investigative practical work

In this chapter relevant literature on classroom implementation of formative assessment of practical work is discussed. The aim is to gain insight into the development and use of curriculum materials by chemistry teachers in developing countries to implement a learner-centred teaching approach. Review of the literature on curriculum change and implementation is included to find promising building blocks for addressing the problem. The chapter begins with discussion of curriculum reform in science education in section 3.1. In section 3.2 the concept of investigative practical work in chemistry is described, while formative assessment is outlined in section 3.4. Section 3.5 discusses the process of curriculum implementation, while teacher support is described in section 3.6. Conclusions are drawn and implications of findings for design are presented and discussed in section 3.7.

3.1 CURRICULUM REFORM IN SCIENCE EDUCATION

3.1.1 Conceptualisation of curriculum

Educational reforms have become inevitable and a constant for educational systems all over the world (Darling-Hammond, 1998). However, success stories about changes due to such reforms have been hard to come by (Fullan, 2001). Often policy documents are developed with promise for change, only to fail to make any impact. Although a lot is now known about why educational reforms often fail it is not often easy to harness such knowledge to produce positive change. Most reform problems are located at the implementation stage, usually involving attempts to change classroom practice (Fullan, 2001). Current challenges in the implementation of science curriculum reform at the classroom level are found in the area of 'pedagogy of understanding,' in which a learner-centred teaching approach and engaging students in investigative practical work are typical. A parallel in assessment reform is formative assessment. A major expectation for the teacher's role in the context of learner-centred teaching is to facilitate student learning that enables all students to 'come to understand ideas deeply enough to apply them to novel situations and to perform proficiently in their own right' (Darling-Hammond, 1998, p. 248).

A generally accepted definition of curriculum is Taba's (1962) 'plan for learning.' This plan usually focuses on the content and purpose of an educational program together with their organisation (Walker, 1990). Extending this discussion, van den Akker (2003) argues that it is useful to differentiate between various levels of the curriculum, especially when talking about curricular activities in terms of policy-making, design and development, and evaluation and implementation. These levels of curriculum include the following: the system/society/nation/state (macro) level; the institutional or school level (meso); the classroom level (micro); and the individual/personal (nano) level. Van den Akker (2003) also points to the nature of these levels in application, that while curriculum development at system level is usually generic, at the other levels it is often specific. However, it is also often the case that where the state is in direct control of the school system, then the distinctions between macro and meso are blurred because the development and distribution of policy and the curriculum blueprint are centralised. This is typical of many curricular approaches in the developing world.

Curriculum distinctions can further be elaborated by distinguishing a range of curriculum representations (Goodlad, Klein & Tye, 1979; van den Akker, 2003), to show how the process of curriculum development evolves. When considering the process of implementing a curriculum change, the levels in this typology begin with the designers' intentions (ideal curriculum), then proceed through written documents (formal curriculum). These two levels together represent the intended curriculum. The next steps include the interpretations of the curriculum made by users (perceived curriculum) and how it is actually implemented in the targeted setting (operational curriculum). These levels embody the implemented curriculum. Finally, the levels of how students experience the curriculum-in-use (experienced curriculum), and the impact it has on learning or cognitive development (learned curriculum) represent the attained curriculum. These six representations of the curriculum are used throughout this book as an analytical framework.

The typology of curriculum representation is a useful tool in understanding the planning of student learning and the development of the accompanying learning materials. This is true especially if the intention is to understand the balance and consistency between the various components of a curriculum (van den Akker, 2003). In order to realise this, van den Akker lists a ten point analytic tool, describing curriculum components to consider for curriculum design and implementation (see Table 3.1).

Table 3.1 Curriculum components (after van den Akker, 2003)

Curriculum component	Focus question
Rationale	Why are they learning?
Aims and objectives	Toward which goals are they learning?
Content	What are they learning
Learning activities	How are they learning?
Teacher role	How is the teacher facilitating learning?
Materials and resources	With what are they learning?
Grouping	With whom are they learning?
Location	Where are they learning?
Time	How much time is available?
Assessment	How far has learning progressed?

In relation to the focus of this study, at least five of the ten components are most important to consider. These include the rationale, aims and objectives, learning activities, teacher role, and assessment, all five very much related to the other five components. Given this, the following questions related to these areas become pertinent: Why are students learning science? Toward which goals are they learning? How are students learning? This has implications for the teaching and learning methods followed and the materials to be used. A learner-centred teaching approach also has implications for both the teacher and the students. The pertinent question then is 'How is the teacher facilitating learning?' Assessment is another focus area in this study, which can be guided by the question on 'How far has the learning progressed?' This question can be elaborated by focusing on combining feedback from both formative assessment and summative assessment. That is, the aim is to create a process in which learning is both evaluated and also guided. For the purposes of a study focusing on the five components listed above, all the other components also have implications in one way or another during implementation of the curriculum at classroom level. In its general application the framework for this tool is presented as curriculum web, with the learner-centred approach (the rationale) as the focal point or orientation point to which the other nine points are linked, i.e., a 9+1 orientation. Therefore, the rationale provides the overall principle or central mission of the plan for learning. Figure 3.1 presents the curriculum spider web, showing the dynamic interactions of various components with the rationale at the centre.

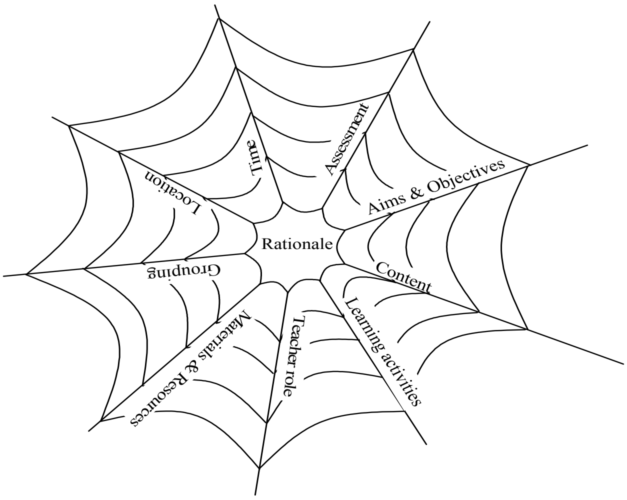

Figure 3.1 Curricular spider web (after van den Akker, 2003)

3.1.2 Current science curriculum reforms

Science curriculum reforms in Botswana, like in most developing countries, often comes about because of changes within and also outside the society. That is, while the need to change curriculum may be due to local socio-economic imperatives, externally determined curricula changes are equally influential. On balance, more externally influenced change often defines the course of change. This relegates the local imperatives to the role of appendages such as 'contextualising the curriculum by reflecting local content;' the language clearly shows working within a predetermined framework, externally conceived. External influence on curricula reforms primarily originates from developed countries, especially those with close ties to a particular developing country. Such a turn of events is almost always unavoidable because of the historical and socio-political ties developing countries share with the more advanced nations, dating back to the colonial era. However, with the advent of globalisation the locus of external influence may be expected to become more global. This in the long run may be more advantageous because it opens opportunities for choice from a variety of contexts. However, what is clear is that science education as it is currently practised in the developing world is generally an imported value commodity product of colonial ties. Botswana and other former British colonies continue to maintain ties with the British system of education. As a result, they change with the waves of curriculum reform in the British system (cf. Ware, 1992).

The learner-centred instructional approach is believed to be a second wave of curriculum reform according to the model of curriculum shift suggested by Ware (1992). Table 3.2 summarises the conceptual model for the transition from first wave to the second wave.

Table 3.2 First and second wave curriculum reforms (Ware, 1992)

First wave	**Second wave**
Preparation for a science career	Science for all students
Generation of science knowledge	Application of knowledge
Focus on the discipline	Focus on the social issues
Broad coverage of content	Less content = more learning
Science on the laboratory bench	Science in the community
Building of conceptual models	Personal decision-making
Mastery of content	'Ownership' of content
The teacher as lecturer	The teacher as manager
Class works as unit	Students work in groups

The conceptual framework of Table 3.2 shows that the purposes and aims of science education are moving from the first wave towards the second wave. According to de Feiter et al. (1995), 'the second wave (popularised by the slogan 'science for all') corresponds with recent international thinking, but has not yet been implemented widely in educational practices in the western world and even less in developing countries' (p. 43), such as Botswana. A curriculum system that embraces the second wave aspirations has been developed in Botswana.

The Botswana curriculum reforms that were based on recommendations of the education policy document, the Revised National Policy on Education (RNPE), include reforms in senior secondary science curriculum. The Botswana General Certificate of Secondary Education (BGCSE) science curriculum follows the format of the British General Certificate of Secondary Education (GCSE) science curriculum. The BGCSE, in line with the GCSE principles, espouses learner-centred instructional approaches. Learner-centred instructional approaches characterise current trends in international educational reforms, which include promoting science education practices that encourage teaching for understanding (Tobin, Kahle & Fraser, 1990). All students are regarded as potentially capable of learning science. Learner-centred approaches emphasise problem solving, inquiry skills, information and communication, and a preference for active, investigatory and independent forms of learning. In addition, often there are efforts to achieve correspondence between curricular guidelines, frameworks, and materials, and the approaches and emphases in assessing and evaluating student learning. The reforms also reflect intentions to make assessment a more productive component of the instructional processes. The mantra for such approaches is 'learning to learn'. However, the learner-centred approaches are difficult to achieve and there is scepticism about realising them in any educational system (Hurd, 1993).

A learner-centred curriculum perspective has implications for instructional practice, assessment, and the roles of teacher and student. The practice of a learner-centred curriculum is based on constructivist principles, in which the assumption knowledge is not transmitted but constructed, and it is influenced by cognitive functions, social interactions and contextual factors (Smith & Ragan, 1999).

Following a more constructivist classroom practice has significant implications for both teacher and students in terms of roles and behaviour. A structured illustration of what this change could mean is clearly captured in the National Research Council (NRC) (1995) report that refers to the change of emphases in teaching science. Table 3.3 presents the NRC report summary.

Table 3.3 Changing emphases in teaching (from the National Science Education Standards, National Research Council, 1995

Less emphasis on	**More emphasis on**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following the curriculum	Selecting and adapting the curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text and demonstration	Guiding students in active and extended science inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of a unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Table 3.3 shows a list of teacher actions, which are usually associated with teacher-centred on the left, under 'less emphasis on,' and on the right a learner-centred approach, under 'more emphasis on.' These are typical of trends in current science curriculum reforms, which are also found in the BGCSE curriculum documents. Recent discussions on what it means to implement more constructivist or learner-centred classroom practices further elaborate the framework of applying learner-centred as classroom practice (NRC 2000 report, expanded edition of 'How people learn'; see Bransford, Brown & Cocking, 2000).

First, the elaboration starts with ideas about student learning in learner-centred practices and discusses implications for teaching. One major issue is that students come to the classroom with preconceptions about how the world works. Therefore, if their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught or they may learn them for purposes of a test but revert to their preconceptions outside the classroom. Such a situation implies that teachers must concern themselves with students' preconceptions in terms of how to elicit them and make them transparent to the students, with the view to engaging students' cognitive development. For this to happen the conditions at school and the classroom must be supportive of a learner-centred approach. Teachers may need time and resources to develop facilitative conditions in which students' preconceptions could be elicited and dealt with. This is a major problem in developing countries where student numbers per class are high and the time allocated to teaching science is insufficient due to content loaded syllabuses.

Second, it is noted that to develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organise knowledge in ways that facilitate retrieval and application. The suggested response for the teacher is to teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge. This calls for changes in the syllabus in terms of the load of topics to cover. A situation in which only a few topics are taken may allow for deeper coverage. Bransford et al. (2000) argue that, to provide a knowledge-centred classroom environment, attention must be given to what is taught (information, subject matter), why it is taught (understanding), and what competence or mastery looks like. It is noted that such learning is harder and takes time, but it is important because it makes new learning easier (transfer).

Third, a 'metacognitive' approach to instruction is recommended because it is likely to help students take control of their learning by defining learning goals and monitoring progress in achieving them. Therefore, the teacher has to integrate the teaching of metacognitive skills into the curriculum in a variety of subject areas. It is noted that because metacognition often takes the form of an internal dialogue, it may be difficult for students to understand its importance unless the processes are explicitly emphasised by teachers. Through a scaffolding approach, actions related to meta-cognition (like keeping time for steps in a lesson, monitoring the progress of an activity against time, and following a logical procedure) can be initially monitored by the teacher. Afterwards, the teacher may progressively withdraw into the background when students begin to take control.

Fourth, to a larger extent learning is influenced in fundamental ways by the context in which it takes place. A community-centred approach (encouraged by the concept of zone of proximal development) requires the development of norms for the classroom and school, as well as connections to the outside world, that support core learning values. It becomes imperative that classroom activities are designed to help students organise their work in ways that promote the kind of intellectual camaraderie and attitudes toward learning that build a sense of community (e.g., group work activities). These conditions are found in activities that follow cooperation in problem solving (Newstead & Evan, 1995). Cooperation within communities (groups) is suggested in order to build 'a sense of comfort with questioning rather than knowing the answer and can develop a model of creating new ideas that build on the contributions of individual members' (Bransford et al., 2000, p. 25).

The fifth aspect of the learner-centred practice and constructivistic approaches concerns the nature of assessments. Assessment with formative purposes is considered to be more useful than one with summative purposes. Formative assessment will be discussed in detail later in this chapter. At this point it suffices to understand that such assessment means ongoing assessments designed to make students' thinking visible to both teachers and students (Bransford et al., 2000). Engaging in formative assessment activities permits the teacher to grasp the students' preconceptions, to understand where the students are in the 'developmental corridor' from informal to formal thinking, and to design instruction accordingly. Formative assessment helps both teacher and students monitor progress.

So far the concept of learner-centred based on ideas of constructivism has been discussed at some length. It should be noted that such research reports on learner-centred literature are in many respects limited in the developing world (Fuller & Clarke, 1994). Most of the research has been done in developed countries, which present contrasting contexts to those of the developing world. As Ogunniyi (1996) aptly observes, 'any innovation introduced in the school system is never left in its naked form but assumes a different form for that setting, depending on the perceived message by the users and the teaching-learning context' (p. 73). The role of context in educational intervention is highlighted by Gunstone (1996) when he argues, '…if a curriculum and classroom change of substance is attempted without changes in assessment that are consistent with the curriculum change, then there is very little chance of any of the implied student change occurring, and teacher change is at best going to be inhibited by the unchanged assessment approaches.' (p. 66). Such a comment was sparked by the tendency of most developing countries' to copy the implementation of developed countries' curricula by random selection following some changes in the package while avoiding others. The case in point is that of change in assessment practices. While there have been attempts at changing classroom practices, often this is not accompanied by a change in assessment practices.

3.2 INVESTIGATIVE PRACTICAL WORK IN A CHEMISTRY CURRICULUM

3.2.1 Introduction

The objective of scientific investigation is to help students acquire scientific knowledge and practical skills. The acquisition of knowledge and skills can be monitored through formative assessment integrated into classroom instruction. Therefore, a classroom practice that is aimed at achieving learner-centred practice through practical work has at least two considerations. These include investigative practical work and formative assessment practices. In the following sections investigative practical work is considered to be one way in which the practice of learner-centred instructional approach can be made more visible in a chemistry lesson. Formative assessment will be discussed separately because, although an integral part of the learner-centred instructional approach, it has unique features and purposes that need to be highlighted. But the next section briefly outlines the learner-centred approaches in general.

3.2.2 A learner-centred instructional approach in science education

The conceptual framework of learner-centred practices

Learner-centred learning is premised in the *constructivist epistemology* of learning which advocates the promotion of more learner-centred learning classroom activities (Jonassen, 1991). With constructivism, learning is founded on the premise that 'we are able to construct our knowledge and understanding of the world, through experiencing things and reflecting on those experiences' (Smith & Ragan, 1999, p.15). That is, when we encounter new experiences, we have to reconcile them with our previous ideas and experience. This may result in changing what we believe, or maybe in discarding the new information as irrelevant. Regardless of which action we take, we are active creators of our own knowledge. When we construct our own knowledge we are learning. This is achievable through mental activities that enable us to generate our own 'rules' and 'mental models,' which we can use to make sense of our experiences. Learning, therefore, becomes the process of adjusting these mental models to accommodate new experiences. That is, learning is a search for meaning. Therefore, learning must start with the issues around which students are actively trying to construct meaning. To do this, we must ask questions, explore, and assess what we know. This construction of knowledge is developed from previous knowledge. Smith and Ragan (1999) highlight at least six key assumptions of constructivism that may have implications for instructional design and development for educational purposes, and these include (cf. Bransford et al., 2000):

- Knowledge is constructed from experience.
- Learning results from a personal interpretation of knowledge.
- Learning is an active process in which meaning is developed on the basis of experience.
- Learning is collaborative with meaning negotiated from multiple perspectives.
- Learning should occur (or be 'situated') in realistic settings.
- Testing should be integrated into the task, not a separate activity.

This list has strong implications for pedagogy:

- Learning is interactive, building on what the student already knows. The purpose of learning is for an individual to construct his or her own meaning, not just to memorise the 'right' answers and regurgitate someone else's meaning.
- Teaching and learning materials include primary sources of material and manipulative materials.
- Teachers have a dialogue with students, helping students construct their own knowledge. Instructors tailor their teaching strategies to student responses and encourage students to analyse, interpret, and predict information. Teachers also rely heavily on open-ended questions and promote extensive dialogue among students.
- Teachers' role is interactive, rooted in negotiation.
- Assessment includes student work, observations and tests. Therefore, process is as important as product. Assessment becomes part of the learning process so that students play a larger role in judging their own progress.
- Knowledge is seen as dynamic, ever changing with our experiences.
- Students work primarily in groups.

In the science classroom, this list of implications can point towards a number of different teaching practices. Often it means encouraging students to participate actively in learning (e.g., through investigations that include experiments and real-world problem solving) to create more knowledge and then to reflect on and talk about what they are doing, and how their understanding is changing.

3.2.3 A learner-centred practical work in chemistry education

Although practical work or lab work is used widely in science lessons, its role in effectively promoting the learning of scientific knowledge and process is questioned (Lunetta, 1998). What has been observed consistently is that teachers do appear to value laboratory activities but observed practise shows that they do not implement them in a manner that facilitates the type of learning intended as learner-centred. That is, often there is a mismatch between goals, behaviour and learning outcomes. Instead, when laboratory investigations are implemented they are often used to confirm something that has already been dealt with in an expository lesson, only requiring students to follow a recipe in order to arrive at a predetermined conclusion (Tobin, 1987). However, notwithstanding the lack of positive reports about the successes of using practical work essential to realising learner-centred instruction in science, the rationale for its continued use is based on the following reasons (Lazarowitz & Tamir, 1994):

- Science involves highly complex and abstract subject matter. Therefore, students need concrete props and opportunities for manipulation afforded in the lab. The lab also offers unique opportunities to identify students' misconceptions.
- Students' participation in actual investigations that develop their inquiry and intellectual skills is an essential component of the inquiry curriculum. It gives students an opportunity to appreciate the spirit of science and promotes their understanding of the nature of science.
- Lab work promotes the development of cognitive abilities such as problem solving, analysis, generalising, evaluating, decision-making, and creativity.
- Lab work is essential for developing skills of various kinds: manipulative, inquiry, investigative, organisational, and communicative.
- Lab work may help students understand the concepts that underlie scientific research: definition of a scientific problem, hypothesis, assumption, prediction, conclusion, and models.
- Lab work may help in development of scientific attitudes, such as honesty, readiness to admit failure, critical assessment of the results and their limitations, curiosity, risk taking, objectivity, precision, confidence, perseverance, responsibility, collaboration, and readiness to reach consensus.
- Students usually enjoy practical work in the laboratory and, when offered a chance to experience meaningful, nontrivial but not difficult experiences, they become motivated and interested not only in their lab assignment but also in studying science.

Research on using practical work or lab work in a more learner-centred instructional approach indicates that the aims of teaching science should reflect the following goals (Lazarowitz & Tamir, 1994; Lunetta, 1998):

- Science labs should provide concrete experiences and ways to help students confront their misconceptions.
- Science labs should provide opportunities for data manipulation through the use of misconceptions.
- Science labs should provide opportunities for developing skills in logical thinking and organisation, especially with respect to science, technology, and society (STS) issues.
- Science labs should provide opportunities for building values, especially as they relate to the nature of science.

These goals of teaching science through lab work are applicable to all science subjects, including chemistry education. According to van den Berg and Giddings (1992), mismatches between lab goals and student behaviour can be avoided by distinguishing various types of lab work, matched to specific intended learning outcomes. To that end they distinguish three types of lab work: skills lab, concept lab, and process lab. The skills lab is the most common of the three and characterises the current practice where teachers use practical work merely to promote 'hands-on' experience. Concept lab is used for correcting or teaching concepts, often carefully designed to promote interaction between students and the experiments. Process lab provides students with relatively open practical work investigations, giving them ample opportunity to make decisions regarding various steps in the experiment, therefore promoting 'minds-on' experience. When the intention is to promote a more learner-centred classroom practice, the process lab is considered appropriate because it offers students both 'hands-on' and 'minds-on' experiences. However, the use of any of the lab approaches depends on the knowledge and skills of the students and also the general goal of the lesson.

Implementing investigative practical work is considered more challenging in chemistry. Compared with other science subjects, chemistry has been noted to present unique challenges to the teacher. According to Gabel (1998) teaching chemistry is complex because many concepts in chemistry are highly dependent on each other, making the necessity of prerequisite knowledge crucial to produce links between modes of representing matter and the interactions that matter undergoes. This makes aligning the teaching of chemistry with the rationale and goals listed above difficult to achieve. In most chemistry topics the existence of prior knowledge, for example, is limited because students can only experience it when it is taught to them. However, with a change in emphasis on lab work to reflect a more learner-centred instructional approach, a promising research direction is found in Johnstone and Letton (1991) who have researched the effectiveness of chemistry laboratory instruction for promoting conceptual understanding from the viewpoint of an information-processing approach (constructivist). Johnstone and Letton's research conclusions can be summarised as suggesting a redesign of practical work experimental instructions in such a way that it:

- prepares students adequately on the prerequisite scientific knowledge and skills relevant to the topic of the activity so that students are aware of the lesson objectives and areas of knowledge that are important for the particular lesson;
- actively involves students in planning the experiment;
- helps students to read and search for information that is relevant to their lesson from different sources (e.g., assignment to read from the library, textbooks, newspaper articles, etc.);

- offers students opportunities for problem solving to enable students to experience both 'hands-on' and 'minds-on' experiences in chemistry practical work.

This list suggests that practical work can be presented and carried out in another way than the current 'following of recipe' which is often criticised in literature. Active participation of students through investigations in which they follow a problem solving approach is suggested. Such practical work would engage students in challenging, real-life tasks intended to promote communication and collaboration (Brush & Saye, 2000). Therefore, investigations bring an inquiry learning approach to classroom instruction. In the science laboratory students can individually engage in inquiry, conduct different investigations, or as whole class focus on one investigation question (Lunetta, 1998). Similarly, the level of openness of the investigation questions can also vary from closed questions in which the activities are structured to more open questions in which there is less structure in the procedure. In its practice, inquiry is an iterative process involving the creation of hypotheses, testing those hypotheses by experimentation or systematic observation, evaluating evidence, and revising hypotheses (Kuhn, Amsel & O'Loughlin, 1988). In following these steps, inquiry is expected to invoke the intellectual skills of deduction, problem-solving and critical thinking (Brush, & Saye, 2000). Studies on students' learning indicate that children's scientific inquiry becomes more adequate simply as a result of opportunities to engage in self-regulated exploration (Kuhn, Schauble & Garcia-Mila, 1992; Schauble, Klopfer & Raghavan, 1991). Thus, conditions that allow for interaction with both scientific process and equipment are crucial to realising the development of scientific and practical skills in learners. Bednar, Cunningham, Duffy and Perry (1992) argue that this 'hands-on' experience is an important consideration in designing an instructional activity for learner-centred instructional approach. However, for practical work to satisfy an investigative status it should also include 'minds-on' experiences. To involve students in 'minds-on' activities they should be encouraged to articulate their own testable hypotheses, and ways to test their questions about ideas, ranging from the criteria for meaningfulness of an inquiry question to what constitutes legitimate evidence for a knowledge claim (Windschitl, 2000).

In implementing investigative lab work in chemistry class Lunetta (1998) suggests four broad phases that teachers can follow: planning and design, performance, analysis and interpretation, and application. Table 3.4 summarises what happens in each of these phases.

Table 3.4 Phases of investigation in chemistry practical lesson

Phases of investigation	Typical activities
Planning and design	Students formulate questions to investigate, predict results, construct hypotheses to be tested, and design experimental procedure.
Performance	Students conduct the investigation, manipulate materials, make decisions about investigative techniques, and observe and record data.
Analysis and interpretation	Students organise and process the data that they have collected, explain relationships, develop generalisations, examine the accuracy of data, outline assumptions and limitations, and formulate new questions based on their conclusions.
Application	Students formulate new hypotheses on the basis of their investigation, make predictions about the application of the information to new situations, and apply to new problems the laboratory techniques which they have developed.

The challenge for teachers in applying this investigation format in secondary school chemistry lessons is fitting it in the timetable. Experience has shown that in an 80± minutes lesson the first phase alone can take more than 40 minutes of the usual single lesson period, leaving only 40 minutes for the rest of the phases. Invariably this results in an incomplete investigation with no impact on the intended students' scientific learning and understanding. Alternatives suggested include (Lunetta, 1998):

- Involving students in a few practical work activities in which the four phases can be applied effectively (i.e., 'less is more').
- Identifying laboratory activities in which it is appropriate to focus on subsets of the four phases of investigation. To this end, group activities may focus either on planning and design for a particular investigation in one lesson and completing the rest in subsequent lessons.
- Presenting students with data gathered by 'other students' or by 'scientists' in an investigation that has been carefully described, perhaps including video clips of the people and the apparatus involved in data collection. The focus of the activity for students would be to concentrate on phase three, the analysis and interpretation.

The fourth alternative may be to choose some elements from each phase of investigation, depending on the intended instructional objectives, and allow students to experience investigative process. For example, in planning and design, students are provided with the investigation question but expected to make predictions, construct a hypothesis, and develop experimental procedure. The first phase is followed by performance of the experiment, and analysis and interpretation phases of investigation. In this alternative, the fourth phase becomes optional in a short-term plan. The fourth phase is also suitable when students have gained experience and confidence about doing investigations. Considering that various activities suggested in each phase overlap and are closely integrated in real practice, it is possible to execute some investigative work in secondary chemistry lessons.

3.2.4 Characteristics of investigative practical work tasks

A typical classroom (laboratory) investigative practical task is typified by Connecticut's Common Core of Learning Performance Tasks (CCCLPT), made up of three parts: (i) individual work at the beginning, including thinking and reflecting on the problem; (ii) group work activities to follow, including comparing individual assumptions and designing and experimenting; and (iii) individual work to conclude, giving report of what was done and what were the results. The CCCLPT includes three phases presented in Table 3.5.

Table 3.5 Phases of the CCCLPT

Part 1	**Part 2**	**Part 3**
At the beginning of the task, each student individually generates information about his or her prior knowledge and understandings about the science concepts and processes relevant to the task. This process provides opportunity for each student to do some preliminary thinking and be better able to make a contribution to the group discussion. It also increases the likelihood that each group can begin its deliberations with different perspectives represented.	Students work in groups to plan strategies for solving a problem and experimenting, collecting data, finding the solution to the problem. Students also learn to communicate their ideas clearly to others and fit their presentations into the presentations of other groups.	In part 3 students are asked to either report their work verbally or by writing for assessment.

Conceptual framework for implementing investigative work in the school laboratory

Investigations aim to allow students to use and apply concepts and cognitive processes, as well as practical skills (Gott & Duggan, 1995). The process of investigation is often an exercise in problem solving which allows students a varying degree of autonomy to search for answers in situations where the solution is not obvious. The concept of investigation involves using prior knowledge in the area investigated as a form of scaffolding. This knowledge will have been gained in practical work activities that are more structured and aimed at specific skills or concepts. The process of investigation has been conceptualised by Gott and Duggan (1995) and Gott and Mashiter (1994), into a working model (see Figure 3.2).

This model conceptualises investigative work as a form of a problem solving exercise involving cognitive processes, which are supported by prior knowledge on subject specific facts and skills. That is, the nature of cognitive processes is premised on subject-specific conceptual understanding and procedural understanding developed by learning facts and skills based on the subject content. Gott and Duggan (1995) argue that it is through the interaction of the conceptual knowledge with the procedural understanding that the cognitive processes can be engaged to solve problems or undertake investigations.

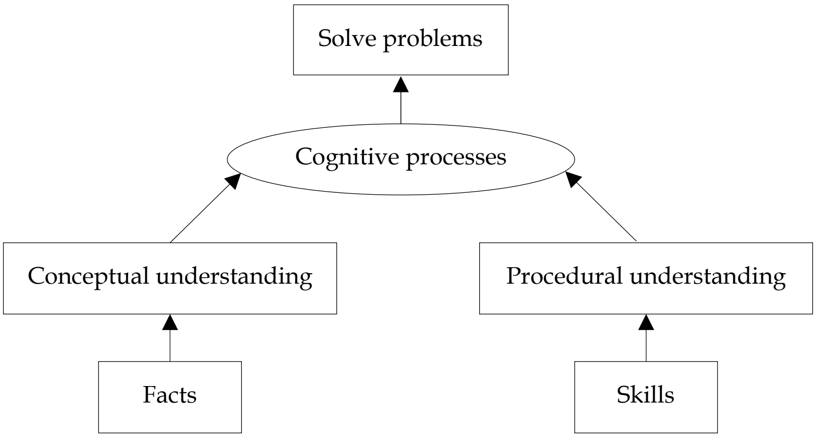

Figure 3.2 A model for problem solving in science

Investigative work is enhanced by knowledge in the area being investigated. That means the ability of a student to carry out the investigation depends on their familiarity both with the concepts underlying the phenomena explored and with systematic procedures (Jones, Slate, Blake & Holifield, 1992). Thus a student engaged in an investigation of acid properties, for instance, is expected to develop knowledge and understanding in the following: acid pH (scientific knowledge); the concept of strong acid and general properties of acids (conceptual knowledge); and procedural understanding, involving systematic procedures used to demonstrate acidic properties.

Other conditions that facilitate effective investigations include the following (van den Berg & Giddings, 1992):

- Exercising the skills involved through activities that portray real situations. Therefore, students need to be given the opportunity to exercise process skills in conditions that will support their development.
- Their specificity on what they are intended to achieve. The choice of process skills to be stressed in a particular investigation depends on its specific objectives and priorities as well as on student characteristics. Students' characteristics are mentioned in relation to their prior experiences.
- A variety of skills instead of repetition of the same skills. It is therefore advisable to vary the skills chosen from one investigation to another to keep students motivated. This will also ensure that the major intended skills are adequately covered.
- Giving the student the opportunity to design investigation activities. This should be done with the teachers' guidance. Thus, if the emphasis is on designing experiments, students should be allowed to design their own experiments to the problem posed and make decisions with regard to how to

measure, which variables to control, which variables to disregard, etc. The teacher should facilitate giving guidance through prompts when it is necessary.

- The teacher assuming a facilitative role. The teacher's role during the investigation activities is crucial. The teacher should carefully consider how to guide the investigation in order not to obstruct its main goals. For example, often specific instructions are needed with respect to equipment use, student safety, and to secure acceptable (educationally) results. For example, in an investigation exercise focusing on designing experiments, such instructions can be given after students have thought about and discussed their own designs, and before execution of the experiment.
- The assessment of the students' investigative work is specific and focused on skills chosen rather than being a 'global' evaluation of a lab report. It is believed in this way student and teacher awareness of process goals can be increased and converted into better performance.

3.3 FORMATIVE ASSESSMENT OF INVESTIGATIVE PRACTICAL WORK

3.3.1 Definition of formative assessment

Assessment refers to the set of processes by which students' learning is judged, and this learning is generally assumed to have come as result of a course of instruction (Nunan, 1988). This definition is, however, limited to outcomes of instruction. A more comprehensive definition comes from Black (1998a) who defines assessment as 'A general term embracing all methods customarily used to appraise performance of an individual student or group. It may refer to a broad appraisal including many sources of evidence and many aspects of a student's knowledge, understanding, skills and attitudes; or to a particular occasion or instrument. An assessment instrument may be any method or procedure, formal or informal, for producing information about students: for example, a written test paper, an interview schedule, a measurement task using equipment, a class quiz' (p. 5).

From the two definitions above, assessment of students is done by various methods or people. Some of the processes used are direct like observation and others by proxy through written tests. Another aspect is that assessment focuses on making decisions about what students know and can do, often what they have been taught as part of instruction. Assessment often has several purposes in education. According to Black (1998a), at least three purposes are identifiable as: (i) formative when it supports learning, (ii) summative when is used for certification, progress and transfer and (iii) evaluating the curriculum when used for accountability. The formative purposes serve to improve learning and teaching by providing diagnostic information about products and the processes of student learning to both the teacher and students (Brookhart, 2001). However, the term formative assessment is not used consistently in the literature (Black & William, 1998a; Sebatane, 1998). Often the term is used as if it is a type of assessment instead of referring to a specific purpose (Brookhart, 2001). However, most authors seem to agree that all classroom assessments can be formative, if only students use the information for formative assessment purposes (Black, 1998a). In this book, the term formative assessment will be used consistently to refer to the formative purpose of assessment.

Formative assessment, which is diagnostic in view of correcting inadequacies in teaching and learning, is often contrasted with summative assessment, which generates information for purposes of reporting on progress to date, certification, and involves comparing the performance of individuals with certain external standards or criteria (Harlen, 1999). In contrast, formative assessment is specifically intended to provide feedback on performance to improve and accelerate learning (Sadler, 1998). Formative assessment with the embedded concept of feedback is the key factor in the promotion of classroom learning (Sebatane, 1998). Thus, although it can be argued that all assessments provide some form of feedback, the nature of the feedback it generates is a major distinguishing feature of formative assessment. The central role of feedback is highlighted by the fact that it is also sometimes referred to as formative assessment (see Black, 1998a; Brookhart, 2001). Thus assessment can be considered formative only if the feedback is used to improve students' learning (Black & William, 1998a). Feedback supplied by the teacher or as self-assessment by the student and intended to improve the student's learning places the learner in the central role (Brookhart, 2001). Therefore, two forms of feedback can be distinguished (Sadler, 1989):

- information about performance supplied to the student, either by the teacher or peers, and
- self-monitoring information about performance from the students' own appraisal of their work.

Thus the student role is central to formative assessment. It is the student who must ultimately improve his or her own performance. In formative assessment, this is conceptualised by a gap that is believed to exist between what a student knows at one end, and on the other, what is intended for the student to know based on the curriculum objectives. Effective learning is achieved when this gap is narrowed or closed (Sadler, 1989). It must be noted, however, that the gap describes a dynamic phenomenon, and it is a description of an individual's unique level of experience within the specific subject knowledge and skills. Therefore, although the locus of such a gap is defined by the distance between the actual and the desired, its expression is different for each student, resulting in heterogeneous needs for the whole class. which the teacher must address using the feedback (Black, 1998a).

3.3.2 The process of formative assessment

The process of formative assessment can be made more visible in a science lesson when it is implemented with investigative practical work. This can be achieved by setting up a task or a situation for students, aiming to elicit information about their understanding of specific science knowledge related to the lesson topic. When such information is interpreted and acted upon by either the teacher or the student, or both, it becomes the feedback (Black, 2001). In the process, the student is expected to be an active learner who can take responsibility and manage his or her own learning, while the teacher's role becomes that of a facilitator, in putting students in direct touch with the subject. The active role of the student in which he or she interprets and acts on feedback is 'self-assessment'. When feedback is generated by his or her interaction with other students (such as in group work) feedback is 'peer-assessment'. Either way, when the student acts on formative assessment feedback he or she must be able to recognise the learning discrepancy, which is a measure of the size of the gap between actual knowledge or skill learned and the intended or desired knowledge or skill. This discrepancy defines the learning goal in formative assessment. That is, if students are to improve, they must have a concept of their learning goal and the ability to act in such a way as to close the gap (Sadler, 1989). On the other hand, the facilitative role of the teacher is believed to serve two purposes (Black, 2001):

- helping individual students to develop their own models of learning;
- developing the capacity of the class as a whole to function as a community of learners.

To achieve these two purposes the teacher's role in formative assessment is to (Harlen, 1999):

- provide students with an opportunity to use the process and practical skills to demonstrate their acquisition and understanding of science knowledge;
- encourage students to critically review their work by engaging in dialogue with students about how they carried out their activities and reflecting on how it could be improved if it were to be repeated;
- give students feedback in a form that focuses on the quality of the work, not on the person (see also Black & William, 1998a);
- give students access to examples of work which meet the criteria of quality, and to point out the aspects which are significant in this (see also William, 1998);

- engage students in metacognitive discussion about procedures so that they see the relevance to other investigations of what they have learned about the way in which they conducted a particular investigation;
- provide students with scaffolding on techniques and the language needed as the skills advance.

Generally, information for formative assessment can be gathered by various methods including (Harlen, 1999):

- observing students – including listening to how they describe their work and their reasoning;
- questioning students – using open questions, phrased to invite students to explore their ideas and reasoning;
- setting tasks – in a way that requires students to use certain skills;
- asking students to communicate their thinking through drawings, artefacts, actions, role-play and concept mapping, as well as writing.

The value of formative assessment as a means of improving learning outcomes in the classroom is generally acknowledged in science education literature (Black, 2001; Harlen, 1999). In the science curriculum, formative assessment is believed to encourage and allow for development of science process and practical skills. Formative assessment is believed to have the potential to help both the teacher and students change their roles in the teaching and learning process. Furthermore, it is believed to have potential to improve practice as well as 'changes in teaching programs and students' on-going learning' (Cowie & Bell, 1999, p. 101). Examples of some of the elements that may change in practice include change in assessment practice necessitating change in assessment procedures and type of feedback, classroom interactions between teacher and students and student-to-student (see Gallagher, 1999). Further evidence of the value of formative assessment is found in Black (1998b), who concludes that education 'standards can be raised only by changes that are put into direct effect by teachers and students in classrooms' (p. 11). Thus, making formative assessment an essential feature of changes that take place in the classroom often has impact on changes that involve both the teacher and students.

3.3.3 What makes formative assessment effective?

The question of necessary conditions for enhancing effective implementation is crucial. Conditions in which formative assessment implementation was successful have been reported in various study reports including the Black and William (1998a) review of assessment and classroom learning. In the review, each of the eight examples of implementing formative assessment practice reported conditions that support success during implementation. These include ecological validity of the assessment, clarity of learning goals, active involvement of both the teacher and the student, and opportunity for the students to be assessed formatively. Ecological validity (Black & William, 1998a) is realised when classroom practice closely resembles the normal classroom teacher practice where the teacher is involved with his or her students in the process of teaching, and learning takes place in a normal classroom (or science laboratory). Ecological validity may increase chances of sustaining the intended change as ownership is developed by those involved.

Clarity of learning goals of the assessed activity is important because the use of a wrong assessment tool for formative assessment should be avoided (van den Berg & Giddings, 1992). In clarifying the goals it is important to avoid giving students answers before they have tried to solve a problem on their own because it may reduce the effectiveness of the formative assessment feedback.

Both teacher and student monitor the process of formative assessment to reduce the discrepancy between actual and desired performance. Monitoring includes the concepts of self-assessment, peer-assessment, and the use of feedback (Brookhart, 2001). Student involvement should also include both verbal and written feedback. Feedback should be directed towards the task itself rather than the student (that is more criterion-referenced than norm-referenced).

Opportunity for the students to be assessed formatively can show what they know and can do. In assessing science investigations, the provision of working space and equipment in the laboratory is necessary.

For the purposes of implementing a formative assessment of investigative practical work intervention and also promoting the facilitative conditions listed above, the teacher needs the following support:

- Class management, which is an important issue in large class sizes, needs to be considered in terms of the space available, management of classroom activities, and access to apparatus.
- A facilitative departmental environment to implement the innovation. This is encouraged by peer support, which is enhanced by a common purpose among colleagues in the department. Thus, the department ought to have supportive structures such as a policy for assessment in the department (a department policy on teaching and assessment).
- Building confidence and exemplary support, because devotion to formative assessment is risky and takes a great deal of energy. It can be expected that the introduction of formative assessment results in radical change in classroom pedagogy. Confidence in teaching the subject (teacher self-efficacy) enhances the chance to be flexible and to adapt to new views about teaching, new roles, and practices (Black, 1998a).

- Relevant teacher experience, resulting in pedagogical content knowledge (Shulman, 1986), is crucial to effective implementation of intervention. This is essential for the teacher to be adept in dealing with content knowledge and possessing a repertoire of skills to guide students in identifying and reducing the gap created by the actual knowledge level and the desired knowledge, or skill level. There are many variables involved in collecting and analysing data to feedback the teaching and learning, which demands both technical and professional knowledge, and skills specific to subject knowledge, and the way students learn it.
- In learner-centred instructional practice, formative assessment information is likely to reveal heterogeneity in learning needs (Black, 1998a). Therefore, feedback information by the teacher is effective when it addresses the identified heterogeneous needs of the students through approaches that are differential in treatment. In large classes the challenge is formidable. The quality of feedback provided is a key feature in any procedure for formative assessment (Black & William, 1998a).

3.4 CURRICULUM IMPLEMENTATION IN CHEMISTRY EDUCATION

3.4.1 Introduction

Realising curriculum reform and influencing change in instructional practice can only be made if teachers do implement in the classroom. However, a major challenge in curriculum reform has always been its implementation. When implementation is based on an imported curriculum, that task may be even more difficult. In this section we discuss the process of implementing a curriculum reform in science education and in particular formative assessment of investigative practical work.

Fullan (2001) argues that there are at least three dimensions at stake in implementing any new curriculum at classroom level. These are:

- new *materials* being introduced; for example, new curriculum content or new technologies;
- new *teaching approaches*, such as innovative teaching and assessment strategies or activities; and
- the possible alteration of teacher *beliefs*; for example, pedagogical assumptions and theories underlying particular new policies or programs.

It is therefore imperative that in helping teachers, teacher support systems should take the three dimensions into consideration. The three dimensions will be discussed in detail in section 3.6. Other science education researchers have echoed and expanded on these conclusions. Ogunniyi (1996) observed that the implementation stage of curriculum development is essentially the stage for teacher-student-material interactions, including the execution of lesson plans, improvisation and laboratory activities. These curricular enactment interactions are often complex and dynamic (Ball & Cohen, 1996). However, it is possible that teachers can be helped to change both their teaching approaches and beliefs through the use of materials (Fullan, 2001). Therefore, we may expect that by using new materials, teachers may be able to change their teaching practices and eventually their beliefs about their students. However, even with this potential for change through use of materials, change itself is influenced by many other factors that include (Fullan, 2001): (i) the characteristics of the innovation itself, (ii) who is involved (local roles), and (iii) external factors. The factors are discussed below as they relate to implementation at classroom level.

3.4.2 Characteristics of the innovation

How the innovation is presented and how teachers and students perceive it is an important issue in implementing change. Fullan (2001) distinguishes four influential characteristics of change. These are:

- need for change by the target group;
- clarity of the innovation to the participants;
- level of complexity of the innovation; and
- quality of the innovation in terms of its practicality.

Teachers' perceived *need* is an important factor in making the change essential for their practice. However, despite the importance of the existence of a need, teachers often do not see the need for advocated change (Fullan, 2001). Establishing specific needs is not easy because there is often an inherent potential for competition between many needs in the field when the education system is in a state of reform. A typical example is the tension between assessment procedures that are formative and those that are summative. Although it is clearly essential that formative assessment procedures should be used to promote learning with understanding, summative purposes of assessment often define the cutting edge. Secondly, precise needs are not often clear at the beginning, but only when the implementation is underway (cf. Bodilly, 1998; Bodilly & Berends, 1999; van den Akker, 1994). Third, need interacts with other factors, including those which are under local and external factors to produce different patterns, which may either add specificity or uncertainty during implementation. To overcome the problems of need, it is important that teachers perceive both that the needs being addressed are significant and that they are making at least some progress toward meeting them (Huberman & Miles, 1984). Early rewards and some tangible success are critical incentives during implementation (Fullan, 2001). Therefore, teachers need to see the benefits of a suggested practice as compared to their current practice. In order for teachers to achieve this, they also need to appreciate the *congruence* of their current classroom practices with the suggested practices in the innovation.

Clarity is achieved when teachers are able to identify the essential features of the innovation including its goals and means. Gaining clarity is important in avoiding 'false clarity' and misconceptualisation of the change involved. 'False clarity occurs when change is interpreted in an oversimplified way, that is, proposed change has more to it than people perceive or realise' (Fullan, 2001, p. 77). Clarity is rarely achieved in most implementation processes. Even where there is agreement between the teacher and designer of the innovation that some kind of change is necessary, when teachers want to improve some area of curriculum, the intended change may not be at all clear about what teachers should do differently (Fullan, 2001). Lack of clarity in the goals and means of an innovation can also cause anxiety and frustration to those sincerely trying to implement it. Therefore, clarity is a double-edged sword, which needs careful balancing. To achieve clarity, the innovation has to be unambiguous about its goals and means. Clarity is also related to complexity of the innovation.

Complexity is the difficulty and extent of change required of the individuals involved in implementation (Fullan, 2001). Complexity is important for maintaining effective levels of motivation for the teacher to engage in the activities. Too simple a change may be ignored while too challenging a one may discourage. Practicality is also important because it ensures the fit of the innovation where it is used. When practicality is low then it is certain that the innovation will not be sustained and changes therefore will not occur. Problems posed by the complexity of the implementation relate to the starting point of any individual or group. A typical example of complexity is presented by Vandeyar and Killen (2003) in their case studies of teachers in implementation (in South Africa). Teachers who understood the fundamental principles of high quality assessment (of the old system) had little difficulty in adapting their assessment practices to the broad guidelines, by outcomes-based education. Apart from taking individuals' starting points into consideration, Fullan (2001) suggests that to overcome problems of complexity, breaking down complex changes into smaller components and implementing them incrementally is necessary (cf. Ogunniyi, 1996; Thijs, 1999).

Quality and practicality of the innovation is the fourth characteristic. Quality in terms of the practicality of the innovation is related and dependent on the variables of need, clarity and complexity (Fullan, 2001). The quality of an innovation is an essential characteristic for successful projects and this has been possible where greater attention has been paid to front-end quality of resources. Quality is also attained when attention is paid to developing and continually refining innovations and engaging people involved in the change. The main goal should be to develop the innovation over time through stepwise processes that continually try out the components in the context of intended application with the target group.

3.4.3 Influences of the school context

The school context includes the characteristics of administration, the teacher and the resources. Fullan (2001) observes that 'principals' actions serve to legitimise whether a change is to be taken seriously (and not at all changes are) and to support teachers both psychologically and with resources' (83). Therefore, the support of the school head in negotiating access in the school context has to be the first step. However, while the blessing of the head of the school is essential, it is also crucial to negotiate access through the department head. The immediate manager for the teacher is the head of the department. Decisions about instruction, timetable, and teaching allocation are the responsibility of the head of department in large schools. While the role of the administration is crucial for gaining access in the school context, it is the individual teacher's motivation that counts in implementation. According to Fullan (2001), 'both individual teacher characteristics and collective or collegial factors play roles in determining implementation' (p. 83). It is therefore important to negotiate implementation with teachers to make transparent how it may support their intentions within their context.

Teachers are also likely to engage in any change when their environment is supportive in terms of colleagues and resources. This is because, although in the final analysis it is the actions of the individual that count, what one does is often influenced by interactions with others. Safety in taking actions during implementation may be achieved if more than one teacher is involved so that collegial support is guaranteed. Teachers are also governed by 'the practicality ethic.' According to Fullan (2001), this ethic implies that teachers judge change proposals along three dimensions: instrumentality, congruence, and costs (cf. Doyle & Ponder, 1977). *Instrumentality refers* to the procedural content and clarity of a change proposal (the 'how' of the implementation). *Congruence* refers to how well a change proposal is aligned to teachers' perception and practice. *Cost* refers to the difference between how much the teacher invests in terms of time, energy and actual personal change and how much he or she gets in terms of tangible rewards (e.g., improvements in students performance, examination results, etc.) in return for engaging in the implementation process (cf. Miles & Huberman, 1984). The practicality ethic is also closely related and influenced by teacher efficacy.

Teacher efficacy has been defined as the teacher's belief that he or she is capable of organising and executing courses of action required to successfully accomplish a specific teaching task in a particular context (Tschannen-Moran, Hoy & Hoy, 1998). Fuller, Wood, Rapoport and Dornbusch (1982) argued for the importance of considering teacher efficacy in implementation because, 'in understanding what tasks the individual tends to pursue, whether resisting organisational interventions or earnestly cooperating with change strategies, we believe individuals will seek to establish niches which maximise the opportunity to feel efficacious – to perform tasks where perceived expectancy of obtaining valued outcomes is sufficiently high' (p. 9). Therefore, it is advisable to take the teacher's personal uncertainty about change into consideration. Teachers often do not want to admit personal ignorance or failure, even when the innovative proposals are felt as an imposition to the 'normal' program in terms of time constraints and efforts invested in accommodating change. Snyder and Fuller (1990) argue that interventions interfere with the work-role and can lead to new contexts that entail different efficacy levels. These may jeopardise comfortable styles and methods, resulting in uncertainty in what one does. Therefore both the teacher and the intended or hoped-for-gains of the innovation should be taken into consideration. To achieve this synergy, the innovation must fit some of the current contexts (i.e. be able to assimilate while introducing minimal changes; cf. de Feiter et al., 1995; Thijs, 1999). In supporting teachers it is also necessary to be aware that teacher efficacy is not enhanced when success depends on extensive external assistance, and also comes relatively late in the implementation process, or the intended intervention is too easy and unimportant (Tschannen-Moran et al., 1998). Therefore, for teachers to cope with a change they must be helped to make judgements about their role by analysis of their teaching task and its context. This analysis is meant to produce inferences about the difficulty of the task and what it would take to be successful in the context. Task factors include students' abilities and motivation, appropriate instructional strategies evaluated against objectives, managerial issues, the availability and quality of instructional materials, and access to adequate physical conditions of the teaching space. A supportive context is provided by a collegial department. The need for flexibility in implementation is highlighted by Ogunniyi (1996, p.73): 'any innovation introduced into the school system is never left in its naked form but assumes a different form for that setting, depending on the perceived message by the users and the teaching-learning context'.

3.4.4 External factors

Essential external factors include support or influence through government or other agencies. Government provides an impetus of change through policies and rhetoric for all to rally around. In the BGCSE curriculum change, the second wave slogan of learner-centred classroom practice has served that purpose. Commenting about curriculum implementation in Africa, Ogunniyi (1996) warned that any curriculum innovation that ignores policy implications is bound for extinction. This is because in most African countries, curriculum changes are centrally controlled. Government also provides resources to facilitate the changes intended at classroom level. Teacher orientation in terms of psychological and professional attributes adds to nothing if there are no materials to realise them (van den Berg, 1996). These resources may be in terms of equipment or other teaching materials such as books. In-service education and lesson materials can also provide external support for teachers who are involved in curriculum practice. Several studies have reported that success in implementation is enhanced when an innovation is introduced through lesson materials imbedded in an in-service program (see van den Berg, 1996; Ottevanger, 2001; Stronkhorst, 2001; Tilya, 2003). The role of lesson materials and how they can be used to support teachers in implementation is the subject of the next section.

3.5 SUPPORTING TEACHERS IN IMPLEMENTING CURRICULUM CHANGE

3.5.1 Design of teacher support

In section 3.4, the main focus of discussion was on the factors that influence implementation of curriculum innovation. The role of the teacher consistently featured in all the discussions was central to the curriculum reform implementation. This underlines the fact that curriculum change necessarily always includes change in teacher classroom practice. It is also true that teacher change will almost always precede student change (Gunstone, 1996). Hence, even though any curriculum change is ultimately aimed at seeing a marked change in the attained curriculum, it is the teacher who facilitates such change. Change in classroom practice for the teacher would also mean learning new roles. This learning process is developmental in nature, evolving early on from 'self' (i.e., how does the change affect me?) concerns, through concern about 'task' (i.e., what is the nature of the change?) itself, to questions about the 'impact' (i.e., what are the consequences of the change?) of the change on students' learning in the later stages. As a developmental process these 'levels' of concerns emerge at different stages of the process of change as a sequential series through which teachers work (Gunstone, 1996). However, this is a complex process. For example, Gunstone (1996, p. 65), highlighting this complexity, notes that a 'self' concern such as 'how will I control 55 children if they are all doing activities?' is relevant in most classes in the developing world. This concern may actually best be addressed by considering the concern as an 'impact' such as 'what will be the likely motivational and learning consequences of the 55 children doing activities, and how can I usefully harness these'? To facilitate this teacher development, teachers need a professional development framework to support them in going through these developmental stages (cf. Thijs, 1999).

The study of teacher learning of new practices, and consequently being able to shift their roles, is possible during the enactment of the curriculum (see section 3.1 for levels of curriculum representations). Radinsky, Loh, Brown, Reiser, Gormez & Edelson (1998) developed a design framework for curriculum materials that have the potential to guide students through inquiry projects while also supporting the teacher in implementation. Using the triangle for elements of curricular enactment (Ball & Cohen, 1996) in Figure 3.3, Radinsky et al. (1998) developed design points for shaping enactment they found useful in designing or redesigning inquiry projects, with students and teachers to promote reflective student inquiry.

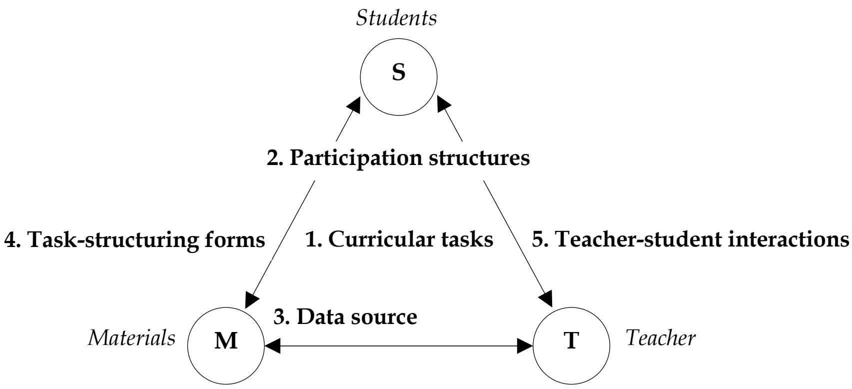

Figure 3.3 Elements of curricular enactment (Ball & Cohen, 1996)

The framework provided by the elements of curricular enactment has a general appeal for any design, be it paper or electronic. Its main elements include the following areas of the support material:

1. The curricular task assignment. These included the assignment of problems students are to work on and specifications for production of students' work.
2. Participation structures for student inquiry work. These included cooperative group work structures during lesson, whole-class activity structures or norms for participation in activities.
3. The sources and representations of data being studied. These included software such as data visualisers, simulators, browsers, or digital libraries; paper-based or tactile representations of data; and materials used to produce or gather data.

4. Forms and materials to structure the task for students. These included worksheets, journals, and lab notebooks; interfaces, or instructions, which constrain students' access to data sets; and any other material prompts for eliciting particular student reflections on data.
5. Teacher interactions with students around inquiry work. These included instructional strategies for interacting with the whole class, groups, or individual students, such as modelling of cognitive strategies; modes of questioning or prompting; and norms for communicating with students.

Radinsky et al. (1998) used the framework to design activities for case studies in the domain of secondary science education. They found that its main advantage was its flexibility for designs that accommodate different contexts. Such a framework is suitable for science implementation at the classroom level because teachers' backgrounds, contexts, and styles of teaching are different.

In the context of implementing curriculum innovation using materials in chemistry education in Botswana, using the five categories would mean that: (1) the curriculum tasks assignment is provided by the BGCSE chemistry syllabus; (2) participation structures for students are given as teacher advice on how to interact with students through group work and whole class discussions, to encourage effective participation during instruction; (3) data sources would include the processes of planning and experimenting, where students would be encouraged to document what they did; this would also include the lab report; (4) forms and materials to structure the task for students would include problem-solving activities and instructions to follow a planning schedule that involves planning, experimenting and peer assessment activities; the instructional sheet would give both the structure of the problem and be suggestive of the number of variables involved in the solution of the problem; (5) teacher interaction with students would be given as teacher advice on how to deal with class, group and individuals during the lesson. These would include the type of questions to ask and what may be expected from student responses and how to deal with such eventualities to guide students along to make their own inquiry decisions as much as the context allows. The design specifications for such teacher support materials are important for their development and use in implementation.

3.5.2 Exemplary curriculum materials

Curriculum materials are considered an important tool for teachers attempting to change their teaching practice (Ball & Cohen, 1996; de Feiter et al., 1995; Ottevanger, 2001; van den Akker, 1988). In this study, curriculum materials are seen as a series of lessons based on a chemistry syllabus for Form 4 stream of the

Botswana senior secondary education, the BGCSE. The materials are chosen to reflect the most essential aspects of the curriculum innovation. At classroom level, lesson materials that teachers can use in their lessons often support classroom practice. When materials are used to support change in classroom practice it should be exemplary to the intended practice and effective at the initial stage of teacher implementation (Van den Akker, 1994). Such materials (cf. Ball & Cohen, 1996; van den Akker, 1994) can:

- provide theoretical background information on the meaning of the change;
- demonstrate the practical meaning of the change at stake;
- give potential users the opportunity to experiment with the innovation to get insight into the consequences of the change for their daily practice; and
- stimulate discussions about the educational changes among teachers who are using the materials.

Examples for using curriculum materials to support teacher implementation of curriculum innovation at classroom level are found in studies by van den Akker (1988) for primary science education in the Netherlands. Van den Akker took the view that 'written materials represent, when contrasted to in-service courses and workshops, a potentially most cost-effective way of influencing teachers' (p. 47). The results of the study showed that 'a careful design of curriculum materials can improve the implementation process and outcomes'.

At secondary education level there also have been several studies while focus on using materials in different ways to support implementation of curriculum reform or change in classroom practice. Gallagher (1999) in the United States of America, reports on using exemplary curriculum materials to support teachers in implementing embedded assessment as a tool for improving student learning in science. The findings of the study showed that in classes where teachers used the exemplary curriculum materials, there were significant positive changes in 'classroom interactions, discourse, classroom climate, students' engagement and motivation, and learning' (p. 12). Other studies at this level showed similar trends. A study by Ottevanger (2001) in Namibia showed that using exemplary curriculum materials as part of an in-service program improved their effectiveness in supporting innovative reforms in science education. Tilya (2003) also found results that were consistent with findings of Ottevanger study when using exemplary materials in a science in-service program in Tanzania.

In each of these studies the aim was to explore the characteristics of effective exemplary curriculum materials that could support implementation of curriculum reform innovation. In all studies it was assumed that curriculum materials could have a positive effect on teachers' initial implementation efforts, by providing detailed support in planning lessons with the new instructional method, pointing at critical features of these lessons, and addressing teachers' concerns about how the change could affect them personally, by offering practical advice to solve arising problems. To achieve these purposes, all studies proposed including careful 'procedural specifications': clear guidelines with specific advice on how to plan and execute the lesson and deal with typical implementation problems. On the basis of literature and observed implementation problems faced by teachers, especially at the level of primary science education, van den Akker (1988) identified four common types of implementation problems (also found useful by Gallagher, 1999; Ottevanger, 2001; Tilya, 2003 for secondary science education), which included lesson preparation, subject content, pedagogy, and learning effects.

Outcomes of these studies show that curriculum materials containing specific advice in each of these four areas can reduce teachers' initial implementation problems, and also enable them to conduct successful lessons. The procedural specifications provide teachers with an orientation to the intended change and support them in performing aspects of tasks in the change that they could have otherwise had difficulty with. In this respect, curriculum materials can stimulate teachers to develop their teaching repertoire by expanding their 'zone of proximal development' (Vygotsky, 1978). However, such detailed procedural specifications tend to be bulky with a potential to overwhelm the teachers. Van den Akker (1994) advised that to avoid such an eventuality, focus must be on the most essential aspects of the change that have proven to be problematic during implementation. To identify these aspects, formative evaluation should play a central role during development of the materials.

Curriculum materials have also been used as part of and in support of in-service education program for teachers to support innovative classroom practices (Ottevanger, 2001; Roes, 1997; Stronkhorst, 2001; van den Berg, 1996) and peer coaching (Thijs, 1999). In all these studies the role of the materials is described as supporting intended changes in classroom practices, and serving as an organising framework of in-service education scenarios respectively. Some of these studies were carried out in Southern Africa. Thijs (1999) studied the use of exemplary materials in supporting peer coaching scenarios in Botswana, while Ottevanger (2001) and Stronkhorst (2001) both studied the use of exemplary curriculum materials in an in-service program to support teachers involved with implementation of curriculum innovation in Namibia and Swaziland, respectively. Tilya (2003) studied the use of exemplary materials to support teachers and students involved in a curriculum reform innovation intended to improve science teacher-learning to promote inquiry practice in A-level physics classes in Tanzania.

3.5.3 Quality of the exemplary curriculum materials

A major condition for employing exemplary curriculum materials to fulfil the functions listed above, thus to facilitate implementation of curriculum innovation, is that they must be of good quality (Nieveen, 1999). Quality is a value judgement and may mean different things to different people. Nieveen (1999) suggests a framework for making the concept of quality in exemplary materials more transparent. The framework is based on three aspects of quality, including validity, practicality and effectiveness. The three aspects of quality can also be related to the various levels of the typology of curriculum representations as distinguished by Goodlad et al. (1979). These are the ideal curriculum, formal curriculum, perceived curriculum, operational curriculum, experiential curriculum, and learned curriculum. Table 3.6 presents a summary of the links between various curriculum representation levels as used by Nieveen (1999) to illustrate the framework of quality of materials.

Table 3.6 Quality aspects of exemplary curriculum materials

Quality aspects	*Validity*	*Practicality*	*Effectiveness*
Descriptions of representations	Intended (ideal + formal): ▪ State-of-the-art ▪ Internally consistent	Consistency between ▪ Intended – Perceived ▪ Intended – Operational	Consistency between ▪ Intended – Experiential ▪ Intended – Learned

The ideal and the formal curriculum present the intended curriculum, and this speaks to the internal consistency of the curriculum materials. *Validity is* attained when there is internal consistency (i) between the materials and the state-of-the-art knowledge (content validity) and (ii) between the different components (construct validity). Consistency between, on one hand, the intended curriculum and the perceived curriculum, and on the other, the intended curriculum and the operational curriculum describes the practicality. *Practicality* is attained when the materials are usable by teachers and students in ways that are compatible with the developer's intentions. When there is consistency, on the one hand, between the intended and experiential curriculum, and on the other, the intended and the learned, then the materials can be regarded as effective. *Effectiveness* is indicated when students appreciate the learning program and desired learning takes place.

A prototyping process can be used to explore and improve the quality of the materials through successive approximations until a satisfactory product is obtained.

This section of the literature review showed that teacher support in curriculum change is necessary because teacher change often precedes student change. Designs for exemplary materials, with the aim of supporting teacher change of practice through classroom implementation, must provide structure for both students and teacher learning in the context of classroom instruction. Radinsky et al. (1998) provide a useful framework to follow in designing materials for curriculum innovation implementation in chemistry education. Materials are seen as more effective in supporting teacher change of practice because, unlike either in-service workshops or peer collaboration, teachers will be able to use curriculum materials over extended period of time in the context of their classroom (Schneider & Krajcik, 2002). Teachers are also accustomed to using such materials to plan and structure student activities (Ball & Cohen, 1996). Materials also support teacher change practice because they are able to stimulate intended teaching repertoires through the expansion of zone of proximal development.

3.6 CONCLUSIONS AND IMPLICATIONS FOR IMPLEMENTING FORMATIVE ASSESSMENT OF PRACTICAL WORK

3.6.1 Conclusions

The review of relevant science education literature showed that science curriculum reform is an intricate web of variables that require careful management when real change is intended, especially at classroom level. The components of this web are the strands of curriculum that radiate from the rationale located at the centre of intended change. In this study the learner-centred instructional approach is that rationale and the variables in the strands include the aims, objectives, learning activities, teacher role, and assessment. Changes in each of these strands have implications for the rest of the components in the web, which include among other issues content, time, and resources. In addition to such intricacies typical of reforms in science curriculum change, one has to realise that this change is more daunting when the context of change is located in developing countries where relevant resources, knowledge, and skill are limited.

Change in classroom practice is defined by the use of new materials, change in beliefs and teaching practices. To support such teacher change, exemplary materials have been identified as a promising medium to guide activities at classroom level. Curriculum materials exemplify the intended practice by offering teachers prototypical experiences of implementing the intervention while being guided by procedural (how-to-do) specifications. The process of implementing the curriculum materials in class provides teachers new ways of teaching and making decisions about what works or what does not. Such materials become more useful when they offer clear and sufficient information to guide teachers. However, high quality materials are necessary to support teacher change. Such quality of the materials is optimised during the implementation of the intervention through design, development and formative evaluation of successive prototypes.

When practical work is conducted in laboratories in such a way that students are encouraged to participate actively through ‘hands-on’ and ‘minds-on’ activities it can promote a learner-centred practice. Such practical work involves investigative work. In chemistry education, investigative work is difficult to implement because in order for students to learn on their own, as advocated by investigations, they need prerequisite chemistry knowledge that is mostly accessible through instruction. The prerequisite knowledge required is often both substantive (chemistry) and procedural (pedagogy of science). This is the pedagogical content knowledge in which most teachers show major weaknesses. Teacher learning of pedagogical knowledge for chemistry education can be promoted by providing teachers with a well-structured implementation plan of the intended curriculum change. Such a plan becomes more effective if it is aligned to the intended practice that teachers are expected to follow with their students in class. With a learner-centred instructional approach in science, the science process skills which resemble problem solving steps for students include: (a) identifying, understanding the problem and posing the problem question or developing a hypothesis, (b) planning for the solution of the problem, (c) carrying out experiments to investigate the assumptions of the problem question, and (d) evaluating the data collected to develop answers to the problem question and the solution of the problem and communicating the results.

Teacher learning during implementation of curriculum reform at classroom level can be enhanced when the teachers are able to make decisions as they interact with materials for the intended new practice and the students and their work through investigations. Formative assessment that the teacher carries out during instruction can provide the teacher with rich feedback from which decisions can be made to remedy students' learning weaknesses or can be used for further planning of subsequent lessons. Formative assessment is a difficult process for teachers and as such they require systematic support on areas such as what kind of information to look for, how to interpret the feedback, and how to give feedback to students. Detailed advice aligned to each investigation or problem-solving step can help the teacher to follow both investigation activities and student experiences as the lesson progresses. This support includes advice on how to ask and respond to questions so that students can be helped to think about what they are doing while working in groups; how to guide students through question and answer without 'telling' to encourage self- and peer-assessment; how to develop conditions that facilitate students to evaluate their work and communicate their results.

3.6.2 Implications for this study

Intended curriculum changes aimed at shifting teacher practice to more learner-centred instructional approach need to be more flexible to accommodate the dynamic interplay between the curriculum rationale and related components such as change in content, learning activities, time and resources. Considering the challenging context of the developing world in relation to implementing science educational reforms, flexibility should also be the guiding principle in transferring and using knowledge, skills and resources from places where these intended changes have been attempted. A more developmental approach based on research knowledge must be followed. However, to optimise the meaningfulness of the intervention application of such research, knowledge should be tempered with the contextual framework of the developing countries.

Considering limitations on the availability of relevant materials and necessary knowledge and skills on successful learner-centred curriculum reforms, especially in developing countries, it is advisable to borrow from the available examples in the developed world. However, such borrowing should be moderated with the context of the developing world. To come close to such an outcome, curriculum materials originating from successful attempts in the developed world should be used in a developmental research process composed of design and development, a series of small steps aimed at optimising the contextual relevance and quality of such materials as used by teachers in class. Sufficient detail in exemplary curriculum materials is necessary to guide teachers efficiently on what-to-do and how-to-do. For teachers to be able to facilitate students to engage in and learn from investigative practical work in chemistry education, they need to be supported with necessary pedagogical content knowledge for learner-centred chemistry labs. To that end, the exemplary materials should contain teacher advice on what content to teach, what methods to promote, and how to monitor student learning. Related student activities should also be developed and included as part of the teacher guide. Teacher advice on implementing investigative practical work should be closely matched with student activities to reflect the following format: (i) sufficient prerequisite chemistry knowledge; (ii) description of the problem to be investigated and instructions for students to develop experimental procedures for solving the problem through an experimental set up; (iii) instructions on how to evaluate and communicate the results.

Considering that change in teacher practice is improved when teachers learn from their classroom implementation, it is essential to highlight the centrality of the feedback they get from their students and their experience with the curriculum materials. Formative assessment of investigative practical work during class needs to form a major focus of the classroom implementation. Because formative assessment is a difficult process for teachers in general, and it is expected to be even more of a major innovation for chemistry teachers in Botswana, a more structured advice of using formative assessment is suggested. Such advice should be aligned with investigative practical work activities and should aim to support the teacher in a number of areas of classroom practice, which includes the following: What questions to ask students? How to ask and respond to questions without 'telling' to facilitate construction of self-knowledge? How facilitate self- and peer-assessment to encourage social learning within students groups? What conditions to promote to encourage students to critically evaluate their work?

CHAPTER 4
Design, development and appraisal of the first prototype

This chapter describes how insights developed from chapter 2 (context analysis) and chapter 3 (literature review) are used to develop design specifications for exemplary teacher support materials that aim at implementation of investigative practical work with formative assessment in a learner-centred setting. The generation and specification of initial design specifications is described in section 4.1. In section 4.2, the design and development of a first prototype is outlined. Section 4.3 reports on the formative evaluation of the first prototype, while section 4.4 presents conclusions of the evaluation and implications for the revision of the first prototype.

4.1 TOWARDS DESIGN SPECIFICATIONS OF THE FIRST PROTOTYPE

4.1.1 Initial ideas

Initial ideas concerning the characteristics of the envisaged materials, were based on insights learned from a literature review on science curriculum implementation and a context analysis of teaching chemistry in the Botswana school system. The context analysis showed that the BGCSE chemistry curriculum encourages learner-centred teaching approaches that include formative assessment of investigative practical work. However, classroom practices in most senior secondary school chemistry lessons in Botswana continue to be more teacher-centred than learner-centred, characterised by chalk-and-talk and little practical work. Where practical work is implemented it only requires students to follow instructions developed by the teacher or from textbooks. Furthermore, even this approach is not widely used, as teachers preferred to demonstrate to whole classes instead of allowing students to engage in lesson activities in a meaningful way. Teachers explain that they are forced to adopt their teaching strategies because they do not have enough time and resources for large classes.

The literature review indicates that it is possible to involve students in meaningful ways, which may help students learn with understanding (Brush & Saye, 2000).

More learner-centred classroom practices can be achieved by involving students in investigative practical work. Also, it is possible to involve students in small-scale investigations while monitoring their involvement and learning through formative assessment processes (Cowie & Bell, 1999). However, changing teacher practice from teacher-centred to more learner-centred is difficult and often takes a long time. Teachers who are accustomed to lecturing to their students and having them do step-by-step cookbook-type laboratory experiments do not make this transition readily. Furthermore, teachers who have not used group work are generally uneasy about trying it. And students who are not accustomed to thinking about loosely structured problems are uncomfortable at first. Because of these uncertainties teachers often need substantial bolstering before they attempt to change their teaching strategies. Studies have shown that it is possible to support the initial implementation of an innovation by teachers by using exemplary materials in ways that demonstrate how the intended change looks and how it can be implemented (see Ottevanger, 2001; van den Akker, 1988). Considering that Botswana chemistry teachers are uncertain how to implement learner-centred teaching approaches that involve formative assessment of investigative practical work as suggested in the syllabus, the use of exemplary teacher support materials was considered a viable proposition.

Since there were no ready-made materials, the materials had to be developed. The development of exemplary materials included developing instructional activities for class lessons, to help teachers and students engage in investigative practical work and formative assessment. Dick and Reiser (1989) summarised seven elements that should be addressed in an instructional plan in order to develop effective classroom instruction. These included the need to *motivate* students, by arousing student curiosity and by making learning relevant. Next, *learning objectives* should be included because by knowing what will be expected of them, learners may be better able to guide themselves through the learning process. *Prerequisite knowledge, skills and attitudes* help students relate new knowledge and skills with what they already know. This includes *information and examples*, given as background for knowledge and skills. It is also important to provide opportunities to apply knowledge; *practice skills and use feedback* in learning, which also include some t*esting*, a form of assessment or monitoring that learning does take place to guide students better. Finally, the materials provide for *enrichment and remediation*, which takes place during classroom instruction.

According to van den Akker (1988) a careful design of curriculum materials can improve the initial implementation process and outcomes. This is considered to be the case because materials may activate and support teachers in lesson preparation and lesson execution by providing a clear orientation to the teaching task, by pointing to critical features of lessons, and by making suggestions about how to deal with emergent problems during the instructional process. Such materials then need to contain a large amount of procedural specification, that is, very accurate how-to-do advice focussed on essential but apparently vulnerable elements of the curriculum. Specifications for such a product, as applied by both van den Akker (1988) and Ottevanger (2001), are formulated in ways that reflect the functions the materials can fulfil for the teacher. Based on observation of teachers using exemplary teacher support materials to attempt to implement curriculum innovation, van den Akker (1988, in the domain of primary science) and Ottevanger (2001, in the domain of secondary science) observed that teachers needed help with lesson preparation, subject matter, teaching sequence and learning effects. After studying teacher use of exemplary materials for lessons, they both concluded that such materials helped teachers, especially at the initial stage of the implementation.

Therefore, based on these findings, it is advisable to develop exemplary teacher support materials that focus on these four support levels. Teacher support on *lesson preparation* includes teacher advice on the background of the problem that students are expected to solve. This includes both content specific knowledge and procedural specifications on investigative practical work. It also includes advice on the type of questions to ask while guiding students in the lesson, and the necessary resources that students would need, and how to prepare equipment for the lesson. Support of *subject knowledge* is specific to the topic studied but also includes making connections with other syllabus topics, disciplines in the curriculum, and the contextualisation of such knowledge for student. This includes also looking at possible students' misconceptions or preconceptions that may hinder learning and making sure it is adequately attended and clarified before students start to solve the problems. The support for *teaching methodology* includes advice on how to guide students in the learner-centred practices, especially with investigative practical work. That is, guidance is provided on the roles of both the teacher and the students, as a class, a group, and individuals. Monitoring how students acquire content knowledge and practical skills is part of the guidance on carrying out investigative practical work. The advice supports teachers with strategies for identifying evidence on experienced problems and how to guide without 'telling' during the lesson. The *assessment advice* also provides guidance on how to assess the artefacts collected from student activities and how to use the results as formative assessment feedback for future planning and remedial purposes.

To enhance chances for teachers to engage in new practice, exemplary teacher (including students) support materials sought to change the teacher practice by redesigning their science lesson activities into a more investigative approach type. The characteristics of such materials are presented in a list of initial specifications of functions below, inferred from context and literature. Such materials need to:

- contain both teacher support materials and students activities;
- be based on the objectives of BGCSE chemistry syllabus for pure science;
- be developed from available materials, which teachers were already using (e.g., recipe-type of practical work activities), and change them into investigative practical work problems;
- be made up of lesson activities that can be taught within the 80 minutes (or in some schools 70 minutes) that is allocated for practical work in the BGCSE pure chemistry syllabus;
- help teachers conduct learner-centred lessons that include formative assessment and investigative practical work. To this end the exemplary materials should include procedural specifications (how-to-do advice) on how to prepare lessons, how to teach the content and skills in the topic, what methods and activities to use, how to monitor students learning, and how to give homework;
- facilitate learning both chemistry content and practical skills in more meaningful ways. Therefore, the content of the topics to be learned should not only be based on the syllabus but also on the essential parts, which also prepare students for tests and examinations;
- involve students in active learning through 'hands-on' and extend to 'minds-on' investigative practical work to encourage learner-centred classroom practice. Therefore, the exemplary materials need to involve students in small-scale investigations within the time available for a practical work period (double lesson);
- provide teachers with viable structures for helping students work in groups to promote effective use of resources and learning.

4.1.2 Expert consultation

The initial design specifications in the form of the list presented in 4.2.1 were given to science education experts. The following two questions guided the expert appraisal:

1. Is there consistency between the suggested design specifications and the conclusions of the state-of-the-art literature knowledge?

2. Do the suggested design specifications make sense when viewed against the conclusions of the context analysis?

Three experts with ample experience in Southern African education were invited to give their appraisal. The experts were asked to give explanations for their responses and make suggestions as to improving, adding, or subtracting any information as seen appropriate. The appraisers concluded that the specifications were consistent with both state-of-the-art knowledge and the context information. Specifically, experts agreed that the materials should contain large amount of procedural specifications in terms of support for lesson preparation, support for subject knowledge, support for teaching methodology, and support for monitoring student learning during instruction. The experts also agreed that the materials should contain teacher support materials (teacher guide) and student worksheets (also to be integrated in the teacher guide). Furthermore, the experts agreed that developing the exemplary materials from materials teachers already used would enhance the zone of proximal development, because teachers would have some knowledge about the exemplary materials. Basing the development of the materials on the BGCSE chemistry syllabus was also seen as a positive step in making the exemplary materials relevant and essential for teachers to use.

However, appraisers also raised some issues that needed attending to make the ideas more workable as a guide for designing and developing exemplary materials. They suggested that it should be made clear why teachers ought to engage in investigative practical work and formative assessment, and how formative assessment of practical work could take place and how teachers could use the results of the assessment.

4.1.3 Articulation of design specifications

The next step was to articulate the design specifications in order to guide the development of both the teacher and student materials. Issues raised in 4.1.2 by the three expert appraisers were used as the platform from which more detailed design specifications were developed. Similar design specifications were found in Ottevanger (2001) and were adapted to suit the requirements of this study. An overview of the design specifications used to develop initial prototype teacher support materials is presented in Table 4.1.

Table 4.1 Design specifications of exemplary teacher support materials

Teacher support function	Design specifications
Support for lesson preparation	*General description of lesson* ▪ Description of concepts: investigative practical work and formative assessment – this would present teachers with clarity of what the change involved. ▪ Description of what the lesson looks like – this was used to exemplify what change was expected. ▪ Aims of the lesson (based on the BGCSE syllabus) – the purpose of the exemplary materials was to help teachers to implement the BGCSE syllabus learner-centred teaching approach. *Lesson preparation* ▪ Lesson plan with timing – suggestions for timing were important to indicate how time could be used efficiently. ▪ Possible difficulties during the lesson – it was important to provide teachers with dynamics of a learner-centred practice. ▪ Materials (apparatus) required during the lesson – advice on use of materials was important because the resources were used strategically to support learner-centred procedures through problem solving, which included planning investigations.
Support for subject know-ledge	*Subject content* ▪ Factual information on subject (acids & bases, see section 4.3 for reasons of choosing topic) ▪ Possible student questions and answers – to reduce uncertainty it was necessary to provide teachers with solutions to problems that may develop during the lesson, and these included preparing teachers for possible student questions.
Support for teaching methodology	*Teaching strategies* ▪ Suggestions for sequencing of activities, including start up and finishing of the lesson – sequencing lessons were necessary to show teachers that students need background knowledge acquired from previous lessons, to expect less support from the teacher. ▪ Suggestions on how to conduct IPW (lessons fit in a double period) ▪ Suggestions for grouping students – grouping suggestions were made to guide teachers in using groups to promote effective learning. ▪ Suggestions on how to hand out materials (apparatus) – same as bullet 3 under lesson preparation. ▪ Concrete suggestions for the role of the teacher in supporting investigations ▪ Concrete suggestions for the role of the teacher in carrying out assessment for formative purposes during and after the lesson. ▪ Suggestions for homework
Suggestions for monitoring stu-dents' learning.	*Monitoring student learning (learning effects)* ▪ Suggestions on how to conduct formative assessment. ▪ Suggestions for marking and analysing student lab reports. ▪ Suggestions for using students feedback class-work and lesson preparation

4.2 DESIGN AND DEVELOPMENT OF THE FIRST PROTOTYPE

To start the development of the exemplary materials the BGCSE chemistry syllabus for pure chemistry was consulted. Box 4.1 presents a list of the BGCSE pure chemistry syllabus objectives relevant to the topics covered in this study. The list of syllabus objectives in Box 4.1 fall under, 'Investigation and experimental skills, the third of three main assessment objectives of the BGCSE chemistry syllabus that include also 'Knowledge and understanding' and 'Handling information, applications and solving problems.'

Box 4.1 BGCSE chemistry syllabus objectives (3.1-3.8)

3.1	Follow a sequence of instructions
3.2	Use appropriate techniques, apparatus, and materials
3.3	Handle instruments, apparatus, and materials safely
3.4	Make and record observations, measurements, and estimates
3.5	Interpret and evaluate observations and data
3.6	Plan investigations and/or evaluate methods and suggest possible improvements
3.7	Convert acquired skills into creative innovations
3.8	Apply knowledge and draw conclusions in practical situations

The development of materials in the study covered objectives 3.1-3.6 with emphasis on 3.6 because it was believed to be especially difficult for teachers to implement (see section 4.2 and also chapter 2 for reasons). For purposes of coursework assessment, the objectives were divided into four skills: (i) making and recording observations, (ii) following instructions and using appropriate techniques, (iii) interpreting data and evaluating observations, and (iv) planning and experimenting. In line with the rationale that teachers start from where they have some familiarity with practical work, the chemistry topic for 'Acids and Bases' was chosen because it had offered many opportunities to develop investigative work. Teachers were already using the topic to involve students in some 'hands-on' practical work. Acids and bases were also suitable for confronting misconceptions usually inherent in immediate preceding topics of the mole and concentrations when related to other concepts such as the strength of an acid.

The researcher developed the first prototype using activities that were often used by teachers in more structured practical work formats that have recipe-type instructions. These practical activities were converted into a problem solving format, presenting scenarios and asking students to develop experimental plans to solve the problems (see appendix A2). This approach was adopted to avoid confronting participating teachers with too many new teaching approaches and too much content. Teachers could concentrate more on the formative assessment of practical work while using familiar content in a different approach. This was in line with the design specifications to develop from what the teacher knows to achieve what he or she knew little of but was expected to do. Box 4.2 shows an example of a student activity for a lesson in the teacher guide.

Box 4.2 Segment of teacher guide with student activity embedded in teacher advice

LESSON 2: WHAT IS THE SOLUTION? [Time: Double period]

What does this lesson look like?
This is a laboratory based activity in which students explore one of the chemical properties of acids, the concept of pH. This involves a laboratory investigation and writing a report. The lesson is three parts:

- In a teacher-led discussion, students identify which questions have to be answered. For example about how the strength and weakness of acids can be represented on a pH value scale. A description of what is meant by pH of acid. What is referred to as strong—the acid or its solution?
- In a practical activity, students compare the colours they get from using a named indicator with the commercial universal strip of pH values.
- Students write a report to share their findings with colleagues in class.

Are the learners ready for the lesson?
Theoretical background knowledge about the pH and acid strength and acid concentration is necessary. Students should be able to differentiate between hydrogen ion (H^+) concentration and concentration in terms of amount acid in moles per volume water in litres.

Planning the investigation
Both the student activity instruction sheet and the steps for scaffolding investigation plan should guide planning for these activities. That is, both the chemistry content and practical procedures are important for students to carry out.

Implementing the investigation plans
Students should continue in their groups to implement their plans. Safety precautions are important. Use of goggles or safety spectacles is essential.
Students should record their results as they carry out the activities for identifying the solutions by recording the colour, and comparing with the pH scale, and noting the numerical value.

Box 2
Lesson 2: What is the solution?
You are given solutions A, B, C, D and E. The solutions are acids, alkalis, or samples of water.
You are provided with indicator solutions: universal indicator, phenolphthalein, methyl orange, and litmus for your tests.
(a) Think up a scheme and plan for identifying all the solutions as strong acids, weak acids, strong alkalis and weak alkalis and/or water. You may not use any other reagents.
(b) Implement your planned experiment and make a report of what you did.

Lesson conclusion
Students should use their knowledge about acids and alkali strengths and weakness to identify the solutions as both a strong or weak acidic solution and strong or weak alkali solution.

Seven lessons were produced by adapting already existing structured experiment procedures into investigative problems. The first prototype consisted of seven lessons with the following characteristics:

Lesson 1: Acids, alkalis and indicators?

In this lesson, students are involved in planning and implementing their investigation plans by carrying out experiments. In the BGCSE chemistry syllabus, acids are recognised by their observable features, which include their (i) ability to change the colours of indicators (ii) reactions with metals (e.g., magnesium) producing hydrogen gas (iii) reactions with carbonates (e.g., calcium carbonate) producing carbon dioxide (iv) pH values indicating their chemical strength. All properties of acids introduced in this lesson are covered in this lesson series. This lesson deals with the first characteristic, action on indicators.

Aim: *Investigating procedures for classifying liquids as acids, alkalis or neutral (e.g., water or salt solution) by using indicators.*

Lesson 2: What is the solution?

In this lesson the students plan and carry out experiments to classify both acids and alkalis using their pH value.

Aim: *Investigating the use of the universal indicator to find the numerical pH value of an unknown acidic solution or alkaline solution.*

Lesson 3: The blackboard chalk!

The blackboard chalk-acid reactions are another easily observable feature of acid properties. This exemplifies the general reaction of acids and carbonates. Chalk is a carbonate. In this lesson, students plan and carry out experiments for reactions of acid and carbonate releasing carbon dioxide.

Aim: *Designing an investigation procedure to collect 500 cm^3 of carbon dioxide from the reaction between an acid and chalk.*

Lesson 4: Strength goes with speed

In this lesson, the observable feature of an acid reaction is the emission of hydrogen gas bubbles when reacting with metals. Students design experiments to find out which acid among acid solutions provided is either strong or weak by observing reactions with a reactive metal such as magnesium, iron or zinc.

Aim: *Investigating simple procedures for classifying acids as strong or weak from the way they react with metals.*

Lesson 5: Comparing indigestion tablets

While it is important to possess knowledge about the constituent and amounts of chemicals in medicine, it is equally important for chemistry education that students learn the methods of science relevant to the acquisition of such knowledge. Such knowledge invariably becomes career related. In this activity, students plan and carry out experiments to find out factors that influence the effectiveness of an acid remedy tablet.

Aim: *Investigating the factors that determine the effectiveness of acid indigestion remedy tablets on stomach acid.*

Lesson 6: Maxiclean

Toothpaste is a common item in the lives of students. Carrying out activities related to students' everyday life is essential and also recommended in the BGCSE chemistry syllabus. In this lesson student chemistry knowledge is extended to career related activities, such as being an analytical or forensic scientist or technician.

Aim: *Using knowledge about chemical reactions to design and investigate the chemical constituent of a compound in the context of a real life situation (e.g., identification of a genuine chemical product from a fake).*

Lesson 7: The gardener's question
The condition of soil is essential to productive farming. Student knowledge about soil quality may have added value to their career in agriculture and vegetable growing. This lesson is concerned with the application of chemistry knowledge related to gardening.
Aim: *Investigating the ideal soil chemical composition for growing cabbage.*

4.3 FORMATIVE EVALUATION OF THE FIRST PROTOTYPE

4.3.1 Design of the study

The research question
The purpose of the formative evaluation was to explore the validity of the first prototype. This was done by eliciting the views of science education experts and also chemistry teachers. The validity of the exemplary materials was understood in terms of the materials based on the BGCSE chemistry curriculum and the consistency between the lessons. Expert and user appraisals were guided by the following research question:

> *What is the validity of the exemplary teacher support materials (including students' activities) that aim to support teachers with implementing investigative practical work with formative assessment in context of the BGCSE curriculum?*

Research group
The evaluation involved three science education experts. Two were based at the University of Botswana (UB) and the third at Michigan State University. The science education experts at UB were science education lecturers with long experience with curriculum reforms in Botswana. The science education expert at Michigan State University had international experience in the area of using exemplary curriculum materials. He was also helpful in providing initial ideas about developing curriculum embedded materials. The second group of participants in the evaluation included three chemistry teachers in two senior secondary schools offering the BGCSE pure chemistry syllabus. Both the University of Botswana science education experts and the chemistry teachers were familiar

with the BGCSE chemistry syllabus content. The science education experts used the syllabus as a resource for pre-service teacher training at the department of Mathematics and Science Education (DMSE) of the University of Botswana, and the teachers had used the syllabus for three years in their classes. All three experts were also given the list of design specifications used as basis for the development of exemplary teacher support materials (including student materials).

Research design

The three teachers in two schools were asked to review student lesson activities and give feedback to the researcher related to the validity of the materials with the syllabus they used and also the consistency between the lesson activities. Teachers were interviewed individually about what they thought about the materials in terms of their relation to the BGCSE syllabus and whether the lesson activities could be regarded as problems that could be used to support investigative practical work with formative assessment. Teachers responded to a semi-structured interview scheme (see appendix A3). Teachers' interviews were tape-recorded, transcribed, and coded.

Experts were given exemplary teacher support materials (including student lesson activities) to read and make comments related to the validity of the materials. A semi-structured interview (used as a questionnaire where interview was not possible) was used to obtain expert views about the materials (see appendix A4). Not all experts were interviewed, but they all gave their responses in writing. Only one expert gave a face-to-face interview to clarify some responses he made in writing. The expert appraisers were asked to give their views on the validity of the exemplary teacher support materials in terms of whether there was internal consistency between the materials and the BGCSE syllabus.

4.3.2 Results of the study

The responses by both science education experts and the teachers were made at two levels: the lesson activities (investigative practical work activities) and the teacher support materials. Expert appraisers were only asked to give their views about the validity of student lesson activities while teachers extended their responses to the potential for practicality of the materials using their experience with teaching similar content on the syllabus topic.

Both science education experts and the teachers concurred that the materials were consistent with the BGCSE chemistry syllabus. Teachers indicated that they liked the student activities and the approach of using investigative practical work.

Teachers also compared the exemplary student activities with the BGCSE chemistry coursework assessment requirements, especially skill 4. One teacher said, "*the materials are fantastic, especially if you consider the skill 4 (see section 4.3) of the chemistry syllabus coursework assessment.*" Both the experts and the teachers agreed that all the lessons (and investigative problems) were related. A further agreement was made about the sequencing of the activities by increasing conceptual difficulty from lesson 1 through to lesson 7. However, teachers also made comments that raised issues about the practicality of the materials when used in real classes. Teachers were fearful of the time and resources that implementation may demand. One teacher commented, "*the time these practical activities are likely to demand may be a bit much, especially if you consider that it is related to coursework assessment which expect us to cover four practical skills, and planning and experimenting being only one.*" Teachers, basing their views on their experience with teaching in science classrooms in Botswana, noted that lessons 6 and 7 were relatively longer and could not fit within the time allocation available for practical work, as intended in the design specifications. Generally both the experts and teachers were comfortable with the sequencing, because each lesson provided background and foundation for the following one, which is an essential element in promoting learner-centred classroom practice.

Experts also gave their views on the teacher advice provided in the teacher guide that accompanied the student lesson activities. Experts found the advice relevant and consistent with teacher action to support students involved in investigative practical work and also that it could support the teacher with ideas on conducting the formative assessment activities. Experts were also of the opinion that more subject knowledge should be included in terms of the content of investigative practical work. In their view more details about the nature of formative assessment were also needed.

4.4 CONCLUSIONS AND IMPLICATIONS FOR FURTHER DEVELOPMENT

4.4.1 Conclusions

Both the experts and the teachers found the exemplary teacher support materials (including student investigative practical work activities) quite consistent with the BGCSE chemistry syllabus. The experts further found that the materials were also consistent with the design specifications from which their development was based.

Both experts and teachers were also satisfied with the consistency between the lesson activities in terms of being typical of problems for investigative practical work. The activities were also found to progressively increase in difficulty from lesson 1 through to lesson 7. Experts and teachers also concluded that lesson 6 and 7 should be dropped because they may not fit the intended use in a double period, and as such, were not valid in terms of the design specifications.

4.4.2 Implications for further development

The results of the evaluation of the first prototype of exemplary teacher support materials (including students' investigative practical work activities) suggest that the design specifications appeared to be promising in the Botswana context, although there was still some room for improvement. Therefore, it seemed justifiable to adopt the design specifications articulated in Table 4.1 as the basis for further development of exemplary teacher support materials (including student investigative practical work activities). On the basis of points raised regarding suggestions to enhance the validity of the materials, the following can be noted:

1. The number of lessons needed to be reduced from seven to five to include only lessons 1 through 5, while lessons 6 and 7 were to be dropped. Lessons 6 and 7 were found not to be valid in terms of the design specification stipulation of a double period.
2. More explanations of what was meant by investigative practical work and formative assessment as relates to practical work needed to be added to the teacher guide to give teachers a clear picture of what they were expected to change in their current practice.
3. More teacher advice related to investigative practical work needed to be added in terms of what the teacher is expected to do during the lesson in guiding students through planning and experimenting.
4. More teacher advice related to formative assessment needed to be added in the form of what questions the teacher could expect from students and what action he or she could take. These suggestions were more open because it was not easy to predict what could happen in any particular class.
5. More advice related to assessment of the lab report and how to analyse the students' feedback and use it for both remedial and future planning purposes needed to be added.

CHAPTER 5
Development and try-out of the second prototype

This chapter reports on how the second prototype of the exemplary materials was developed and used by teachers and students in a try out. The purpose of the try out was to explore the practicality of the materials. The results of this formative evaluation were used to develop the materials further. Section 5.1 presents the characteristics of the second prototype, while section 5.2 presents the design of the try out. The data collection procedures and instruments used in the try out are described in section 5.3, and the results are presented in section 5.4. Section 5.5 presents conclusions and implications for further development.

5.1 CHARACTERISTICS OF THE SECOND PROTOTYPE

The second prototype, building on implications from the first prototype, was made up of five lessons. The lessons were presented in a teacher guide made up of teacher advice and student problems. The main features of the teacher guide were based on the four support functions of the exemplary materials presented in chapter 4: lesson preparation, subject knowledge, methodology, and monitoring learning. Box 5.1 presents a segment of the teacher guide to demonstrate how the four support levels were featured.

Box 5.1 A segment of the teacher guide (lesson 2)

Lesson implementation

Planning and implementing investigation

The lesson is introduced by a teacher-led discussion. Acids and alkalis are referred to as weak or strong according to their behaviour in a solution. The pH signifies the degree of hydrogen ion release into a solution. The pH of a neutral solution has 7 only in the middle if we start the pH scale with 0 ending with 14. Thus the pH value of strong acid solution is 0, neutral solution pH is 7 and strong alkali solution pH is 14. The numerical values and colours can represent pH values.

Planning the investigation
Both the student activity instruction sheet and steps for the scaffolding investigation plan should guide planning for these activities. That is, both the chemistry content and practical procedures are important for students to carry out.

Implementing the investigation plans

Students should continue in their groups to implement their plans. Safety precautions are important. Use of goggles or safety spectacles is essential.

Students should record their results as they identify the solutions by recording the colour, comparing with the pH scale, and noting the numerical value.

Conclusion
Students should use their knowledge about acids and alkali strengths and weakness to identify the solutions as either a strong or weak acidic solution and either a strong or weak alkali solution.

Homework: Writing the report
Students write a report about the procedures followed, results/observations and conclusions made. This report will be shared with other students.

Box 2
You are given solutions A, B, C, D and E. The solutions are acids, alkalis, or samples of water.
You are provided with indicator solutions: universal indicator, phenolphthalein, methyl orange, and litmus for your tests.
(a) Think up a scheme and plan for identifying all the solutions as strong acids, weak acids, strong alkalis and weak alkalis and/or water. You may not use any other reagents.
(b) Implement your planned experiment and make a report of what you did.

Assessment criteria
Do the students' plans show an indication that they have enough knowledge and understanding of the action and use of indicators to identify acidic or alkali conditions? For example: Universal indicator (u.i.) colour in strong acidic solution is red, weak acidic solution is orange, neutral solution is green, weak alkaline solution is blue, and strong alkaline solution is violet.
Do students' plans show that they appreciate that the focus of the tests is qualitative and hence only a mere change is required? No quantitative measurements.
Do students correctly choose and state the action of u.i. on acids, neutral solutions and alkalis? (See 2.)
Is appropriate equipment suggested and used? E.g., beakers instead of test tubes?
Are requirements of sampling suggested to complete the activity? (See also 4.)

The complete list of the lessons with brief descriptions is presented below:

Lesson 1: Acids, alkalis, and indicators
In this lesson students are involved in planning and implementing their investigation plans by carrying out experiments. In the BGCSE chemistry syllabus, acids are recognised by their observable features, which include their (i) ability to change the colours of indicators, (ii) reactions with metals (e.g., magnesium),

producing hydrogen gas (iii) reactions with carbonates (e.g., calcium carbonate) producing carbon dioxide, and (iv) pH values indicating their chemical strength. All these properties of acids introduced in this lesson are covered in this lesson series. This lesson deals with the first characteristic, action on indicators. The investigation question is:

In changing the colours of acids and alkalis, how can the properties of acids be used to identify liquids of similar appearance such as acid, alkali, and indicator?

Alkalis are introduced as major chemical opposites of acids. This lesson includes both planning and experimenting.

Lesson 2: What is the solution?

In this lesson the students plan and carry out experiments to classify both acids and alkalis using their pH value. The investigation question is:

How can the colour change of the universal indicator be used to find the numerical pH value of an unknown acidic solution or alkaline solution?

The pH value of an acid solution or alkaline solution signifies its strength. Acids are termed strong when they release a high proportion of hydrogen ions in a solution, while strong alkalis release a high proportion of hydroxyl ions in a solution. The pH as a measure of chemical strength of either an acidic or alkaline solution is contrasted with acid concentration. Both colour and numerical value denote the pH scale. Students transform the colour coding to numerical values and are able to classify the unknown solutions as either strongly acidic/alkaline or weakly acidic/alkaline.

Lesson 3: The blackboard chalk!

The blackboard chalk-acid reactions are another easily observable feature of acid properties because They exemplify the general reaction of acids and carbonates. Chalk is a carbonate. In this lesson, students plan and carry out experiments for reactions of acid and carbonate releasing carbon dioxide. The investigation question is:

What is the best method of collecting 500 cm^3 of carbon dioxide from the reaction between blackboard chalk and hydrochloric acid?

In this lesson, students use the pressure created by carbon dioxide gas to measure about 500 cm^3 volume of gas. The planning and experimentation in this activity are crucial to the control of variables in the experiment.

Lesson 4: Strength goes with speed

In this lesson, the observable feature of acid reaction is giving out hydrogen gas bubbles when reacting with metals. Students design experiments to find out which acid among acid solutions provided is either strong or weak by observing reactions with a reactive metal such as magnesium, iron, or zinc. The investigation question is:

How can the rate of hydrogen gas bubbles produced during metal acid reaction be used to determine the relative strength of an acid solution?
The hydrogen released is visible as bubbles, and this is a measurable variable used for comparison. The more the bubbles are seen, the faster the reaction. Students conclude that faster reactions denote strong acidic solutions while slower reactions denote weakly acidic solutions. When there is no reaction, students may conclude that the reaction may be neutral. Students should be able to confirm their observations and conclusions using pH values. This confirmation experiment will have to be planned for and not incidental. Students will be encouraged to follow their plans.

Lesson 5: Comparing indigestion tablets
While it is important to possess knowledge about the constituent and amounts of chemicals in medicine, it is equally important for students to learn the relevant methods of acquiring chemistry knowledge. Such knowledge invariably becomes career-related. In this activity, the investigation question is:
What is the relationship between the amount of carbonate in an acid indigestion remedy and its effectiveness against the stomach acid, hydrochloric acid?
Students plan and carry out experiments indicating that the amount of carbonate in the tablet neutralises a specific amount of acid. Many people use acid indigestion tablets often, meaning they have an important role in individual health. In this lesson activity, students will find that a simpler method is to keep the acidic medium constant while they measure the use of the tables. It could be expected that varying amounts of different brands of tablets will be needed with equal amounts of acid. A possible conclusion would be that the more tablets needed, the less carbonate present.

5.2 DESIGN OF THE TRY OUT

5.2.1 Research focus

A try out aimed at exploring the 'fit-for-use' in terms of practicality of the exemplary materials with a small number of teachers and their students in limited cases was conducted. At the same time, the try out was also a pilot of a field test envisaged as a next third prototype. These included the use of the materials by teachers, the use of the research instruments and analysis of data along the three curriculum levels of operational curriculum, perceived curriculum, and the experiential curriculum. The primary aim of the try out was to explore the practicality of the exemplary materials in Botswana Form 4 chemistry classes:

What is the practicality of the second prototype of exemplary teacher support materials that aim to support chemistry teachers implementing formative assessment of investigative practical work in Botswana?

An in-depth study of practicality was explored to determine how possible it was to use the exemplary materials in the context of Botswana form 4 and 5 classes. The goal was to find out whether teachers and students were able to use it as the designer intended, and whether resources and time allow for implementation. Based on the evaluation of the first prototype, it was important to know whether the materials could be useful in helping students engage independently in learning activities, and also learn both subject content knowledge and practical skills at the same time.

5.2.2 Research design

A case study approach involving a small number of teachers (3) and classes was employed for the try out. According to Miles and Huberman (1994), a case study is a phenomenon that occurs in a bound context. The teacher (or teacher's practice) was the phenomenon and the boundary was defined by the context of his classroom practice. It was important to adopt a multi-case approach because the intended use of the exemplary materials was in different contexts. As stated earlier, the try out was also aimed at piloting procedures and instruments that would be used in the field test for a further prototype. Throughout the try out, the researcher used a variety of methods to collect data. Table 5.1 summarises research questions and instruments used and explored during the try out.

Table 5.1 Summary of the try out

Analysis questions	Curriculum level application	Instruments	Target group
▪ How did teachers implement the lessons? ▪ Were the lesson materials implemented as intended (in terms of investigations)? ▪ Did the students follow and carry out the activities?	Operational curriculum	Curriculum profile & logbook	3 teachers
▪ Did teachers find the materials helpful in supporting them for tasks expected of them? ▪ Did teachers find the materials clear on what they were expected to do? ▪ Did the teachers find the materials congruent with the practice they normally use in their lessons? ▪ How did the teachers perceive the complexity of the innovation as suggested by the TEACHER GUIDE advice? ▪ How did teachers perceive the cost of adopting practices suggested in the exemplary materials?	Perceived curriculum	Logbook & interviews	3 teachers
▪ Did students enjoy the lessons? ▪ Were students perceived to have learned? ▪ Do students feel they were able to follow the activities with little teacher help?	Experiential curriculum	Group interviews	6 x 3 students

Data were collected from teachers and students. Data were collected on the operational curriculum by observing the operationalisation of lesson activities by teachers with their students. The perceived curriculum was explored by collecting data on how teachers perceive to have used the materials and also how practical they found the materials in their lessons. Practicality was evaluated as a measure of the materials' quality, which was indicated by clarity, congruence, complexity, and cost when used in the context of the teachers' practice. *Clarity* of the exemplary materials was determined as the extent to which the materials were perceived to provide the teachers with a clear image of what the intervention composed of. That is, implementing a learner-centred approach through investigative practical work and formative assessment. *Congruence* of the materials was conceptualised as the extent to which the practice suggested by the exemplary materials (including students' materials) is observed to be consistent with teacher perceptions of their practice during a class lesson. This can also mean the extent to which they see possibilities and opportunities to conduct the investigative practical work activities with formative assessment as proposed by the exemplary materials. *Complexity* was conceptualised in terms of the consistency between what teachers find difficult (or easy) and what they find interesting (or discouraging) and the scope of the change (learner-centred investigative practical work with formative assessment). That is, is the change within the teachers' focus of practice and interest? Finally, the *cost* as the consistency between the teacher's personal (e.g., personal change in beliefs and practices) investment in operationalising the innovation (learner-centred investigative practical work with formative assessment) as part of their practice and the output of the investments (e.g., positive reactions from students).

Experiential curriculum data were explored by asking students about their experiences with the exemplary materials.

5.2.3 Selection of cases

A small-scale, in-depth case study of a limited number of teachers and students was considered relevant to gain deeper insight into the 'fit-for-use' exemplary materials in the contexts of the selected schools. It was also important that qualified teachers with at least two years of experience in teaching the subject be selected because informed feedback was necessary to evaluate the practicality of the exemplary materials in the selected contexts. Teachers were also selected based on their willingness to participate and motivation to try out things and give critical feedback. A summary of information about the teachers is presented in Table 5.2.

Table 5.2 Background information of teachers in the try out

	J	K	L
Age	40	42	26
Professional qualification	B.Ed (science)	B.Sc (chemistry), M.Phil, PGDE.	B.Sc. (chem. & Enviro sc.) + PGDE
Teaching experience	12 years	12 (6 in Botswana) years	2 years

The three teachers who participated in the try out and their schools were different from the teachers who participated in the evaluation of the first prototype for validity. Teachers in the new sites did not readily engage in the research activities, and did not try out all the lessons as requested. Of the five lessons, teachers were allowed to choose the ones they wanted while following the requirements of the exemplary materials.

5.3 DATA COLLECTION PROCEDURES AND INSTRUMENTS

5.3.1 Procedures

The try out of the teacher (also student) support materials took place in two cycles. The first cycle involved two teachers (J and K), located in two different schools. Lessons were conducted in the afternoon. Each teacher tried the lesson activities with 16 students (half a class). The researcher observed all lessons taught by teacher J, K and L using the exemplary teacher support materials (including student materials). All three teachers filled a logbook as an exercise in reflection on how they perceived the materials and how they perceived to have used the materials in their lessons. All teachers were interviewed by appointment. The interviews were not possible immediately after the lesson because of the time factor and teachers had other commitments. Students could not be interviewed, but they filled out an adapted interview-questionnaire form with the original structure of the interview schedule. In contrast with teachers J and K, teacher L used the exemplary materials to run a complete class. A decision was made by the researcher to try the material in a complete class and compare the results with the micro-class teaching situations concentrating more on resources and the teacher's ability to conduct group work activities, which were important for large classes. The same procedures used for micro-classes with teachers J and K were applied to teacher L's class lesson.

Students

Students in teachers J and K classes were chosen randomly, but care was taken to include both boys and girls in all groups. In teacher L's case, a whole class composed of 32 boys and girls was used. All students in the try out study were offered the BGCSE pure science chemistry syllabus and in their final year, Form 5.

Therefore all students had experience and knowledge of science content in the pure science syllabus including the topic used in the study, acids and bases, which were covered in, Form 4.

Procedures for data collection used in the try out therefore, included lesson observation, interviews for teachers and students, and a teacher logbook (see Appendix A7). These procedures are discussed in more detail next.

Lesson observation

Three teachers were involved in the try out (see Table 5.3). Teacher J implemented lessons 1, 2, and 3 with 16 students in his class; teacher K implemented lessons 2, 3, and 4 with 16 students in his class while teacher L implemented only lesson 1 with 32 students in his class. Students were chosen randomly for participation in the lessons but the total number of students for teachers J and K were half of the class while teacher L used a whole class. Table 5.3 presents a summary of the number of students involved and the lessons implemented for each teacher.

Table 5.3 Number of students and lessons for each teacher

Teacher	**J**	**K**	**L**
Number of students	16	16	32
Class form:	5	5	4
Lesson activity choice	1, 2, & 3	2, 3, & 4	1 & 5
Lesson activity implementation	1, 2, & 3	2, 3, & 4	1

Table 5.3 shows that teachers J and K implemented at least two same lesson activities (lesson 2 & 3), but also different lessons in lesson 1 (teacher J) and lesson 4 (teacher K). In addition, teacher L also implemented lesson 1 which had been implemented by teacher J. The reasons for these apparent overlaps in implementation were related to two factors. The first of which were choices made by teachers on the activities they thought they could implement with resources readily available in their laboratories. The second overlap was due to an attempt by the researcher to get most of the exemplary lesson activity materials in the classroom within as short a time period as possible. The period of try out implementation was characterised by teacher industrial action, which limited the time and opportunity for implementation. Hence, the researcher took the opportunity to implement the try out in as many classes as possible before the industrial action stopped normal class lessons and afternoon study supervision, which were necessary for the research activities. Specific to implementation by teachers J and K, there was also the added pressure of preparing students for the national examinations and teachers were not keen to spend a long time in the implementation of a try out. For implementation

with teacher L, the researcher decided to take a further step in bringing the try out into a normal timetabled lesson instead of a half-class (e.g., 16 students) in the afternoon. This was an attempt to see what possible pressures existed (as pilot for field test) in a real situation. For this implementation, lesson activities 1 and 5 were chosen. Lesson 1 was more of an introduction to the process of investigation and the chemistry topic on Acids and Bases. The lesson also presented the teacher with opportunities to assess students formatively for learning content and science procedures. Lesson 5 was more of transfer/application type in which there are many chances for students to show their knowledge about the content and ability to manage variables in investigative practical work (see section 5.1). However, due to the prevailing industrial action activities, teacher L was only able to implement lesson 1 before research activities were suspended.

During the implementation of the try out, each of the teachers implemented the lessons following the teacher guide (section 5.1). Each implementation was observed as a class lesson composed of three steps (lesson introduction, body of lesson, and lesson conclusion). All activities involved group work. Within each lesson different groups were allocated different activities to cover all the activities the teacher chose. For example, in one lesson teacher J implemented lesson activities 1, 2, and 3. The main focus was on the use of the activities by students and how the teacher was able to support students through group work. The researcher carried out all observations using the curriculum profile instrument (see appendix A5). The focus of the observations was on the extent to which the teacher followed the teacher guide on essential aspects of learner-centred practical work (investigative practical work) and formative assessment. The results of the lesson observations were analysed to find out how teachers used the materials. This provided evidence at the level of operational curriculum, showing how the exemplary materials were operationalised.

Teacher interview

Teachers were interviewed to provide evidence on the perceived curriculum. Face-to-face interviews were carried out for all participating teachers at different times. Interviews were carried out after lessons had been implemented. This was done either immediately after the lesson or on an appointed date agreed upon by the researcher and the teacher. Teacher interviews were audiotaped and notes taken simultaneously. The recorded conversations were transcribed and summarised and grouped into themes showing how teachers perceived the exemplary materials in terms of its support in lesson preparation, conduct of lesson, and formative assessment.

Student interviews

Students were interviewed to provide evidence about the experiential curriculum. Group interviews were carried out with six students from each teacher at different times. The groups were composed of a mixture of boys and girls randomly chosen by the teacher. Because the lessons were carried out using cooperative group activities, each group was represented by at least one student. Student interviews were audiotaped and notes were taken at the same time. The recorded conversations were transcribed and summarised. Sentences were grouped to establish themes to show how students experienced using the materials.

Teacher journal keeping

The teacher was also required to keep a journal of lesson implementation. Because implementation only took place at one time for each teacher, journals were kept for the purpose of reflecting on the process of implementing the lesson. The reflection exercise sought to encourage the teacher to think about the materials used in lesson preparation and lesson execution. All teachers were expected to reflect about the lesson using a logbook framework with questions related to areas of support for lesson preparation, lesson conduct, and assessment. Data from journal keeping (the teacher logbook) were in text form. The responses were grouped according to the headings under which they appear as part of the analysis. Data from teacher reflections provided evidence at the level of both operational curriculum and the perceived curriculum.

5.3.2 Instrumentation

In the try out 4 data collection instruments were piloted as they may be used in the field test. The instruments included the following:

- Curriculum profile (appendix A5);
- Teacher logbook (appendix A6);
- Teacher interview schedule (appendix A7);
- Students interview schedule (appendix A8).

Each of the instruments and procedures are described in the following sections.

Curriculum profile

A *curriculum profile* has been defined as a set of statements about the intended actions of teachers during lessons (van den Akker & Voogt, 1994). According to Ottevanger (2001), the curriculum profile reflects the central parts of the curriculum innovation and indicates what the designers of the materials would like to see happening (or not happening) in the classroom. A curriculum profile instrument was used for the first time in the study in the try out. A curriculum profile instrument was used in this study for similar intentions, as expressed by Ottevanger's (2001) purpose, to collect data for operational curriculum. The curriculum profile instrument used in this study was based on information from state-of-the-art knowledge review, curriculum document analysis, and interview data (teachers and experts). The literature review has revealed learner-centred as including both investigative practical work and formative assessment. Therefore, learner-centred practice can be realised through implementation of investigative practical work with formative assessment. The study focused on investigative practical work and formative assessment. In the curriculum profile instrument, investigative practical work and formative assessment statements were grouped into three phases of a lesson: *lesson introduction, body of lesson, and lesson conclusion*. The third column was left blank to record any salient practices of teacher actions. Table 5.4 presents the lesson introduction segment of the whole instrument with three phases of a lesson.

The curriculum profile instrument used in this study differed from the one used in Ottevanger's (2001) due to differences in study focus. The curriculum profile in this study sought to streamline profile statements along the major concepts of investigative practical work and formative assessment, while unlike Ottevanger (2001), also covering the three phases of the lesson (lesson introduction, body of lesson and lesson conclusion). Another difference was in the spaces this study provided for the curriculum profile to record the most salient points of teacher practice at the moment it was captured. Table 5.4 presents the curriculum profile as it was used in the try out pertaining to lesson introduction. Each lesson step was composed of a number of expected teacher behaviours during class, appropriately placed under investigative practical work orientation and formative assessment orientation. The other steps in the curriculum profile instrument followed the same structure.

To score and analyse the results of the observation schedule the observer marked a + against each observed action. For example, in step 4 of the introduction, a positive (+) mark is made when the teacher divides or asks students to group themselves in small groups. When the observation is complete, those levels where there is no mark are then marked with a negative (-) mark. The weight of positive or negative marks indicates whether the intentions of the developer of the materials have been put into practice or not. For analysis purposes, the weightings were converted into percentages of actions performed and not performed by the teacher during the lesson. Cross-case analyses included comparing the results between each teacher practice.

Table 5.4 Curriculum profile (try out): Introduction to the lesson

	Lesson step	Investigative practical work orientation	+ -	Formative assessment orientation	+ -	Notes on salient points.
Introduction	1	Teacher presents the background of the problem to learners and the objectives of the lab activity. *E.g., Acids are sour. What other properties of acids do you know?*		Teacher clarifies with learners, areas and periods in the lesson where assessment would take place. E.g., during: *Presenting and reviewing plans – peer assessment. Making report of the investigation.*		
	2	Teacher helps learners clarify the question to be answered by the activity. E.g., *I have two clear liquids. One is an acid and the other an alkali. Hhow can we differentiate between the two?*		Teacher advises learners on what evidence will be expected when they are assessed. *We are going to make comments on each group's presentation on the basis of whether the plan is workable and safe.*		
	3	Teacher informs learners on how participation will be carried out. *(E.g., starting individually, working in groups, and developing individual reports).*		Teacher encourages critical review of the activity by learners (e.g., how do think they would have achieved the objectives). *We should make sure that we provide alternatives or advice with reasons why we think the plan is not workable or safe.*		
	4	Teacher divides class into groups in numbers that insure maximum participation *(E.g., 2-3 students per group)*		Teacher engages learners in meta-cognition discussions about the procedures they intend to adopt. *Teacher discusses with students why they have to keep to plan schedule. The use of apparatus and chemicals. Checking their progress against the plan.*		
	5	Teacher informs learners about the timing of the various activities in the investigation (e.g., planning, post planning discussion, experimenting, and report writing) *Helps students plan use of time available. Suggest times for each step in the investigation.*		Teacher encourages learners to ask questions – engage in peer assessment. *As you listen to the presentation, think about 'what questions can we ask about the plan?' E.g., think about the use of chemicals, apparatus, and safety issues.*		
	6	Teacher presents learners with a list of apparatus available for the activities possible in the laboratory. *These could be on a handout or on the board*				
	7	Teacher gives practical instructions to the groups. *T: Read the problem sheet and discuss in your group. When your plan has been reviewed by the class, collect the apparatus you need from the trolley (indicated location) After the experiments, clean and return all the apparatus.*				

Notes: + denotes observed teacher actions, - denotes unobserved teacher actions.

Teacher interview

The *teacher interview* sought to explore teacher perceptions about the practicality of the exemplary materials and how they used them. The teacher interview schedule was semi-structured. Probing and follow-up questions were used to get further clarifications on statements made by teachers. Interview questions were also obtained from observed teacher practices to find out why for instance certain actions were not taken. To analyse teacher interview data, statements made by each teacher were summarised according to the interview schedule questions and compared in cross-case analyses. When statements were the same or presented the same ideas, a summarising statement was developed to represent the common experience of participating teachers. In this way, statements were compared and contrasted and conclusions were made about teacher perceptions.

Student interviews

Student interview schedules were semi-structured as well, guided by semi-open questions. The interview sought to explore student experiences during the lesson. The student interview focused on what students liked or disliked about their activities, what they learned and understood as a result of using the materials, and what they thought their role was and that of their teacher during the lesson. Like the teacher interview, the student interview was summarised by listing the questions under each question and grouping statements according to the ideas and sense they represented. Comparing and contrasting the statements helped the researcher to make conclusions about student perceptions and experiences in cross-case analyses.

Teacher logbook

The *teacher logbook* was used to help teachers reflect about the lesson they implemented in class. The teacher logbook sought to explore teacher opinions about their experiences with the exemplary materials during lessons and how they perceived they were supported in carrying out their expected tasks. The logbook contained a set of questions that the teacher would answer quickly while the lesson experience was still fresh in their minds. The information sought related to the practicality of the materials in class in terms of how teachers perceived they were supported in lesson preparation and lesson execution and carrying out formative assessment activities. The logbook, besides providing the researcher with valuable information about teacher reflections about their experiences, also gave teachers the opportunity to think more seriously about their practice in a more reflective approach. Therefore, the logbook information provided evidence for the perceived curriculum and the operational curriculum. Analysis of teacher logbook data was also done by grouping all the responses for each teacher under each question asked in the logbook, followed with comparing and contrasting the statements and coming to general or unique statements in cross-case analyses.

5.3.3 Expert appraisal

As part of the design in the try out, an expert appraisal was included to learn more about the teacher guide and the research instruments, which were introduced and used for the first time in the study (curriculum profile instrument, teacher logbook, teacher interview, and student group interview schedules). The aim of the appraisal was to find out if there was internal consistency between the exemplary materials and the instruments. That is, the instruments were in line with the teacher guide statements and had potential to collect the intended data. The appraisal was, therefore, guided by the following questions:

> *What is the consistency between the teacher guide advice and the content of the research instruments used in the study?*
>
> *What is the potential for the research instrument to be an adequate measure and provide evidence for perceived curriculum, operational curriculum, and experiential curriculum?*

A panel of expert appraisers was asked to evaluate the materials for consistency with research questions and the design specifications. The panel was composed of three education specialists, two from the Netherlands and one from Botswana. The following specific questions were given to the expert panel to guide them in the expert appraisal task:

1. Is there consistency between items in any of these documents:
   - Teacher guide and student materials;
   - Curriculum profile observation schedule;
   - Teacher interview schedule;
   - Students interview schedule;
   - Teacher logbook.
2. Are the various items in each document specific enough to convey the intentions of the developer about the purposes of the innovation (promoting formative assessment of investigative practical work)?
3. To what extent are the statements in the curriculum profile instrument typical of investigative practical work and formative assessment orientations, as exemplified in the teacher guide and student materials?

5.4 RESULTS OF THE TRY OUT

5.4.1 Operational curriculum

OVERALL RESULTS

The data presented in this section were obtained through the use of the curriculum profile instrument (see section 5.3). All teachers conducted one session for all the lesson activities they have used in either micro-teaching class or full class. To be able to cover more activities, teachers J and K used more than one activity at one time by giving different groups different activities to carry out. Tables 5.5a and 5.5b present a summary of results of lesson observations carried out by teacher J, K and L.

Table 5.5a Summary of observation investigative practical work results for J, K and L (curriculum profile data – try out)*

Teacher	J (16 students)	K (16 students)	L (32 students)
Lessons taught	1, 2, & 3	2, 3, & 4	1
Lesson introduction (7 items)	100	71	86
Body of lesson (10 items)	90	70	70
Lesson conclusion (4 items)	75	50	50

Table 5.5b Summary of observation formative assessment results for J, K and L (curriculum profile data – try out)*

Teacher	J (16 students)	K (16 students)	L (32 students)
Lessons taught	Lessons 1, 2,& 3	Lessons 2, 3, & 4	Lesson 1
Lesson introduction (5 items)	60	60	40
Body of lesson (5 items)	80	60	60
Lesson conclusion (2 items)	100	50	50

Notes: * Scores are expressed out of 100% of (+ and -) of the curriculum profile during the lesson, + Observed teacher actions in line with the teacher guide, - Teacher guide advice expected, but teacher action not observed.

Tables 5.5a and 5.5b demonstrate that generally teachers scored higher on the teacher actions on investigative practical work orientations than on formative assessment orientations. With the exception of teacher J, the trend between lesson steps for K and L showed that the lesson introduction phase in investigative practical work orientation was higher than in formative assessment orientation while both the body of lesson and the lesson conclusion phases scored the same at 60%, for the body of lesson, and 50%, for lesson conclusion for both teachers. All teachers followed most of the suggested teacher actions except during the conclusion for teacher K (50%) and teacher L (50%). The lesson introduction in terms of investigative practical work orientations was well done; J (100%), K (71%), and L (86%) as compared to scores of J (60%), K (60%), and L (40%) for formative assessment orientations. Teachers involved students in question and answer sessions for the lesson introduction; some of the questions were closed to allow students to think more reflectively about their tasks. The body of the lesson involved students in activities, and they were observed to be actively and lively involved. However, teacher intervention was limited and sometimes students were left for too long without apparent guidance. For the lesson conclusions, the results show that teacher J did well (70%) in implementing according to the investigative practical work orientations, while the performance of teachers K and L (each 50%) was weak in this area. The difference between teacher J and the others was due to his having the opportunity to have students work beyond afternoon study time allocated for the activities. Teacher K could not maintain control of class when the bell rang for the end of afternoon study. Teacher L conducted his lesson within the school day timetable, and his class also ran out of time for proper conclusion. In the following section, the results of individual lesson phases are presented along with the teacher action advice expected during class. The results also show what teacher action advice was used and what was not used.

DETAILS OF LESSON IMPLEMENTATION

Lesson introduction

At the start of the lesson, teachers were mostly organised to begin the lessons. Table 5.6 presents overall results for the lesson introduction phase of the lesson for teachers J, K, and L.

Table 5.6 demonstrates that during the lesson introduction phase, for investigative practical work orientations, all three teachers were able to present students with lesson background and clarify the problem task. Teachers were also able to inform students about how they would work in groups (except for teacher K) and how they would use the time available efficiently to complete the tasks. Teachers were further able to discuss the steps of the investigation with students. However, 2 out of 3 teachers were not observed presenting students with a list of apparatus before the planning was completed. 2 out of 3 teachers were also not observed giving students clear instructions about what they were able to do (with the exception of teacher J). For formative assessment orientations, most teachers were able to inform students how to prepare for a peer plan review and encourage students to make assumptions and explanations of how they would achieve the solution of the problem as part of the planning. Teachers also were able to encourage students to begin to monitor their work without expecting the teacher to remind them. However, some teachers were not able to discuss with students what evidence of their work would be expected during the lesson (with exception of teacher K) and also to encourage students to engage in peer assessment by giving them the opportunity to ask questions about their work (with the exception of teacher J, who indeed did).

Table 5.6 Lesson introduction (curriculum profile data – try out)

Teacher			J	K	L
IPW	1	Teacher presents the background of the problem to learners and the objectives of the lab activity. [*E.g., Acids are sour. What other properties of acids do you know?]*	+	+	+
	2	Teacher helps learners clarify the question to be answered by the activity. [E.g., *I have two clear liquids. One is an acid and the other an alkali. How can we differentiate between the two?]*	+	+	+
	3	Teacher informs learners how participation will be carried out. [*(E.g., starting individually, working in groups, and developing individual reports).]*	+	–	+
	4	Teacher divides class into groups in numbers that insure maximum participation *[E.g., 2-3 students per group]*	+	+	+
	5	Teacher informs learners about the timing of the various activities in the investigation (e.g., planning, post planning discussion, experimenting, and report writing) [*Helps students to plan use of time available. Suggest the times for each step in the investigation.]*	+	+	+
	6	Teacher presents learners with a list of apparatus available for the activities possible in the laboratory. [*These could be on a handout or on the board.]*	+	–	–
	7	Teacher gives practical instructions to the groups. [*T. Read the problem sheet and discuss in your group.; When your plan has been reviewed by the class collect the apparatus you need from the trolley (indicated location); After the experiments clean and return all the apparatus.]*	+	–	–
FA	8	Teacher clarifies with learner, areas and periods in the lesson where assessment would take place. E.g., during: [*Presenting and reviewing plans – peer assessment; Making report of the investigation.]*	+	+	+
	9	Teacher advises learners on what evidence will be expected when they are assessed. [*We are going to make comments on each group's presentation on the basis of whether the plan is workable and safe.]*	–	+	–
	10	Teacher encourages critical review of the activity by learners (e.g., how do think they would have achieved the objectives). [*We should make sure that we provide alternatives or advice with reasons why we think the plan is not workable or safe.]*	+	+	+
	11	Teacher engages learners in metacognition discussions about the procedures they intend to adopt. [*Teacher discusses with students why they have to keep to the schedule plan; the use of apparatus and chemicals; checking their progress against the plan.]*	+	+	+
	12	Teacher encourages learners to ask questions – engage in peer assessment. *[As you listen to the presentation, think about what questions we can ask about the plan; E.g., think about the use of chemicals, apparatus and safety issues.]*	+	–	–

Notes: + Observed teacher actions in line with the teacher guide advice, **–** Teacher guide advice expected, but teacher action not observed.

Body of lesson

The body of the lesson was composed of the bulk of student activities. Teacher tasks were mainly guidance through questions, and as a result, more informal formative assessment processes. Table 5.7 presents the results of the body of lesson activities.

Table 5.7 demonstrated that for investigative practical work orientations, most teachers were able to alert students to time management. Teachers also encouraged students to make their decisions as groups and stressed safety issues.

Table 5.7 Body of lesson (curriculum profile data – try out)

Teacher			J	K	L
IPW	1	Teacher reminds learners about timing and when they will be alerted or stopped for various transitions in the lesson. [*Timing is important because of time constraints of the context.]*	+	+	+
	2	Teacher allows learners to work in their allocated groups.	+	+	+
	3	Teacher stresses safety instructions (where applicable)	+	+	+
	4	Teacher allows (encourages) learners 'room to choose' their own approach	–	–	–
	5	Teacher assists learners when necessary (but not immediately) via questioning, referral, scaffolding, etc. [*E.g. T. When we mix the indicator phenolphthalein with acids or neutral substance it remains colourless. If a liquid remains coloured with phenolphthalein what could it be? How can we make sure it is what it is? Etc.]*	+	–	–
	6	Teacher stops learners at appropriate times agreed with students to review various lesson activities. [*As agreed earlier in the introduction, the students will be helped to keep track of their steps in the investigation. T. It is time to move to the next step now. Etc.]*	+	+	+
	7	Teacher discusses results /problems with a particular group when invited by the group. [*Teacher may move between groups to listen to what they say – but intervene only when necessary and feel they have tried enough.]*	+	+	+
	8	Teacher makes sure learners execute activity and use materials/equipment correctly. [*During the review of plans, teacher makes sure that the experiments are workable and safe. This will avoid distracting from what students should learn – content and process.]*	+	+	+
	9	Teacher allows learners to draw own conclusions in groups	+	–	–
	10	Teacher helps students to start immediately. [*T. What is the first thing we do? T. What are you planning for? St. Well, we are looking… etc.]*	+	+	+
FA	11	Teacher guides learners (via questioning, referral, scaffolding, etc.) during the lesson. (Due to wide ability among students, it is expected that some may not start off easily – time is of essence): *T. Are we clear of what to do here? St. Well, (either yes or no) – T. Well, let's look at the problem sheet, refer to the demonstration. What are we supposed to do? T. Think of….*	+	+	+
	12	Teacher encourages learners to ask each other questions – peer assessment exercise. [During the plenary plan *review session: T: Let us look at the plan presented and make comments to help the group. Make sure you also correct your plan if it has the same weakness. (I.e. the teacher does not ask the group him- or herself, but instead directs questions through other students). E.g., let us look at the apparatus used, what can we say about them, what questions or comments can we make? Etc.]*	+	+	–
	13	Teacher uses representative sample number of groups in class to present the post planning review and encourages others to comment and adjust their plans. [*Class review will allow students to comment on each other's plans – this is peer assessment; Looking at the plan for: understanding of the problem, e.g., correct plan for the problem? Correct procedure for the problem solution? Safety issues observed? How to record the results?]*	+	–	–
	14	Teacher helps learners think about possible sources of error in the experiment. [*Errors due to type of apparatus? Errors due to the use of apparatus? Errors due to loss of matter, temperature, etc.]*	–	–	+
	15	Teacher gives feedback summarising by highlighting major points of the scientific investigation including safety precautions. [*Planning including POE; Experimenting; Analysis of the results; Concluding and communicating your results.]*	+	+	+

Note: + Observed teacher actions in line with the teacher guide, **–** teacher guide expected teacher action not observed.

During student experiments, most teachers were also able to advise students about their progress against time available, discuss with groups how work was progressing, and monitor the safe use of apparatus. However, teachers were not yet able to let students do most of the work without interference. Teachers tended to prescribe to students what methods to use. For example, although it was necessary and teachers were able to support students in starting work immediately for efficient use of time, teachers seemed to be more directing than facilitating (with the exception of teacher J). Some teachers were also more directing in summarising conclusions in a more convergent way (with the exception of teacher J). As regards the conclusion, time pressures had fewer effects in teacher J because he was able to go beyond the time for afternoon studies, and students worked with patience.

For formative assessment orientations, teachers were able to guide students by listening and questioning during planning and most of the experimenting. In micro-teaching lessons, for teachers J and K, students were encouraged to ask each other questions, but this was not visible in the lesson conducted by teacher L. All teachers were able to give feedback at the end of the lesson by summarising the important points of the lesson, but some did not give students the opportunity to engage in peer assessment through peer plan review, and also did not discuss possible practical discrepancies with students.

Lesson conclusion

The lesson conclusion was done under pressures of time, but most of the activities suggested to the teacher for both investigative practical work and formative assessment orientation were carried out. Table 5.8 presents the results of the lesson conclusion step.

Table 5.8 demonstrates that for investigative practical work orientations, 2 out of 3 teachers did ask the groups to report their results to the whole class and also helped the groups draw conclusions in one way or another. All teachers allowed time for the apparatus to be put away and for students to settle before any further instructions; however, teachers did not ask students to evaluate their results against possible experimental discrepancies.

For formative assessment orientations, 2 out of 3 teachers were able to ask students or groups to present specific information about their results; for example, measurements and units. Teachers were also able to ask students to make reports of their work and present them as laboratory reports. Two out of 3 teachers asked for a group report instead of individual reports.

Table 5.8 Lesson conclusion (curriculum profile data – try out)

Teacher			J	K	L
IPW	1	Teacher asks each (or some) group to report their results to the class to help the class reflect on the lesson activities. [*Were the plans followed? Were the collected results useful? Did the plan provide a solution? What were the challenges and how were they resolved?]*	+	-	+
	2	Teacher helps learners draw conclusions from the activity by asking reflective questions when they need guidance.	+	+	-
	3	Teacher helps learners understand discrepancies in their results by asking the class to reflect on the activities.	-	-	-
	4	Teacher allows time for apparatus to be put away before the bell goes.	+	+	+
FA	5	Teacher asks groups for specific information/results [*T. Asks groups to report on the results they obtained; T. Asks students to consider their results and decide whether the answer for the problem has been obtained; T. Asks students to think about the things that could have affected their results.]*	+	+	-
	6	Teacher asks learners to report on their methods and results in written form as homework. [*T. Asks students to use their results and write a report of the experiment during prep time; The report should include the statement of the problem (aim or question); the experiment as it was carried out, the results, conclusion and evaluation (what was changed from the original plan and possible sources of error).]*	+	-	+

Note: + Observed teacher actions in line with the teacher guide, **–** Teacher guide expected, but teacher action not observed.

5.4.2 Perceived curriculum

Data for the perceived curriculum were obtained from the teacher logbooks and the teacher interview. The aim was to find out, first, how teachers were perceived to have used the materials for preparation and lesson execution. Second, how teachers perceived the practicality of the materials in terms of clarity, complexity, congruence, and cost (see section 5.2 for detailed explanation of these concepts). Specifically, teachers were asked to give their views on what they thought about the exemplary materials in terms of it's learner-centeredness and practicality in their contexts.

PERCEPTIONS ON USE OF THE EXEMPLARY MATERIALS

Teachers used the materials for lesson preparation and also ideas on how to help students do planning for solving problems presented by the practical lesson activities. Teacher L said, "*Planning for such a lesson would have been difficult, but the stepwise lists of resources and activities to do before and during the lesson made preparation easy.*" He continued, "*Most importantly it was good in helping one to check what was available before the lesson to avoid surprises.*" Teacher J continued, "*Especially I found it useful in listing all the necessary apparatus, and that made it possible for me to check what materials I had before the lesson. In preparing in advance one can even borrow from other schools if the equipment is not in school*" Teacher L found it useful to provide some ideas and skills on how to prepare some solutions. He said, *"It was good in giving the method for preparing some indicators we usually do not have in stock*". Teacher J found the teacher guide also useful in giving ideas on what background knowledge and skills to consider when introducing the lesson. He said, "*The background knowledge and skills were necessary to remind the students of the important points of the lesson,* *especially at the beginning of the lesson. After the reminder, students were able to follow the instructions and carry out the activity without asking for help from me*". Teacher K found the teacher guide helpful in providing him with ideas about guiding students during the planning phase of the investigation. He said, "*With the advice, I was able to guide the whole group in carrying different activities because I treated each group differently while maintaining the structure for planning and experimenting*".

Teachers also were perceived to have been well served by the ideas presented in the teacher guide for scaffolding student work, in planning for the experiments, and eventual implementation of the plans. Teacher K said, "*I found the approach suggested of using questions useful and often effective; my only problem is that it took a long time sometimes to get some students understand what was expected because they are used to being given directives about what to do and not questions.*" (This is also related to the cost). Teachers perceived that the materials had the potential to support them in implementing a learner-centred practice, characterised by investigative practical work with formative assessment.

PERCEPTIONS ON PRACTICALITY OF THE EXEMPLARY MATERIALS

Clarity

Teachers expressed the view that they had no problems in understanding what was expected of them from reading the teacher guide. They perceived the teacher guide to be guiding them on implementing a practice that related to the coursework assessment some of them were piloting for Examinations Research and Testing Division (ERTD) of the Ministry of education. Teacher J said, "*I had no problem in understanding this materials because it looks like what we have been talking about in UB-INSET (in reference to Department of Mathematics & Science Education In-service training for teachers, DMSE-INSET, the University of Botswana) workshops, the idea is to promote learner-centred teaching and learning*". On what the innovation promoted by the teacher guide entailed, Teacher J indicated that he perceived the teacher guide to guide him on both investigative practical work and formative assessment. Teacher J said, "*These are very closely linked concepts. I mean how do I advise students on planning and doing experiments without making some assessment before I make decisions? We are dealing with a very closely linked process.*" Teacher K's comments agreed with those of teacher J when he said, "*really, even when I begin the class by question and answer approach, I am involved in assessing and giving feedback. I get what students know and do not know, and also I confirm their knowledge or lack of during these discussions.*" However, Teacher L's comments did not show the same type of perception as with the other two, when he said, "*the purpose basically is to promote the learner-centred practice, which involves students actively in doing science*". His comment showed that he perceived the innovation more in terms of investigative practical work than formative assessment.

Congruence

All three teachers perceived the practice promoted by the teacher guide as incongruent with their normal practice. Teacher L said, "*The practice we are expected to follow in this document is not the same with what I usually do. We have not yet implemented the changes that relate to coursework*". Teacher J said, "*The learner-centred method encouraged is desirable, but I do not often practice it*". He continued, "*there are a few aspects of it which I sometimes practice with completing classes because we are revising and I want them to start understand what they are doing than just memorise. These include discussing experiment questions just like we did in these lessons*". Teacher K also admitted not often using the learner-centred investigations on account of not having enough time and resources (points which will be discussed under cost). He said, "*I rarely use it, but I think it is a good approach*". However, although the teachers found the practice incongruent, its effects inspired them. Teacher J said, "*The activities gave the students opportunity to think and practically engage in laboratory work*." Teacher K said, "*I found the materials stimulating and students were motivated to work actively with little help from me*." He added, "*I have already used some of the materials for other classes and I find the same reaction from students; they like working with these activities*." Teacher L found the materials ideal for promoting effective group work in the laboratory. He said, "*we use group in science classes as a given, but most of the time it is just because there are not enough apparatus to go around and therefore, it is convenient to involve all students through dividing them into groups*." He added, "*The way group work is used here, it is focused on getting maximum participation for most students and making sure they learn as well*."

Complexity

Teachers perceived the complexity of the materials to be within their level of understanding, and manageable. Teacher K indicated that if the resources allow, he saw no problem in adopting and changing his practice according to the teacher guide. He showed this by indicating that, in fact, in his department, they were already considering using the structure of the materials to implement in class lessons as part of their piloting of the coursework assessment. The inferences that can be made here also indicate that the main focus is more on the investigative practical work than on the formative assessment. Teacher K said, "*In the science department, the chemistry section, with the blessing of the head of department, has begun to incorporate some of the ideas in the activities to help us develop activities we need for implementing coursework assessment*." They perceived the materials to be clear in terms of what syllabus objectives to cover and what activities to use. Teacher K said, "*With provision of structure of the lesson plan, with time allocations and the suggested activities preparation was very easy, and the only task I was left with was to locate the necessary resources which were also listed, the teacher's guide was very helpful*." Teachers perceived the practice promoted by the materials in line with the BGCSE suggested teaching innovations and that was not a common practice in their classes.

Cost

Teachers also generally perceived the implementation of the practice suggested by the exemplary materials possible in their classes. Comments of all other teachers were in line with tTeacher L's observation that, "*generally there is enough resources for all the activities, especially for the topic, acids and bases; there is plenty of stuff around.*" Teacher J said, "*in fact, the activities are not very different from the practical work we usually do, except of course for emphasis on investigative approach in these activities. Otherwise we can use the same resources and within the time we have allocated for practical work.*" Teacher L said, "*My class was able to do a lot in one lesson I taught. I believe time was adequate and can be managed with practice.*"

Teacher J said, "*One appreciates the benefits of such an approach because learning is indeed promoted, but it is nothing like what we do at the moment. Although the syllabus has changed, most of our practices are still the same with those used for the previous science curriculum, the Cambridge Overseas School Certificate (COSC, see chapter 2 for explanation)*". He continued, "*due to limited time we do the best we can and often teach to prepare students for national examinations. The examination does not demand a learner-centred approach that would require students to answer questions that are investigative.*"

5.4.3 Experiential curriculum

Student level of enjoyment of the lessons was indicated by the amount of active participation. All students in each group participated readily in both discussions and subsequent 'hands-on' activities without being prompted by the teacher. Students were also amazingly prompt at managing their work in terms of pacing themselves within the time they were allocated. This included time management and a sense of knowing when they had done enough in one step, e.g., planning, and when to move to the next step, experimenting without the teacher prompting them. Students perceived they had enjoyed carrying out the activities. Most students also revealed that they had not been involved in similar science learning, as presented by the activities. They said their work had included a lot of demonstrations, in contrast with the exemplary materials in the study, which gave them opportunity to (student from J) "*work on things by ourselves.*" Another student (from K) said, "*I was able to think about what I did; before I just followed the teacher's instructions*". Another student (from L) said, "*Always we wait to be told what to do by the teacher, but to plan for yourself is good.*"

Most students readily said they liked all the lessons, but a few picked lesson one and gave the reason that it was tricky but enjoyable and took time to find the answer. Another student (from student L) said, "*although it took us sometimes to find the answer, it was not difficult at all; we were not looking at the question and results carefully, the answer was just there, and needed one to think*!"

5.4.4 Results of the expert appraisal

The results of the expert appraisal are presented by listing the comments made under each question.

1. *What is the consistency between teacher guide and student materials and the research instruments composing the curriculum profile, the teacher logbook, the teacher interview schedule, and the student interview schedule?*

All three expert appraisers agreed that there was internal consistency between the various documents but there was need to improve in the context of some documents, especially the teacher guide. Regarding the content of the teacher advice, they alerted the researcher to the following points:

- There was still need for a clearer and specific advice for what teachers should be doing during lesson conclusion to make it meaningful.
- Be consistent in providing procedural (how-to-do) advice throughout the teacher guide from lesson to lesson.
- Avoid use of jargon that may confuse teachers, such as 'heuristics of planning'.

2. *Are the various documents specific enough to convey the intentions of the developer about the purposes of the innovation (promoting investigative practical work and formative assessment)?*

All three expert appraisers agreed that the documents were specific enough regarding what was to be achieved but could still do with some improvements. Specifically the advice for improving the specificity was intended to make sure that it is clear how teachers are to collect the formative assessment results when assessing students (i.e., is it on paper? per group? the whole class?). Secondly, they also advised that it should be stated what the teachers were supposed to do with the results of the formative assessment.

3. *To what extent are the statements in the curriculum profile instrument typical of investigative practical work and formative assessment orientations as exemplified by the teacher guide and the student materials?*

The response of the expert appraisers was that some statements were specific and others needed to be made more specific. For example, one of the experts was not happy with the use of the label teacher at the beginning of every statement because it does not show the shift from teacher-centred to learner-centred, which was the purpose of the innovation. He suggested that the word paper be used to replace teacher. Another problem cited was the nature of the problem questions for lesson activities; they were regarded more on the practical work side along the 'practical work – investigation continuum' (i.e., the problem statements were not open enough). The expert appraisers also raised issues on the structure of the instrument. They observed that the copy they were reviewing (see Table 5.3) did not make clear distinctions between investigative practical work and formative assessment orientations, and because of spaces left on the document, it did not look appealing. So they suggested that it be restructured to place all statements in a single column and responses on the right hand side. They also suggested that each lesson step (e.g., introduction) should have an equal number of statements composed of both investigative practical work and formative assessment orientation statements (see appendix A6). The suggested curriculum profile instrument was to contain the following sections: pre-lesson planning, introduction, body of lesson, lesson conclusion, and post-lesson impressions.

Additional comments related to the overall structure of the teacher guide.

- To make clear definitions of both what is meant by investigative practical work and formative assessment.
- Typographical advice included the use of different fonts with different sizes and headers, boxes to indicate highlights and differentiate between teacher guide advice for various sections.

5.5 CONCLUSIONS AND IMPLICATIONS FOR REVISION

5.5.1 Conclusions

THE OPERATIONAL, PERCEIVED, AND EXPERIENCED CURRICULUM

The data analysis for the try out study was guided by the following research question:

> *What is the practicality of the second prototype of the exemplary teacher support materials that aim to support chemistry teachers in implementing investigative practical work with formative assessment in Botswana?*

The results of the various lesson phases show that, as regards the teacher use of the advice of the exemplary materials, teachers used most of the advice provided by the exemplary materials for both investigative practical work and formative assessment orientations. Teacher use of the exemplary materials advice was spread down the lesson phases with almost equal emphasis. As in the field test, teachers tended to use more investigative practical work orientation advice more than formative assessment orientation advice. In regards to the investigative practical work orientations, most of the teacher advice not used was related to allowing students to work more independently in their groups. Therefore, an overall analysis of data for the operational curriculum demonstrated that teachers were more able to use the materials in class lessons to help students carry out investigative practical work than in carrying out formative assessment.

Teacher comments on the perceived curriculum show that they perceived the materials to have the potential to promote a more learner-centred practice in their classes because they were able to involve students actively in meaningful group work activities. On the practicality of the materials, teachers were perceived not to have had problems with the exemplary materials in terms of its clarity and complexity. Teachers perceived the exemplary materials to be incongruent with their usual classroom practice, and this was related to the costs, which they perceived to be in terms of constraints originating from national examination requirements. With the exception of teacher L, other teachers did not perceive costs of implementation as a hindrance to classroom implementation. Teachers were perceived to have enough resources to implement what was advised in the teacher guide.

Although teachers gave positive comments indicating that they perceived the exemplary teacher support materials to be useful in supporting their lesson preparation and conduct of lesson, their lesson practices were not consistent with their expressed perceptions. Observations made on teacher operationalisation of the lesson activities indicated that they had problems with following some of the teacher guide advice relating to both investigative practical work and formative assessment orientations. However, weaknesses were detected more in following the teacher guide advice on the formative assessment orientations. Teachers were also observed to have had problems in making a meaningful lesson conclusion. Discussions during lesson conclusion tended to be convergent on the 'correct answer' given by the teacher rather than encouraging students to explore what their answers meant. Teacher perceptions about the intended change also seemed to be clearer on the investigative practical work than on the formative assessment orientations and practices.

Student comments demonstrated that they enjoyed the activities and were happy doing the type of science learning approach suggested by the exemplary materials. Students liked to be actively involved instead of observing the teacher. Students perceived the materials as not very difficult to do but demanding some engagement of thinking. Students appreciated the role of their teacher as facilitative, especially during the planning and experimenting. They also perceived their role as active learners.

The conclusion that can be drawn from this data, in answer to the research question, is that the exemplary curriculum materials have shown some potential for practicality in Botswana chemistry classes. This was demonstrated in the cases where teachers participating in the study used the exemplary materials at the initial stage of implementation. However, although teachers showed a positive desire to change and perceived the role of the materials positively, there were still many areas in which teachers did not implement in line with the intended change in terms of the investigative practical work orientations and the formative assessment orientations. Related to both investigative practical work and formative assessment, teachers needed more support in preparing and managing the conduct of a learner-centred lesson in which students are given the opportunity to make decisions. Teachers need to be guided on what structures to create that would facilitate student learner-centred learning and little prompting from the teacher. These include what questions to ask and how to ask them in order to facilitate both investigative practical work and formative assessment orientations. The conclusions for the findings are presented along the following headings: lesson preparation and lesson execution. Both investigative practical work and formative assessment orientations are discussed under these topics.

Lesson preparation

Teachers were able to prepare for most of the lesson, according to the advice of the teacher guide, in terms of what lesson topic to focus on, what resources to organise, and how to group students and what the students would be doing in different steps of the lesson. Most of the preparations were in line with the investigative practical work orientations. However, teachers did not seem to pay much attention to planning for formative assessment related orientations, such as how they would make sure necessary background on the lesson topic would be introduced to help students make the transition into the intended activity of planning and experimenting. For example, planning on what essential areas of content and skills to be highlighted was often missing. This was also consistent with the teachers' stated perceptions of what the innovation involved, in which the investigative practical work orientations were more visible than the formative assessment orientations.

Lesson execution

<u>Related to investigative practical work</u>

- Teachers had problems with major aspects of the lesson introduction such as providing clear and adequate background on science knowledge content and practical skills. Proper introduction with adequate background on both science content and practical skills necessary for students to be able to engage in the intended problem solving activities were often skipped and students started on the planning and experimenting. Introductions were not given enough time to engage the class in question and answer sessions that would result in clarification of the intended activities.

- Teachers had problems helping students to plan and experiment in ways that may result in effective learning and understanding. Teachers did not give students enough structure for planning and experimenting. Groups were asked to plan without knowing what resources they had. The list of apparatus given at the beginning of the experiments, with clear information on what it should be used for, did help students to think about what they were doing. Therefore, the issue of resources has implications for investigative practical work.
- Teachers had problems in helping students make choices on what method plan to follow and what decisions to make on the format of the lab report.

<u>For formative assessment</u>

- Teachers had problems engaging in question-and-answer sessions throughout the lesson. A question-and-answer session was suggested to help students clarify their thoughts about the intended activity while the teacher would also be able to make judgements about students understanding of what they are expected to do. Therefore, this had strong implications for formative assessment.
- Teachers had problems helping students to make assumptions on what they expected to find as consequence of their plan. Teachers did not often ask students to make assumptions in their planning about what they expected in line with the predict-observe-explain procedure. The importance of making public one's assumptions also is not highlighted during the lesson conclusion where it has implications for formative assessment.
- Teachers had problems in helping students engage in peer assessment activities. Teachers did not often inform or give students opportunity and time to engage in peer assessment activities.
- Teachers had problems in helping students evaluate their investigation results as part of the lesson conclusion. Ideas about evaluating experimental results by reference to practical discrepancies were ignored. These are essential for meaningful conclusions in making decisions on explanations for the outcome of the investigation. These had implications for formative assessment.

EXPERT APPRAISAL

Experts made suggestions for improvements in both the teacher guide and the research instruments, especially the structures of the curriculum profile instrument and the teacher logbook. Experts did not make any specific comments on both teacher interview schedule and student interview schedule. The conclusions that can be made from the expert appraisal is that although the research instruments were found to be quite consistent with the teacher guide a number of changes on both the teacher guide and the research instruments could improve the consistency further. According to the experts, the teacher guide was not clear and specific enough on what teachers should be doing during lesson conclusion. For example, they felt that the teacher guide was not clear and specific on how teachers should collect the formative assessment results when assessing students (i.e., is it on paper? Per group? The whole class?), and what they should do with the results. The teacher guide was also inconsistent in providing procedural (how-to-do) advice throughout the teacher guide from lesson to lesson. The teacher guide was not adequate in explaining the meaning of both investigative practical work and formative assessment. Finally, there was no consistency in the use of icons, headings, and fonts.

Regarding the research instruments, the experts felt that some statements in the curriculum profile were not specific enough. For example, the use of the label 'teacher' at the beginning of every statement seemed to connote a more teacher-centred approach than the learner-centred approach being promoted. The structure of the instrument did not make clear distinctions between investigative practical work and formative assessment orientations, and because of spaces left on the document it did not look appealing. To address this structural problem, a single column for both investigative practical work and formative assessment, with spaces indicating responses on the right hand side, was suggested. Experts also suggested that the curriculum profile include introduction, body of lesson, lesson conclusion, all composed of ten statements on essential aspects of both investigative practical work and formative assessment orientations.

Regarding the teacher logbook, the main issue was with its length. A shorter teacher logbook (e.g., one page length) was preferred because it would be easier for the teacher to complete.

Attention to these areas would mean that some changes would have to be made on the teacher guide and the curriculum profile. Specific details of implications for these findings are discussed in section 5.5.2.

5.5.2 Implications for revisions of exemplary materials

TEACHER GUIDE

Implications for the findings of the evaluation of the second prototype, in terms of its practicality as reflected in the conclusions, suggest that more support for teachers to implement effectively in both investigative practical work and formative assessment is needed in various areas of the teacher advice. The following points raised in the conclusion could be noted:

For investigative practical work:

- The role and need of background knowledge, especially when students meet the topic for the first time, would need to be highlighted for emphasis.
- Teachers would need stepwise instructions that also include when to hand out apparatus and reasons for doing so.
- More information on making choices about the methods and reports needs to be included and highlighted in the teacher guide.

For formative assessment:

- More information about carrying out question-and-answer and suitable examples needs to be provided in the teacher guide. This can also be highlighted to make easy references.
- More advice on helping students make assumptions needs to be included in the teacher guide. This also needs to be highlighted to give teacher a quicker reference and save time.
- Alerts for procedural advice such as engaging students in peer assessment need to be used to help teachers recognise necessary action.
- More ideas about the importance and use of practical discrepancies in evaluation of experimental results need to be included and highlighted in the teacher guide.

CURRICULUM PROFILE

Implications for revisions suggested that the curriculum profile would need:

- To be modified to include three columns composed of the following headings: investigative practical work/formative assessment statements, spaces for marking the observed (√) or not observed (×), orientations of both investigative practical work and formative assessment.
- To include ten statements (composed of both investigative practical work and formative assessment orientations) in each of the three lesson steps: Lesson introduction, body of lesson, and lesson conclusion.

TEACHER LOGBOOK

Implications for revisions suggested that the teacher logbook would need

- to be made shorter to increase the chance for teachers to complete it between lessons.
- to include four essential headings related to the use of the materials for preparation and lesson execution (in terms of support for investigative practical work and formative assessment).

CHAPTER 6
Development and field test of the third prototype

This chapter reports on a formative evaluation of the third prototype of the exemplary materials by means of a field test. The primary aim of the field test was to explore the practicality of the exemplary materials (teacher and student materials) in Botswana chemistry classroom settings. Furthermore, the study sought to explore how teachers and students experienced lessons guided by the exemplary materials. After a discussion of characteristics of the third prototype (6.1), the design of the field test is described in section 6.2. Section 6.3 presents the results of the study, while conclusions are made in section 6.4.

6.1 CHARACTERISTICS OF THE THIRD PROTOTYPE

The third prototype was composed of exemplary teacher support materials and student materials. The differences between the second and third prototypes related to both structure and detail in presenting aspects of both investigative practical work and formative assessment. Related to the form or structure, the third prototype differed in its inclusion of outlined numbering of headings and use of bullets and icons to identify same text and differentiate between types of information. The major headings included 1.0 Introduction; 2.0 General strategies; 3.0 Assessment of student work; 4.0 Overview of lessons; 5.0 The BGCSE syllabus objectives; 6.0 The lesson series. Each of the headings had subheadings and various icons to identify and differentiate various information for the teacher. There was also consistency of use of the same numbering and use of icons from lesson to lesson. Related to detail the investigative practical work and formative assessment themes were described in greater detail giving reasons why teacher practice should shift from teacher-centred to learner-centred and what that shift entails. This was done by relating the proposed changes to the coursework assessment teachers are expected to adopt when the BGCSE is fully implemented. Furthermore, sections 2.0 General strategies and 3.0 Assessment of student work were expanded under each of the lesson contents to provide more specific information on 'what to do', 'how to do,' and 'when to do' teacher advice. For example, the general strategies included how the lesson was structured, including the investigation plan and also the naming of the icons. Box 6.1 shows how the investigation lesson guide was structured.

Box 6.1 The general lesson strategies

Investigation step	Guiding questions	Actions involved
Helping students define the problem	*What is this investigation about?*	A brief summary of background for the activity
	What is involved in this problem?	Identify and discuss variables to be controlled and measured.
	What are you trying to achieve (by the end of this lesson)?	In terms of knowledge with understanding, handling information, solving problems, experimental skills, and investigative work.
	Are the students ready for the lesson?	Including prior knowledge required on content and skills.
Helping students choose a method	*Preparation for the lesson*	Outline of necessary preparations to be done beforehand
	Resources	A list of materials and worksheets needed and how they should be made available to students
	Lesson plan and timing	Including a set of approximate timing for each section of the activity.
	Lesson implementation	A step-by-step guide to lesson activity in the laboratory.
Helping students arrive at the answer	*Planning and experimenting*	Following the investigation plans, students carry out their experiments
	Conclusions	Guide students by asking questions, but let them analyse their results and make conclusions.

More details were also included for guidance in performing formative assessment. These included new specific subheadings and advice on establishing assessment criteria, assessment during lesson (while groups are planning and experimenting), assessment of the lab report. Box 6.2 shows information provided to the teacher for conducting assessment during lesson.

Box 6.2 Guide for assessment during the lesson

Formative assessment during lesson
During the course of the lesson students are able to engage in self- and peer-assessment. To engage in self- and peer-assessment, students need to be supported by the teacher through a system of reflective questions:
1. What is to be changed?
2. What is to be measured (or observed)?
3. What is to be kept the same during the experiment and measuring?

Other guidance focused on assessment of the lab reports, analysis of lab report feedback, and the teacher's plan.

The lessons were also grouped as physical properties of acids and their reactions with some metals (lessons 1 to 3) and reactions of acids with carbonates (lessons 4 and 5). Grouping lessons according to their chemical reaction type made it easier for teachers and students to concentrate on the same content and concepts when focussing on one group. The list of all the lessons in the third prototype is presented below with a brief description about what they involve.

Lesson 1: Acids, alkalis, and indicators?
This lesson deals with the tendency of acids and alkali to change the colour of indicators. The aim of the investigation is *to detect the presence of acid or alkali in a clear colourless unidentified solution.*

Lesson 2: What is the solution?
This lesson deals with student use of scientific knowledge of acids and alkalis with indicators in order to identify unknown chemicals as either strong or weak acids or alkalis using pH values. The aim of the investigation is *to use the pH value of an acid or an alkali to determine the strengths of acid and alkali solutions.*

Lesson 3: Acids strength
In this lesson, the observable feature of an acid reaction is the emission of *hydrogen gas bubbles* and *temperature change*, when reacting with metals. Students design experiments to find out which acid among acid solutions is either strong or weak by observing reactions with a reactive metal such as magnesium, iron, or zinc. The aim of the investigation is *to use the reaction of acids and moderately reactive metal to differentiate between strong and weak acids.*

Lesson 4: Acids and carbonates
In this lesson, students plan and carry out experiments for reactions of acid and carbonate releasing carbon dioxide. Students use the pressure created by the carbon dioxide gas to measure a specified X cm^3 volume of gas. Planning and experimentation are crucial to the control of variables in the experiment. The aim of the investigation is *to use standard laboratory apparatus to produce a volume of carbon dioxide gas from reaction of dilute hydrochloric acid and calcium carbonate.*

Lesson 5: Comparing indigestion tablets
This is a transfer task in which students are expected to rely on their knowledge about neutralisation reaction of acids with carbonates or alkalis. Students are asked to compare the effectiveness of common indigestion (anti-acid) tablets by observing their reactions with a dilute acid, an action similar to what may take place in the stomach remedy for indigestion. The aim of the investigation is *to determine the relationship between the ingredients (constituents) of specified anti-acid tablets and their ability to remedy stomach indigestion.*

An example of prototype three is presented as a segment of the teacher guide for lesson 2 in Box 6.3.

Box 6.3 Segment of exemplary teacher support materials

Lesson implementation

Lesson 2: What is the solution?

Step 1: Planning the investigation

Lesson introduction

The lesson is introduced by a teacher-led discussion. Acids and alkalis are referred to as weak or strong because of their behaviour in solution. The pH signifies the degree of hydrogen ion release into solution. The pH of the neutral solution has only 7 in the middle if we start from a pH scale of 0 to 14. Thus the pH value of strong acid solution is 0, neutral solution pH is 7, and the strong alkali solution pH is 14. The Numerical values and colours can represent pH values.

◇ **Planning the investigation**

Students work in small groups of 2-3. Each group has access to a copy of Box 2. Both the student activity instruction sheet and the steps for scaffolding investigation plan should guide planning for these activities. That is, both chemistry content and practical procedures are important for students to carry out.

While students discuss and plan:

- Distribute list of apparatus.
- Move around to observe what is happening and offer help to any group.
- Intervene only when it is necessary, e.g., when students seem reluctant to start or ask for help.

◇ **Plenary discussions:**

- Random selection of groups to present to whole class
- Facilitate the discussions by asking leading questions: How would we know the solution contains an acid? Etc.
- While the reports are made the rest of the groups check their plans against comments made.

When discussions are complete:

- Inform students about the location of a set of apparatus for the experiment.
- Allow students to carry out their plans in their groups (see step 2).

Box 2

What is the solution?

Background Information

Acidic and alkaline solutions can be classified as strongly acidic/alkaline and weakly acidic/alkaline. The 'strong' description of an acid or alkali solution refers to the ability of the acid or alkali to readily release (dissociation) hydrogen ions (H^+) into aqueous solution. The 'weak' description of acid/alkali refers to the incomplete dissociation of the acid/alkali into the solution. A solution of hydrochloric acid is strongly acidic while ethanoic acid is weakly acidic. A solution of sodium hydroxide is strongly alkaline while ammonia solution is weakly alkaline.

The problem

You are given solutions A, B, C, D, and E. They are solutions of acids, alkalis, and water. You are not told which is which. You have a choice of indicators (solutions or paper): litmus, methyl orange, phenolphthalein and universal indicator.

What to do

(a) Think up a scheme and plan for identifying which solutions are strongly and weakly acidic; strongly and weakly alkaline or neutral. You may not use any other reagents. For guidance, use the 'planning for an investigation' scheme in fig. 1.

(b) Carry out the experiment you have planned for solving this problem.

(c) For your homework, make a report of what you did in your group.

◇ **Step 2: Implementing the investigation plans**
Experimenting by implementing the plans

Students should continue in their groups to implement their plans. Safety precautions are important. ***Use of goggles or safety spectacles is essential.***

As they carry out the activities for identifying the solutions, students should record their results by noting the colour and comparing with the pH scale, and noting the numerical value.

- Remind students to follow their plans
- Remind students about safety precautions
- During implementation, continue to guide students when necessary to complete the process: For example, why is it important to measure equal amounts of solution? Etc.
- However, students should be allowed to work as independently as possible.

◇ **Conclusion**

Students should use their knowledge about acids and alkali strengths and weakness to identify the solutions as both a strong or weak acidic solution and strong or weak alkali solution. The best choice of indicator is the universal indicator (UI). **Results**:

Solution	Colour change with UI	Conclusion
A	Purple	Strongly alkaline solution
B	No colour change	Neutral solution
C	Red	Strongly acidic solution
D	Yellowish green	Weakly alkaline solution
E	Orange	Weakly acidic solution

Answers

Strong acid (C); Strong alkali (A); Weak acid (E); Weak Alkali (D); Neutral (B).

6.2 DESIGN OF THE FIELD TEST

6.2.1 Research focus

A field test was conducted to explore the practicality of the materials in the context of Botswana chemistry classes. The research focus was on three curriculum representations as described by Goodlad et al. (1979). These included the operational curriculum, the perceived curriculum, and the experienced curriculum. The *operational curriculum* was explored by evaluating the use of the materials in the science lab by teachers, the *perceived curriculum* by asking teachers to give their perceptions, and *the experiential curriculum* by asking students to provide their experiences when the materials were used. The study was guided by the following research question:

> *What is the practicality of exemplary materials (third prototype) that aim to support chemistry teachers in implementing investigative practical work (learner-centred) with formative assessment in Botswana General Certificate of Secondary Education chemistry education in Form 4 in Botswana?*

Practicality was evaluated as measure of the materials' quality, which was indicated by clarity, congruence, complexity, and cost to the teacher in using it in the context of his or her practice (see section 5.2.2 for detailed discussion of clarity, congruence, complexity and cost). *Clarity* of the exemplary materials was taken as the extent to which the materials were perceived to provide teachers with a clear image of what the intervention was composed of. That is, implementing a learner-centred approach through investigative practical work and formative assessment. *Congruence* of the materials was conceptualised as the extent to which the practice suggested by the exemplary materials (including student materials) is observed to be consistent with teacher perceptions of their practice during class lesson. This also means what they would like to do and the extent to which they see possibilities and opportunities to conduct the investigative practical work activities with formative assessment as proposed by the exemplary materials. *Complexity* was conceptualised as the consistency between what teachers find difficult (or easy) and what they find interesting (or discouraging) and the scope of the change (learner-centred investigative practical work with formative assessment). In other words, is the change within the teachers' locus of practice and interest? Finally, the *cost* was viewed as the consistency between the teacher's personal (e.g., personal change in beliefs and practices) investment in operationalising the innovation (learner-centred investigative practical work with formative assessment) as part of their practice and the output of the investments (e.g., positive reactions from students).

6.2.2 Research design

A case study approach involving a small number of teachers (5) was employed for an in-depth study of how teachers used the exemplary materials and of the role the materials play in supporting teacher practice. A case study approach is an appropriate method for investigating a particular phenomenon within its real-life context, when that phenomenon and context are closely related (Yin, 1994). Implementation of the study took place from May through July 2003. The researcher visited schools almost everyday for short periods of time for class observations and possibly an informal chat.

All teachers were asked to teach all lessons covered by the exemplary materials. Four out of the 5 participating teachers were able to teach all the 5 lessons. The fifth teacher was only able to teach 4 lessons (1-4). The teacher developed personal problems and he could not continue after completion of lesson 1 through to lesson 4. However, the data already generated was accepted on the basis of at least having covered the two main themes of the lesson series (Acid-metals reactions and Acid-carbonate reactions). Lesson 5 was the application (with context) of acid-carbonate reactions. To facilitate implementation, the researcher supplied the teachers with one copy of the teacher guide each and forty copies of students' practical problem manual each for the five classes. The researcher also supplied some of the resources listed in the exemplary materials but which were not in stock at school.

The researcher used a variety of methods to collect data. Triangulation of methods and data sources was used to enhance corroboration of findings (Miles & Huberman, 1994). Table 6.1 summarises the research questions, curriculum level application, conceptual focus, the instruments, and the research group.

Table 6.1 Main feature of the field test design

Analysis questions	Curriculum level application	Instruments	Research group
▪ How did the teacher implement the formative assessment of investigative practical work in his or her lessons? ▪ How did the exemplary materials support implementation of the innovation by teachers?	Operational curriculum	Curriculum profile (observation instrument) & logbook	5 teachers
▪ What were teacher perceptions about the practicality of the materials in terms of its clarity, congruence, complexity, and cost to their practice?	Perceived curriculum	Logbook & interviews	5 teachers
▪ What were student experiences of using the materials in terms of learning effects and role definitions?	Experiential curriculum	Group interviews	5 x 6 students

Data was collected from both teachers and students. Methods of data collection included a classroom profile (observation instrument) and teacher logbook to explore the *operational curriculum,* while the *perceived curriculum* was explored through semi-structured teacher interview and the teacher logbook. Data on students' *experiential curriculum* was collected using a semi-structured (group) interview. Collection of data was executed chronologically, beginning with lesson observation followed by teacher and students interviews at the end of the lesson series. The teacher logbook was used throughout the implementation of the lessons. The teacher interview came at the end, after both the teacher logbook and student interviews have been reviewed to generate more questions. A total of 24 (double period) lessons were observed for all the 5 teachers who participated in the study. More information about research instruments would be discussed in section 6.3.4.

6.2.3 Selection and composition of the research group

Schools

All schools in Botswana offer the same science curriculum. Teacher qualification is suitable both in level and subject orientation for all teachers who teach the pure science syllabus (Table 6.3 is representative of staff qualifications in other schools). Therefore, decisions on what schools to use were determined mainly by constraints of time available for the study and the cost of travel. Related to time, the BGCSE is a centralised curriculum both in content and examination. This has a strong bearing on school timetable and classroom teaching. Scheming for a term or year's work is departmental (or a unit of depart such as chemistry section) because the department is preparing students for the national examination. That is, it is often only possible to teach a syllabus topic once on the schemed timetable. Missing the opportunity may have meant waiting for another year. Therefore, the researcher had to work under a tight schedule to complete the study within the teachers' timetable lessons. Related to cost of travel, Botswana is a large but sparsely populated country (see chapter 2). Distances between schools can also be great. The choice made was to use schools in proximity from which the teacher could travel from one lesson to another in two schools in a day. Covering more lessons per day also made it possible to complete the study in a relatively shorter time.

Teachers

A small-scale in-depth case study of a limited number of teachers was considered relevant to gain a deep insight in the dynamics of the implementation process, rather than a large-scale approach where probably more superficial information would be gathered. Furthermore, purposive sampling was used in selecting cases that were expected to advance understanding of the implementation process rather than a random selection of cases. The selection focused on information rich cases (cf. Patton, 1990). By definition, the classroom practice of any form 4 chemistry teacher who offered a pure science BGCSE chemistry syllabus satisfied the conditions for a purposively selected case. However, other criteria included that the teacher would be willing to participate. Implementing a learner-centred teaching approach was generally going against the tide of practice in Botswana science classes, and therefore the teacher had to be willing to challenge his beliefs and practices. In this regard, only teachers who felt happy to take part were selected. Although even still, teachers often needed to be persuaded to participate. To create a safe environment for the participating teachers, choices were made to pair them in each school. Pairing teachers was also done to facilitate sharing of resources and, specific to the study, to be able to compare how schools could implement them and the factors that could have influenced them. Furthermore, due to the demands of the innovation, for teachers to be comfortable with the subject content and to have had sufficient experience teaching at this level, they were expected to have completed the probationary period of two years teaching.

Initially, the plan was to use six teachers from three schools (two from each school) to implement the field test. However, due to internal school timetable changes and teacher turnout, combined with time limits, one of the participating teachers could not participate in the study because he lost his class to a new teacher, who also could not participate in the study. Therefore, only five teachers participated. That is, two pairs of teachers from two schools and one teacher from the third school. A summary of information about the teachers is presented in Table 6.2.

Table 6.2 Background information for the teachers in the field test

	School A		**School B**		**School C**
	T	**U**	**W**	**X**	**Y**
Age	31	31	29	28	33
Professional qualification	B.Sc. + PGDE**	B.Sc. + PGDE	B.Sc. + PGDE	B.Sc. + PGDE	B.Ed (Chem.sc.)*
Teaching experience (years)	3	3	3	3	6
Teaching load	21 hrs/7dw	21 hrs/7dw	11 hrs/7dw	15 hrs/7dw	16 hrs/5dw
Departmental staffing	20	20	20	20	22
Chemistry section staffing	7	7	6	6	7
Number of labs	3	3	3	3	3
Number of students in this class	36	38	40	40	27

Notes: * B.Ed. (chem. sc.) denotes Bachelor of Education in Chemistry Science, ** B.Sc. + PGDE denotes Bachelor of Science with Post-Graduate Diploma in Education.

The three schools are typical of the main secondary schools where the BGCSE curriculum is used in Botswana. School A is located in a semi-urban area and school C in an urban area. Both school A and B are government schools. Government schools are financially provided for and controlled by the Ministry of Education. Government schools are usually sufficiently equipped for the syllabus because the government supplies both the science syllabus and the resources. School B is a government-aided school. Government-aided schools are supported by the government financially and with staff, but they control their funds. Priorities for spending the money may not be the same as that of the government. Some government-aided schools may not get resources as quick as government schools. However, officially both types of schools should have the same facilities because government funding is provided per student. Four teachers have the same experience of teaching, in terms of years, while the fifth, teacher Y, has twice the experience of the others.

Students

Students were mainly determined by the teacher's class allocation. The materials were developed based on the BGCSE pure chemistry syllabus. Students followed the lesson series just like they would in any of the usual laboratory classes in which they are expected to do class work and homework. At the end of the lesson series, student interviews were conducted as group interviews of 6 students each. Students were selected randomly by the teacher, with specific instruction by the researcher to make sure that each student came from a different group and that the interview group should be a mixture of boys and girls to reflect the class composition. The researcher conducted five group interviews with students from five different classes who participated in the study.

6.2.4 Instruments and procedures for data analysis

In field test 4, data collection instruments were used. These included the following:

- a curriculum profile (see appendix A5);
- a teacher logbook (see appendix A6);
- a teacher interview scheme (see appendix A7);
- a student interview scheme (see appendix A8).

These instruments are explained below.

Curriculum profile

Classroom observations were carried out with the help of a *curriculum profile*. A curriculum is a set of statements about the activities and preferred behaviour of teachers during the observed lessons (van den Akker & Voogt, 1994). Such a profile reflects the core of the curriculum innovation as perceived by its designers (van den Berg, 1996). The use of the curriculum profile helps to establish the relation between the intended curriculum and the implemented curriculum at a very concrete level (Ottevanger, 2001). The curriculum profile in this study was adapted from other research studies (see Ottevanger, 2001; van den Akker, 1988) and earlier experiences with lesson observations during the tryout of the second prototype.

The profile curriculum was made of 30 action statements, each indicating what the teacher was expected to do during the lesson. Each statement was related to the teacher advice given in the teacher guide. The curriculum profile was divided into three sections that mirrored the lesson phases: lesson introduction, body of lesson and lesson conclusion, each containing 10 statements. Each statement was provided with space (box) in which a tick (√) might be marked to indicate observed teacher action or a cross (X) to indicate absence of expected teacher action. Space was also provided to take notes about other observed actions relevant but not covered by the curriculum profile statements (critical incidents).

The curriculum profile statements in each section were meant to obtain information on teacher actions that reflect investigative practical work orientations and formative assessment orientations. By presenting a picture of what was done and what was not done, as could be obtained from the ticks and crosses related to the two orientations, the instruments could help evaluate how teachers were able to use the teacher guide advice in the classroom. Table 6.3 shows the introduction segment of the curriculum profile as it was used in the study.

Table 6.3 Introduction segment of the curriculum profile (Field test)

Curriculum Profile Instrument Items			√/x	**Critical incidents** (Notes)
IPW	1.	Discusses background of problem		
	2.	Distributes problem sheet(s)		
	3.	Groups students for activities		
	4.	Clarifies problem question with students		
	5.	Lists available apparatus (resources)		
	6.	Discusses safety precautions		
	7.	Discusses lesson objectives		
	8.	Discusses stages of investigation		
FA	9.	Guides students through question and answer		
	10	Informs students about plan review		

Notes: √ denotes **yes** the action is observed; X denotes not observed, IPW denotes investigative practical work, FA denotes formative assessment.

The curriculum profile instrument was completed by the researcher at the end of the lesson by filling the boxes with a tick (√) to indicate observed teacher actions and with a cross (X) to show actions that were not observed.

Analyses of curriculum profile data involved counting the number of ticks (√) for each lesson phase for each lesson and expressing them as a fraction of the number of statements in investigative practical work orientations or formative assessment orientations. This process was done separately for lesson introduction, body of lesson, and lesson conclusion. The result of the analysis helped in evaluating what was or was not implemented and to what extent.

Teacher logbook

Teachers kept a *logbook* of all the lessons they taught and which were observed. Records of un-taught lessons were not kept because they would not offer complete information involved in preparation and execution. The teacher logbook provided the researcher with feedback on teacher perceptions on the use of the exemplary materials in preparation and execution of lessons for investigative practical work and formative assessment. The logbook also provided teachers with a structure to reflect on their actions during the implemented lesson and to make adjustments for the following lesson. The logbook asked for feedback on specific investigative practical work and the formative assessment activities teachers were able to implement and what problems were encountered in achieving the lesson objectives. The logbook was adapted from similar instruments in other studies, also used in previous adaptations (cf. Ottevanger, 2001).

The analysis of teacher logbook data included descriptive patterns. Descriptive patterns usually entail summarising segments of text in order to interpret a phenomenon it is considered to represent (Miles & Huberman, 1994). To analyse logbook data for this study, repeated sentences were used as codes and retained as representative of the logbook evidence from the data analysis. These sentences were then used to represent teacher perception about their use of the materials for lesson preparation, lesson execution, and lesson formative assessment actions.

Teacher interview

The *teacher interview* was carried out at the end of the lesson series. Interviews were audiotaped, and brief notes were taken at the same time. Notes were necessary for interpreting transcribed data and also as a guard against any possible failure of the audiotape. The purpose of the interview was to help teachers reflect on their practice during implementation by looking back at how they used the materials and how the use of such exemplary materials supported their practice. The researcher carried out all interviews. The interviews were semi-structured and concentrated on teacher experiences and general impressions in relation to the use of materials and their practicality in class lessons. Teacher interviews sought information on teacher perception of the materials, whether they liked them or not and whether they were likely to use them again. Emphasis was placed on how the teachers perceived the practicality of implementing the materials in class. Related to lesson execution, the interview also sought to find out answers and explanations to observed teacher actions that were striking. Also, it sought to find answers to observed actions that did not either fall into the capture of the curriculum profile or actions that were not observed to be consistently left out. Other information sought included that which was picked up through informal discussions between the teacher and the researcher, or with students. More specifically, the teacher interview sought information that would help evaluate teacher perceptions as to the clarity of the content, purposes and practices of the exemplary materials; appreciation of the congruence of the teacher guide suggested practice and their usual practice; perceived level of complexity of the exemplary materials with teacher understanding of their expected practice; and the cost, in terms of cost-benefit ratio, of using the materials and possible benefits. Teacher interviews took about 45 minutes.

Analysis of the interview data included the descriptive patterning to code teacher responses and make interpretations by representing the common responses as representative of teacher perceptions. Thus, teacher perceptions were represented by specific quotes under generalised inferred meanings.

Student interview

The researcher conducted *interviews with* a sampling of *students* per class. Interviews were audiotaped and notes were taken to assist in the coding during interview report writing. Student interviews were semi-structured and intended to establish the experiential curriculum. Students were asked about their experiences in the lessons and the roles they perceived for themselves, the teacher, and the materials in the lessons. Students were always asked to respond to the first question of the interview individually, and thereafter a conversational approach was adopted so they could speak when they felt they had something to contribute. The researcher made sure that the students covered the questions asked in the interview, but not necessarily in order of appearance in the interview schedule. Student interviews sometimes took a whole hour. Student interviews tended to take more time because it took a bit of time to have students talking about their experiences. The researcher regulated discussions during student interviews by using the semi-structured questions in the interview schedule to focus on specific issues at a time.

Analysis of student interviews followed a similar pattern to that of the teachers. Statements were match-patterned through a descriptive approach and excerpts of real quotes were used to represent general views and ascertain inferential statements reflecting the perceptions about learning and understanding the roles of teacher, materials, and students in the learning process.

6.3 RESULTS OF THE FIELD TEST

6.3.1 Operational curriculum

OVERALL RESULTS

The operational curriculum focused on the lesson execution by teachers in their classes. Tables 6.4a and 6.4b present the overall results of lesson execution for all the five teachers of investigative practical work and formative assessment orientations. The scores in Tables 6.4a and 6.4b are averaged over all lessons in terms of investigative practical work and formative assessment orientations. The scores are expressed in percentages as fractions of the number of teacher advice that were implemented for investigative practical work during lesson introduction (8 items), body of lesson (7 items), lesson conclusion (4 items) and for formative assessment during lesson introduction (2 items), body of lesson (3 items), lesson conclusion (6 items). Results for individual cases are appended in appendix 6e.

Table 6.4a Average scores for investigative practical work orientation (curriculum profile data averages) (Field test)*

Lesson phase	T	U	W	X	Y	Average
Lesson introduction (8 items)	80	85	66	55	88	74
Body of lesson (7 items)	90	90	72	70	95	83
Lesson conclusion (4 items)	55	65	63	45	75	61
Overall %	**75**	**80**	**67**	**57**	**86**	**73**

Note: * Scores as percentage of maximum possible score.

Table 6.4b Average scores for formative assessment orientation (curriculum profile data averages) (Field test)*

Lesson phase	T	U	W	X	Y	Average
Lesson introduction (2 items)	70	60	50	40	50	54
Body of lesson (3 items)	60	50	38	40	60	50
Lesson conclusion (6 items)	80	67	42	43	86	64
Overall %	**70**	**59**	**43**	**41**	**65**	**56**

Note: * Scores as percentage of maximum possible score.

Tables 6.4a and 6.4b demonstrate that the average scores of investigative practical work orientation scores (73%) are generally above scores for formative assessment orientations (56%). Variations can also be read between lesson phases. In investigative practical work Table 6.4a, the body of the lesson has the highest scores (83%), followed closely by lesson introduction (74% of 8 investigative practical work orientation statements), with lesson conclusion showing the lowest scores for all teachers (61%). In formative assessment Table 6.4b, lesson conclusion generally (64%) shows higher scores than both the body of the lesson (54%) and lesson introduction (50%). The results also show that scores between teachers vary for both investigative practical work and formative assessment orientations. Details of how lessons were executed by individual teachers are presented in the next section.

DETAILS OF LESSON IMPLEMENTATION

Lesson introduction

At the start of the lesson not all teachers were observed to be prepared. Some teachers were observed to be collecting and organising apparatus and taking more time from the lesson time. A record of how teachers implemented the teacher guide advice in lessons is presented in Table 6.5 as performance on orientations towards investigative practical work and formative assessment as advised in the teacher guide.

Table 6.5 Lesson introduction – summary scores for all lessons per teacher (Curriculum profile data) (Field test)

Curriculum profile Instrument Items			Teachers				
			T	**U**	**W**	**X**	**Y**
IPW	1.	Discusses background of problem	√√	√√	√√	√√	√√
	2.	Distributes problem sheet(s)	√√	√√	√√	√√	√√
	3.	Groups students for activities	√√	√√	√√	√√	√√
	4.	Clarifies problem question with students	√√	√√	√	0	√√
	5.	Lists available apparatus (resources)	0	-	0	0	-
	6.	Discusses safety precautions	-	√	0	0	√
	7.	Discusses lesson objectives	√√	√√	√	√	√√
	8.	Discusses stages of investigation	√√	√√	√	√√	√√
FA	9.	Guides students through question and answer	√√	√√	√√	√√	√√
	10.	Informs students about plan review	-	-	0	0	0

Notes: √√ denotes item was observed at least once in at least 4 lessons, √ denotes item was observed at least once in at least 3 lessons (threshold), - denotes items observed at least once in 2 or less lessons, 0 denotes not implemented at all, IPW denotes investigative practical work, FA denotes formative assessment.

Table 6.5 demonstrates variations and similarities in implementation of the teacher guide for both investigative practical work and formative assessment orientations. In investigative practical work orientations, the trend shows that all teachers were able to discuss the background of the problem with students in the introduction, distribute, or make sure students had a copy of the problem sheets, and group students in ways aimed at maximising participation in group discussions. However, the implementation for other actions varied across lessons and between teachers. For example, teacher X did not clarify the problem question with students in any of the lessons, while teacher W implemented it in three lessons. Teachers T, W and X were also observed to have been unable to list apparatus for students at the appropriate time for planning activities, while teachers U and Y implemented the advice in one lesson each. List of apparatus was considered to be part of the planning resources. Teachers W and X did not discuss with students in any of the lessons the safety precautions specific to each problem. Teacher T implemented it in two lessons, while teachers U and Y were able to implement it in three lessons.

In the formative assessment orientations, all teachers were able to guide students through question and answers. However, teachers W, Y, and X did not ask students to prepare for a peer plan preview exercise, while teachers T and U implemented it twice and once, respectively. Question and answer seemed easier for most teachers to implement, perhaps because it involved the whole class, and as such, was similar to their usual practice.

Body of the lesson

The body of the lesson phase of the lesson often took more time than the rest of the lesson. The body of lesson involved two student activities: planning and experimenting. During the lesson the teacher was expected to organise and help students carry out their activities. The teacher should also carry out formative assessment of student actions to be able to make decisions about supporting them. Formative assessment during the lesson was about listening and asking questions to get feedback from students as they worked. When students experienced problems the teacher was expected to guide them in overcoming their problem in a timely fashion because time had to be used efficiently. However, for most teachers, lesson practice did not show a distinction between the planning phase and the experimenting phase. Introductions were short and often, to the observer, it was ambiguous what the lesson was about and what it was expected to achieve. The teacher would ask students to start their work without specifying where they should start.

The events of the lessons, for most teachers, often depicted the following scenario: Students were told to start their work with no clear understanding whether to start with the planning or the experiments. Some students would start planning, while others would be involved in trial and error work. Students were observed carrying on experimenting as well as going back to check what the problem could be if things do not work, and modifying their approach, a bit of 'evolutionary planning.' Others would start experimenting, clearly following a plan. This indicated that the teacher had given the planning assignment before, but perhaps did not co-ordinate its implementation. A summary of the classroom practice during the body of lesson is presented in Table 6.6.

Table 6.6 Body of lesson (Curriculum profile data) (Field test)

Curriculum profile Instrument Items			Teachers				
			T	U	W	X	Y
IPW	1.	Uses effective groups of 2-4	√√	√√	√	√√	√√
	2.	Encourages students' approach	√√	√√	√	√√	√√
	3.	Guides by questions not 'telling'	√√	√√	√	√	√√
	4.	Encourages group collaboration	√√	√√	√√	√√	√√
	5.	Monitors experimental set-ups for safety	√√	√√	√√	√	√√
	6.	Checks that plans specify safety	-	-	0	-	√
	7.	Ensures collection of apparatus is orderly	√√	√√	√√	√√	√√
	8.	Encourages time self-management	√√	√√	-	√	√√
FA	9.	Asks students (groups) to specify assumptions	√√	√√	√	√√	√√
	10.	Facilitates peer plan review	-	0	0	0	-

Notes: √√ denotes item was observed at least once in at least 4 lessons, √ denotes item was observed at least once in at least 3 lessons (threshold), - denotes items observed at least once in 2 or less lessons, 0denotes not implemented at all, IPW denotes investigative practical work, FA denotes formative assessment.

Table 6.6 demonstrates that most teachers implemented the teacher guide advice for investigative practical work in most of the lessons, but generally did not check student plans for specifying safety precautions and also did not facilitate student peer plan review. A closer look at the table shows some variations between teachers according to their implementation for investigative practical work and formative assessment. Generally the variations place teachers in two groups. One group is characterised by a high level of teacher implementation of investigative practical work--teachers T, U, and Y and those with limited implementation, teachers W and X; for example, for investigative practical work. However, the general trend is that most teachers were able to group students in small groups, enhancing effectiveness in group activities, to encourage and promote students' own approach to problem-solving, guide students by questions and not 'telling', encourage group collaboration by facilitating student group discussions; for example, asking students questions and giving them time to discuss among themselves, monitor experimental set-ups for safety, ensure that collection of apparatus is done orderly. To achieve orderliness in collection of apparatus, students were asked to appoint individuals to collect apparatus in order to avoid crowding around the trolley or a place where apparatus were kept. Generally, most teachers seem to have had problems checking that student plans specified safety. Teacher W did not check it at all in any of the lessons, while teachers T, U, and X were observed to have checked it in two lessons each. Teacher Y checked student plans for specifying safety in three lessons. Other teacher guide advice that was implemented did not follow the trend described and showed more variation between teachers.

The table of results shows that teacher W, in contrast with the others, grouped students in ways that enhanced effectiveness in group activities, encouraged students to approach investigations, used questions to guide students without 'telling', and asked students to specify their assumptions once in only three lessons. In comparison, teacher X implemented the use of questions to guide students without 'telling', monitored experimental set-ups for safety, and encouraged time self-management in about an equal number of lessons.

In the formative assessment orientations, the trend shows that most teachers asked students to specify assumptions they made about what they expected the results to be and give explanations for their assumptions. When students made their assumptions public, they also committed themselves to following a chosen approach to solving the problem. Making assumptions in the form of predict-observe-explain helps students to focus on the aim of the investigation. However, teacher W was able to implement it only in three lessons. All teachers found the facilitation of peer plan review difficult because implementation was either limited or did not take place. Teachers U, W and X did not implement at all in all the lessons while teachers T and Y implemented minimally once in one lesson each.

Lesson conclusion

For all teachers, the conclusion part of the lesson varied in terms of time allowed and content. Few teachers had enough time to help students carry out comprehensive conclusion of the lesson activities. Most lessons were completed in a rush because time was not sufficient to engage students in meaningful conclusion. However, the results of records of the curriculum profile show that teachers had varied experiences from lesson to lesson. A summary of lesson conclusion activities for all teachers implementing in the lesson series is presented in Table 6.7.

Table 6.6 demonstrates great variations in the use of the teacher guide between teachers. Trends can be shown between teachers' preferred teacher guide advice for class implementation, and also between teachers in terms of who implemented the most and least teacher guide advice. For investigative practical work orientations, all teachers were observed to ensure that clear up of apparatus before the next lesson was done. Clearing up before the next lesson was related to time management. A well-managed lesson would give enough opportunity for students to clear up and settle down and make proper conclusions. This also indicated the level of preparedness of the teacher. Time is always a factor in lessons and hence the focus of the exemplary materials was also to make sure teachers were made time conscious. Most teachers were also able to assign homework to prepare for the next lesson, with the exception of teacher X, who was only able to implement it in three lessons. Homework was important in preparing students for the next lesson by reading ahead. Most teachers also, did not discuss experimental discrepancies with students.

Only teacher Y was observed to have implemented in all the lessons, while teacher U implemented it in only three lessons. Teachers did not find it easy to encourage groups to make decisions on how they wished to present their laboratory report. Only teacher Y tried it once in lesson 5. It would seem the suggestion in the teacher guide to allow students to take initiative in designing their presentation was not acceptable or practicable in the context of implementation.

Table 6.7 Lesson conclusion (Curriculum profile data) (Field test)

Curriculum profile Instrument Items			Teachers				
			T	U	W	X	Y
IPW	1.	Ensures clear up before next lesson	√√	√√	√√	√√	√√
	2.	Discusses experimental discrepancies	_	√	_	_	√√
	3.	Encourages groups to decide what format to adopt for presentation	0	0	0	0	_
	4.	Assigns homework to prepare for next lesson	√√	√√	√√	√	√√
FA	5.	Reminds students to base conclusions on data collected	√√	√√	√	√√	√√
	6.	Reminds students to evaluate results against specified assumptions for conclusion	√√	√√	_	_	√√
	7.	Encourages students to ask questions	√√	√	_	_	√√
	8.	Asks for students' opinion when responding to class questions	√√	_	0	_	√√
	9.	Makes sure students are clear before proceeding to the next point	√√	√√	√	0	√√
	10.	Encourages students to write a group laboratory report	_	_	_	√	_

Notes: √√ denotes item was observed at least once in at least 4 lessons, √ denotes item was observed at least once in at least 3 lessons (threshold), - denotes items observed at least once in 2 or less lessons, 0 denotes not implemented at all, IPW denotes investigative practical work, FA denotes formative assessment.

For formative assessment orientations, most teachers were able to remind students that when they make conclusions they should only base the outcome on the results they collected during experiment. However, teacher W was only able to implement this in three lessons. Teachers T, U and Y were observed to have been able to remind students to evaluate results against specified assumptions when making the conclusion, and also often made sure students were clear before proceeding to the next point during class discussions. On the same issues, teacher W was only observed to have implemented in two lessons for the first issue and in three lessons for the second issue. Teacher X only reminded students to evaluate their results against assumptions in one lesson, and related to the second issue, he often was observed to not to give students time to understand what was said before moving to the next point. Teachers T and Y were observed to have consistently encouraged students to ask questions in their classes and also involved students in answering some of the questions. Teacher U encouraged students to ask questions only in three lessons and in other two lessons he was pressed for time, while teachers W and X were able to implement in one and two lessons, respectively. Teacher W was never observed to have encouraged students to answer questions from their peers, while teachers U and X were able to do so only in one and two lessons, respectively. Almost all teachers encouraged students to make group report for lesson 5. However, teacher W was only able to do so in lesson 2 and thereafter did not refer to it. Teacher X was able to encourage group lab report in at most three lessons.

CLASSROOM OBSERVATIONS – PORTRAITS OF TWO LESSON PRACTICES

The outcome of analysis of average results for all teachers has shown that at least two types of teacher practices may be identifiable. Generally, results of teachers W and X contrast with those of teachers T, U, and Y. Tables 6.3a and 6.3b show that investigative practical work orientations of the overall percentage performance result of implementation of teachers W (67%) and X (57%) are lower than that of teachers T (75%), U (80%), and Y (73%). For formative assessment, a similar trend is shown with scores of W (43%) and X (41%) being lower than those of T (70%), U (59%), and Y (63%). This trend has also been consistent in the results of the different phases for all lessons. To characterise the contrasts for each of the representations, we look in depth at the results of the observed practices of teacher X and teacher Y. Teacher X's observed practice was more teacher-centred than learner-centred while teacher Y's observed practice was more learner-centred than teacher-centred. The representation of observed lesson practices are presented as general descriptions with vignettes to provide a window of what took place in a particular lesson for each teacher. The scores of the curriculum profile of individual teachers are presented in appendix 6e.

Teacher X

Lesson Introduction

Teacher X often started lessons after time. Therefore, lessons often started without clear introduction and clear instructions of what procedure students were expected to follow in the lesson. The teacher was observed often to begin lessons by asking students to start going into '*your groups and carry out the task in the problem sheet*'. Listing of objectives for the lesson was done while students were already busy into their activities. The lesson objectives and the problem question was not be discussed and clarified as was advised in the exemplary materials. However, students were invariably observed to be able to collect the apparatus and do a number of tasks. Some students immediately and promptly started setting up the activities and experimenting while others were still involved in working out their plans. This was striking, and intrigued the researcher enough that he was compelled to seek clarification from the students on what they were doing and how they were doing it. In lesson 3, students informed the researcher that they had been given the planning as homework. However, what was observed did not show that the intended outcome had been achieved because students were at different stages of the lesson, the approach lacked order and co-ordination. While some students managed to complete their planning as a group before the lesson, some only started doing it during the lesson and this lacked the teacher's monitoring. An example of an introduction scenario is presented as a vignette in Box 6.4. Consequent from the observed practices, it became clear that the teacher did not clarify problem questions with students. Students are only able to benefit from an activity if they are clear about the problem they are solving; otherwise their actions are limited to 'hands-on' engagement in the activity. The teacher did not list available resources, such as apparatus, for students as part the planning. The teacher did not discuss safety precautions. Safety is another factor for making decisions about what can be done and what cannot in the context. These decisions are important for the process of science. For formative assessment orientation, the teacher did not inform students about plan review. Knowing what to expect helps focus student efforts on how to communicate their intended solution, and that in turn forces them to consider their plans very carefully.

Box 6.4

Lesson 3: Lesson introduction (Acid strength)
The lesson started about 15 minutes late because students were coming back from tea break.

When the students were settled, teacher X asked them to come to the front and collect apparatus and do the experiment. He added, "Are you prepared for the practical?" Students shouted "yes!" The lesson had begun with the stage of experimenting. There was no time set for clarifying the problem question and planning. There was also no distinction between planning and experimenting because while some students started with experiments, some could be observed either doing both or still doing planning.

Body of lesson

The transition from introduction, planning, and experimenting was not often clearly defined. This made it impossible to accommodate suggestions from the teacher guide to review group plans by the whole class in order to encourage and facilitate peer-assessment. Teacher X often asked students to go into their 'usual groups'. From the observed student response, the '*go into your usual group and start work*' signalled, 'start doing experiments,' because most of them started doing experiments. Even those who were still involved in doing some planning felt they did so because they failed to do their homework. In lesson 3, while students were carrying out their planning/experimenting exercises, the teacher was observed going from group to group and stopping momentarily to listen or ask a question. Often he would shout out instructions about time allocated for the planning and the experimenting. An example of teacher X's actions in lesson 3 body of lesson is presented as a vignette in Box 6.5. From the observations of teacher X's practice it was clear that he consistently did not guide students by question and answers and instead 'told' them what to do as part of advice on investigative practical work. To encourage students to construct their knowledge, the teacher guide advocated using questions to help students think and make decisions in their groups. The teacher also did not facilitate plan review as part of formative assessment orientation. Plan review was used to help students engage in peer assessment, which in turn encouraged self-assessment and signalled to students that they have a responsibility to think seriously about their work and not depend on teacher sanctions.

> **Box 6.5**
>
> **Lesson 3: Body of lesson (Acid strength)**
> Students had collected the apparatus, but did not begin their experiments waiting for the teacher do to something. Eventually teacher X called them to the front to weigh (he had been fiddling with an electric balance) their samples of materials (according to the plan?). Students had more than one option to plan for the solution. However, that the teacher decided to do the weighing streamlined their approach.
>
> Calling students to the front detained the teacher in one spot, and hence he could not visit groups as they carried out their work as was advised in the teacher guide. The balance also did not work well; the teacher guide advice to prepare for the lesson had been not implemented.

Conclusion

Teacher X often drew a table on the board for all the groups to enter their results. The table was used to compare and discuss the results. For all the 5 lessons the conclusion included a table of results on the board where all groups entered their results. When asked about the reasons for using the table for conclusion, the teacher said (in interview) that what he did was part of the formative assessment because he could easily see who did not get the answers correct. However, the correct answer often converged with the teacher's opinion. The advice on giving students a voice and encouraging transparency was not often observed. Analysis of observation records show that during the lesson conclusion teacher X was able to use some advice from the teacher guide to complete the lesson. From the observations it turned out that, as part of investigative practical work orientations, the teacher did not discuss possible experimental discrepancies. Accuracy is an important element in measurement; therefore students should be alert and used to. The teacher did not encourage students (groups) to decide on what format to adopt for presentation of their laboratory report. Making students think about how to communicate their results helped them be clearer about what they do. For formative assessment orientations the teacher did not remind students to evaluate results against specified assumptions. Students benefited from comparing their conclusions with their original guesses (hypotheses) so as to seek explanations for the outcome. The teacher did not encourage students to ask questions. When the teacher allows for sufficient time at the end, students are encouraged to think about their results and seek clarifications when necessary. However, teacher questioning must be open to help engage student thinking. The teacher did not ask for student opinion when responding to class questions. Encouraging students to formulate answers to peer questions helps reinforce their learning and motivates them. The teacher also did not make sure students were clear before proceeding to the next point. When students are unclear, they are afraid to ask questions because they may be exposed to lack. Often the questions they asked amount to "*I do not understand everything*," a frustrating revelation to the teacher.

Teacher Y

Lesson Introduction

Teacher Y often started the lesson on time with class explanation on what the activities would involve. These explanations included the background and discussion of the lesson objectives. An example of an introduction scenario is presented as a vignette in box 6.6.

> **Box 6.6**
>
> **Lesson 3 Lesson conclusion (Acid strength)**
> The class started on time. The teacher had already prepared the apparatus and placed them on the lab tables for students to use. The teacher, after settling the students, asked them to go into groups of 4. This was done.
>
> The teacher then informed students about the changes in the materials he would be providing them. He alerted students to the changes in the amount of carbon dioxide they would be expected to collect (the student manual asked for 500 cubic centimetres)--50 cubic centimetres. He then asked students if they had any questions before they started planning.

However, in this lesson and the subsequent lessons, the teacher consistently did not list apparatus before students completed their planning as part of the investigative practical work orientations. Apparatus are resources students should be familiar with before they make decisions about which approach to use for solving a problem. For formative assessment orientations, the teacher did not inform students about plan review. When students know what they are working towards they are likely to be more careful with their decisions and the plans they draw because of the need to have clear communication of ideas.

Body of lesson

Teacher Y often followed the teacher guide very closely. His lessons were distinct in presenting the introduction, the planning phase, and the experimenting phase. However, sometimes this co-ordination proved difficult, and groups could be observed to be doing either one or the other. Some

> **Box 6.7**
>
> **Lesson 3 Acid strength**
> Teacher Y announced at the end of the introduction that he expected the groups to keep their time, and he looked at his watch and said "We are left with about 65 minutes and I want you to make sure you use it efficiently. I suggest we take about 25 minutes planning, then if we complete before that we can go straight into experimenting. Let's use 30 minutes for experimenting and I need the rest for winding up the lesson". Teacher W moved around the groups while they were working and talked to group members as well as the whole group. Students worked seriously without any persuasion from the teacher because they competed with time. The lesson was completed with enough time to clear up and make conclusions.

groups would still be discussing their plans while others would already be carrying out experiments. Eventually, the teacher decided to be flexible and provide global timing, e.g., 25 minutes for planning and 25 minutes for experimenting. This worked, and from lesson 3 to 5 he did not need to remind students and every group seemed to complete on time. An example of teacher Y's actions at this level of the lesson is exemplified in Box 6.7.

Teacher Y was observed to implement all the teacher guide advice in at least three lessons. Observable also was the fact that the teacher began the lesson series with selective approach to some teacher guide advice. This was observed in at least the first three lessons. However, for the last two lessons of the series, the teacher was observed to be implementing in accordance with most of the expected actions in the lesson profile instrument. However, teacher Y did not facilitate plan review. Plan review was viewed as an opportunity for students to engage in peer assessment, which is integrated and preceded by self-assessment.

Conclusion

Teacher Y generally had enough time for his lesson conclusions. In lesson 4, when the students completed their experiments the lesson was still left with 20 minutes. The reason there was enough time was that most students often completed pre-lesson preparation. The teacher also had an understanding with the class that they must be settled when class time began; hence there was no wastage of time by students coming late to class. Indicative of teacher Y's approach to lesson practice, he was able to implement most of the teacher guide. However, analysis of the data recorded for teacher Y's lesson conclusion showed that he was less consistent when encouraging groups to decide what format to adopt for presentations, implementing it only in one lesson. The teacher also did not encourage students to make decisions about how they would want to present their report. Making decisions about the report was expected to give students more opportunity to engage in discussions and clarification of knowledge and result in effective learning. For formative assessment orientations, the teacher did not often encourage students to write a group laboratory report; he was only observed doing that in one lesson.

Comparing teacher X and teacher Y shows that they had similar preferences and differences in what they implemented from the teacher guide. In lesson introduction they both did not adopt the advice on listing of apparatus and informing students about peer plan review. However, they also differed, as teacher X did not adopt advice on clarifying problem questions with students as part of the introduction and discussing safety precautions. Generally teacher X's introductions did not contain any significant discussions while teacher Y always started with discussions that aimed to clarify the problem to students before they started off.

6.3.2 Perceived curriculum

Teacher perceptions were explored by analysing data from interviews collected at the end of the lesson series and logbooks the teacher kept during all of the lessons observed. The perceived curriculum was analysed by focusing on teacher perceived use of materials and teacher perceptions on the practicality of the material.

PERCEPTIONS ON USE OF THE EXEMPLARY MATERIALS

The results of the analysis of teacher logbook and teacher interview data show that all teachers have used the exemplary materials in lesson preparation, lesson execution, and assessment activities. In *lesson preparation* the materials were mainly used for guidance on how to prepare or assemble lesson materials in terms of apparatus and chemicals. Guidance on how to plan for the lesson in terms of time allocation for lesson introduction, body of lesson, and lesson conclusion, and guidelines as to what extent (with respect to the BGCSE chemistry syllabus) depth and width of the content to be covered during lesson were followed. Teacher U explained, "*The materials were able to focus what students should learn as content from the syllabus, as the lessons are based on the BGCSE chemistry objectives.*" Materials were also used as guidance on what background information may be needed and how to present it to students, and guidance on the problem to be solved and questions to use to guide students during planning and experimenting. Teacher T noted that the teacher guide "*contained almost all the materials one needed to prepare for the activities and guide during the lesson*."

In *lesson execution* teachers mainly used the materials for guidance on how to advise students during investigations, including planning and experimenting; how to use questions to establish students' readiness to the activities for the lesson problem, during introduction. Teacher U rhetorically asked, "*For example, how do I know that they are ready?*" The materials were also used as a guide of how to support students during the lesson by checking their learning and understanding. Teacher Y reflected that through the use of the teacher guide, "*I think I was able to make decisions about students understanding by observing them and asking them questions during lessons.*"

In assessment activities teachers used the exemplary materials for lesson conduct formative assessment and assessment of laboratory report. Teachers perceived the information in the teacher guide useful for making decisions about feedback from marking student lab books.

PERCEPTIONS ON PRACTICALITY OF THE EXEMPLARY MATERIALS

Analysis of teacher interview results for all teachers demonstrated that all teachers perceived the exemplary materials as supportive to their tasks of organising investigative practical work for students and carrying out formative assessment so they could be better informed about student needs and problems. Practicality was conceptualised as indicated by perceptions on clarity, congruence, complexity, and the cost of the purposes and practices that were suggested by the teacher guide.

Clarity

Teachers were clearer on what to do regarding investigative practical work than on formative assessment. Teacher T said he understood the innovation as integrating investigative work with formative assessment to involve and support students actively during the lesson. Teacher U explained that he perceived the teacher guide to be "*encouraging learner-centred approach as suggested in the BGCSE chemistry syllabus.*" Teacher Y said that his understanding was that "*I create an environment in which students can work safely and, using their minds and hands, perform investigations to find out about the problems I give them.*" However, teacher X said he understood the change in terms *of "helping students engage in practical activities, some 'hands-on' activities.*" Teacher W said he understood the innovation to be based on the BGCSE chemistry syllabus and closely related to some elements of coursework assessment. He observed that, "*I think I understood its content to be based on teaching acids and bases in a way that investigative work is promoted. Formative assessment then would be used to guide the teacher make decisions about students learning*."

Congruence

Although teachers implemented the five lessons as suggested, they perceived the practice suggested by the exemplary materials incongruent with their usual practice. Teacher X lamented, "*Generally I would say I just wish I could teach this way* (referring to the teacher guide), *but there is no time to do. In fact, this is what is expected by the BGCSE chemistry syllabus, but as you can see we are struggling to implement the piloting* (referring to piloting the BGCSE coursework assessment)." Teacher X said "*however, I believed I do some formative assessment as I make sure students leave the lesson with answers to what they did*." Asked how he made sure that happened, he said, "*We discuss the results as whole class* (this was in reference to the table of results noted during lesson observations)." Teacher Y said he liked the activities because they were effective in helping students understand what they are learning in science. He said "*but they are not what I usually do; it is not possible in our normal circumstances to implement such elaborate schemes of activities. There is no time.*"

Complexity

All teachers said the complexity of the exemplary materials was at an acceptable level. Teachers were perceived to have used the materials comfortably in their lessons. A general perception was that the materials were simple in presentation, in terms of reading and understanding and also in the format of presentation where text with similar purpose and use is indicated consistently in the same way from lesson to lesson. Teachers also perceived the format of the teacher guidebook helpful because both teacher advice and student activities were in a single source. Teacher T said, "*It is most convenient to have all that is needed in one document*." Teacher Y said, "*I have not encountered any problems using the materials, I can tell you; I often consult it very quickly and get what I want without a hassle.*" He added, "*If anything, the materials are presented in a simple format, easy to follow and use. Having all information in one source was also helpful in terms of saving time that is so scarce*." Teacher U also perceived the teacher guide advice to be adequate for lessons, adding, "*Most of the things you need are really in the teacher guide.*" Teacher X perceived the teacher guide advice to be "*accessible and user-friendly in terms of reading and locating information needed quickly*." However, sometimes some teachers also experienced challenges when they tried to translate the exemplary materials into classroom actions. Teacher U reflected, "*I do not mean it's that simple. I had to read it several times before I could make decisions about what to use. I was not familiar with the approach suggested, especially supporting students with formative assessment during the lesson.*" However, teacher W revealed that he had major challenges with understanding formative assessment. He said, "*I am still not sure about this formative assessment business, but I tried my best and I think I managed some*."

Cost

All teachers expressed some concern about the cost of implementing the innovation practice as suggested by the exemplary materials. Although all teachers were observed to have been able to implement most of the lessons using the exemplary materials advice, teachers perceived the implementation to have been achieved at some cost. Most concerns were related to the sustainability of the innovation over the long term. Teachers perceived many constraints on the school system environment in terms of focus on the examination, lack of resources and time. Teacher X reflected, "*The time I needed to prepare, and considering my teaching load, was too much*." Commenting on the apparatus and materials issues Teacher X added, "*The buying of things like the Rennies and Gaviscon tablets is not possible in this school*." Teacher W lamented, "*groups were also too many for the apparatus available for experiments, so we lack resources to implement the practice suggested in the teacher guide.*" Teacher U said the materials could help students not only learn but also understand; however, he added, "*it is possible to implement at a cost to other commitments, for example, other classes we teach*." Teacher T said he was able to implement successfully, but "*all the lessons were done with extra cost on other classes, because the amount of materials used were too much.*" Some teachers also perceived the students to have been challenged by the need to plan. Teacher U said, "*Some groups often took too much time to understand what was expected, and I tended to spend more time with them and not visiting others sufficiently.*"

Teacher U concluded his remarks by saying he feared that "*planning and reviewing plans would take most of the time, which is already limited anyway*."

6.3.3 Experiential curriculum

Data for the experiential curriculum was obtained through student interviews, which were carried out at the end of the lesson series. Students were asked about issues relating to their learning experiences with the materials, and their perceptions of the roles of the teacher, the materials and their own role. Results of the summary of all student data analyses showed that students enjoyed taking part in activities that used the exemplary materials. Students said they liked engaging in investigative work and perceived them to have been interesting. One student (from T) said, "*Doing investigations gives us the chance to work with apparatus and think about how they are used. Before, things used to happen very quickly for me when the teacher demonstrated things (experiments); I was ashamed to say I did not understand when asked if there were any questions*." Another student (from T) added, "*I enjoyed because I understood what I was doing, before I just did things.*" A girl student (from U) said, "*I was able to touch a gas syringe for the first time. I have seen it before demonstrated by the teacher at JC* (junior secondary school*), but never used it myself.*"

Student perceptions on the ability of the materials to motivate them to engage in investigative work were divided. One student (from Y) said, "*to me the problem with these lessons is that they all look the same and predictable. If you got one correct the others should follow*". She explained that what she meant was that, "*the way we carry out our problem-solving, the investigations*" and not the level of content; she perceived that to be different because most of it she had just begun to understand. On the other hand, the rest of the students who were interviewed did not agree with her view, some of them saying they actually experienced some difficulties and were challenged especially initially by the planning exercise so much that they needed the teacher to explain. Students therefore rejected the suggestion that perhaps the activities are so easy the teacher was not needed. Another (from Y) student said, "*You cannot say they are the same when the planning included different things. I felt I was always learning new things, like new apparatus, indicators and other chemicals*."

Students perceived the exemplary materials helpful to their learning and understanding. They perceived to have learned and understood some properties of acids. One student (from U) said, "*For the first time I have begun to understand what the difference between concentrated acid and strong acid and weak acid is*." Another student (from X) noted that she had learned the difference between dissolving and dissociation as they relate to concentration and acid strength, saying, "*the way we did the practical helped us understand what we were doing. Like I did not know the* *difference between concentrated acid and a strong acid; for example, at home we talk about strong tea, meaning that it has dissolved a lot of tea from tea leaves. Now I understand this is concentration not strength.*"

Students perceived they learned because the problem-solving approach made them think about what they were doing. One student (from U) said, "*Before, I only followed instructions, but planning and working in small group forced me to try to understand what I was doing.*" Students were perceived to make and take decisions in planning and experimenting. One student (from W) noted, "*You need to be clear of what you are going to do in order to make a good plan and do an experiment to solve a problem*." Another student (also from W) said, "*We also needed to know what was possible in the laboratory; we did not want to blow the lab*." Students perceived they experienced a new learning approach they had not been exposed to, in learning about the process of science. One student (from T) said, "*in these lessons we were more active. I am surprised this is the end of the lessons, we would like more. I wish our teacher continues the same way; for me it was very interesting because I want to be a scientist and I think we were behaving like scientists, investigating*."

Student interviews also showed that students perceived the role of the exemplary materials as motivating and helpful to them in what they were doing. They perceived they caused them to learn and also understand. One student (from U) said, "*The activities were interesting and made us think.*" Another student (from T) said, "*In our group we never called the teacher. He came on his own, but we understood the experiments, we never had problems*."

The role of the teacher was perceived as supportive and facilitative in setting the scene and maintaining support throughout the lesson and also evaluating the results at the end. One student (from U) commented, "*In our group … we needed to call the teacher … he came and explained.*" Another from the same group added, "*The teacher's questions made the whole group participate because we often argued about what we think he meant and these discussions involved everybody. We also discovered the answer as we discussed*." Another student (from X) said, "*The teacher helped us by giving us the problems and equipment, and we can (could) call him and ask him if we do (did) not understand.*"

Students also perceived their role as active learners. One student (from U) said, "*I think you can say we are planners and experimenters*." Another student (from W) added, "*I can say we were actively involved*". Another student (from X) said, "*we participated actively, we discussed, during prep (afternoon or evening study time) and this continued during the lesson, and we also experimented.*"

6.4 CONCLUSIONS

6.4.1 Summary

The study described in this chapter explored the practicality of exemplary materials when used to support chemistry teachers in implementing investigative practical work with formative assessment. To get insights into the practicality of the exemplary materials in lessons, the study focused on three levels of curriculum representations: operational curriculum, perceived curriculum and the experiential curriculum. The study followed a case study approach using a small number of teachers to achieve an in-depth study of the problem. The activities of the study were guided by the research question:

> *What is the practicality of exemplary materials (third prototype) that aim to support chemistry teachers in implementing an investigative practical work (learner-centred) with formative assessment in Botswana General Certificate of Secondary Education chemistry education in form 4 in Botswana?*

Analysis of lesson execution data of the level of the operational curriculum showed that all teachers used the exemplary materials in one way or the other. The teacher guide was implemented with varying degrees between teachers and across lessons, and also between teacher actions with both investigative practical work and formative assessment orientations. The results show that implementation according to teacher guide advice for investigative practical work orientations was higher in the body of the lesson compared to lesson introduction and lesson conclusion phases of the lessons, while for formative assessment orientations implementation was higher in lesson conclusion compared to lesson introduction and body of lesson.

Data analyses for the perceived curriculum showed that teachers used the materials for advice on lesson preparation, lesson execution, and post-lesson assessment activities. Teachers generally were perceived to have used the materials in preparing activities for student investigative practical work and also for formative assessment purposes. On the practicality of the materials in lessons, teachers perceived more clarity on investigative practical work activities than formative assessment activities. Although teachers implemented the lessons with most of the teacher guide advice, they perceived some problems related to congruence between the practice suggested by the exemplary materials and their usual practice. Teachers perceived the complexity of the materials as of an acceptable level; nevertheless, the cost of using the innovation was a major issue of concern for all teachers. Problems were perceived in terms of the time teachers needed to prepare for the lessons and the lack of resources they experienced in terms of apparatus and frustrations with having to deal with many groups, which raises doubts about the sustainability of the innovation in the long term.

Students were perceived to have experienced enjoyment when participating in lessons with activities from the exemplary materials. They also were perceived to have learned and understood subject content and science processes in terms of the investigation procedure. Students perceived the role of the exemplary materials as providing them with problems that helped them think and learn. The role of the teacher was perceived as facilitative in helping students understand the problems they had to solve. The teacher was also perceived as facilitative because he provides students with apparatus to use to solve the problems. Students perceived themselves as active participants in learning.

6.4.2 Support for teachers' implementation of investigative practical work and formative assessment

The teacher guide stimulated teachers to engage students in investigative practical work and formatively assessing students to guide them. All teachers used the materials for their lesson preparation, lesson conduct, and post-lesson assessment activities to support implementation of investigative practical work and formative assessment activities. In lesson execution teachers used the exemplary materials for ideas on how they could guide students throughout the lesson in planning and experimenting. In post lesson activities the exemplary materials were used by teachers to provide support for assessing lab reports and how to deal with the feedback from student work. Teachers were also observed using the exemplary materials in the lessons. However, the results of the observation of lesson activities showed that in using the exemplary materials, teacher actions veered more towards investigative practical work (investigative practical work) than formative assessment (formative assessment). This is consistent with the shift teachers may have experienced from their usual practice to the approach suggested in the teacher guide. Teachers who needed to make bigger shifts often tended to emphasise 'hands-on,' exemplified by teachers Y and Z, and less the learner-centred and formative assessment orientations. However, teachers who had to make a relatively smaller shift often succeeded in promoting some level of learner-centeredness and formative assessment orientations in their lessons.

Within the investigative practical work orientations of the lesson, it was also observed that teachers generally tended to focus more on actions that reflected the body of lesson activities than on lesson introduction and lesson conclusion. Most actions that promoted the scores for the body of the lesson were also more on classroom management than on learner-centeredness. This shows the dilemma between facilitating and controlling. Teachers found it easier to adopt actions that gave them control than those that helped learners act with some independence. However, in the formative assessment, focus of application tended to be on the conclusion phase of the lesson. Focusing on the body of the lesson in the investigative practical work and on conclusion in the formative assessment may indicate the teacher's perception of the learner-centred approach being to let students 'do their own thing'. However, formative assessment emphasis on the conclusion could be an indication of a dilemma in trusting students to achieve meaningful learning when not closely sanctioned. Teachers tended to focus on bringing out the 'correct' answer in the conclusion stage, to be sure learning had taken place in terms of clarity with content. Teacher approach was also aimed at establishing accountability measure in banking information.

6.4.3 Practicality of the exemplary teacher support materials

Teachers who participated in the implementation of the study perceived the practicality of the exemplary materials in their lessons feasible but not sustainable in the long term. Teacher perception of clarity showed that they were clearer about the investigative practical work purposes of the innovation than the formative assessment purposes. Teachers still needed more help in clarifying and exemplifying the innovation as both investigative practical work and the formative assessment practices. Although teachers were observed to be able to implement according to most of the teacher guide advice, they still perceived the practice suggested by the exemplary materials in the teacher guide incongruent to their usual practice. The practice of most teachers showed more investigative practical work orientation than formative assessment orientation. However, although teachers still needed more help with creating conditions that facilitate learner-centred teaching approaches, the exemplary teacher support materials caused them to make a small shift in practice towards learner-centred approach through active involvement of students. The exemplary materials may need to be strengthened in areas where they are meant to advise on students 'planning' and 'conclusion' activities.

Most teachers were able to read and translate the approach suggested in the teacher guide into practices in lessons. From the observed classroom practices it was clear teachers were able to guide students through the experimenting stage of the lesson and also that groups often followed a plan. Although most lessons were implemented adequately, time management, as evidenced by lack of proper conclusions, was a limiting factor. The materials may need to provide more advice on how time can be managed and still get students to learn meaningfully.

CHAPTER 7
Discussion

In this final chapter the findings of the study are discussed. After a recapitulation of the research problem and approach (7.1), the major results are summarised (7.2). These results are discussed in section 7.3, and a reflection on the roles played by the researcher is included in section 7.4. In section 7.5 conclusions are drawn and recommendations are formulated.

7.1 RECAPITULATION OF THE RESEARCH PROBLEM AND APPROACH

Since 1998 Botswana has been implementing a learner-centred science curriculum in senior secondary schools. The Botswana General Certificate of Secondary Education (BGCSE) science curriculum is based on the format of the British GCSE science curriculum, in which a learner-centred instructional approach is promoted. In the chemistry syllabus this is exemplified through investigative practical work together with formative assessment of student work.

Before 1998, science teachers in Botswana used the Cambridge Overseas School Certificate (COSC) science curriculum, in which learner-centeredness was not a main focus. As a consequence, the implementation of a more learner-centred instructional approach in the science curriculum is a major innovation in teaching and learning science in Botswana. With the aim of helping science teachers overcome the problems of changing their classroom practice to more learner-centred instructional approaches, curriculum materials composed of teacher advice and student activities were considered necessary. A basic assumption was that, especially during the initial stages of implementing a curriculum change, lesson materials that are exemplary of the intended curriculum change can:

- provide theoretical background information on the meaning of the change;
- demonstrate the practical meaning of the intended change (through procedural specifications);
- provide potential users with opportunities to experiment with exemplary activities to get insight into the consequences of the change for their classroom practice;
- provide a frame of reference for the intended educational change and stimulate discussions among teachers who are using the materials.

In September 1999, this study was initiated to investigate the characteristics of curriculum materials that could be used to support teachers in the implementation of formative assessment of investigative practical work in science education. The study focused on the design, development, and formative evaluation of the exemplary materials for Form 4 classes of the senior secondary school BGCSE chemistry syllabus. The study was guided by the following research question:

> *How can exemplary curriculum materials support senior secondary chemistry teachers in Botswana with the implementation of formative assessment of students' investigative practical work?*

In order to answer this question, a development research approach was applied. This approach was characterised by a cyclic iteration of design, development, and formative evaluation activities. The study as a whole consisted of three related phases.

The first phase was composed of:

- a front-end analysis consisting of a context study and analysis of the problem (both reported in chapter 2) and a comprehensive literature review in the area of science curriculum reform, learner-centred practice, investigative practical work, and formative assessment (reported in chapter 3);
- a formulation and refinement (based on an expert appraisal) of design specifications for exemplary curriculum materials, based on the literature review and the context analysis;
- a development of a first prototype of the exemplary curriculum materials and their appraisal by experts and teachers for validity (reported in chapter 4).

The second phase consisted of the development of a second prototype (based on expert and teacher appraisal findings) and a try out of this prototype in a limited number of sites. In the try out, the research instruments to be used during the third phase of the study were also piloted (reported in chapter 5).

In the third and final phase (reported in chapter 6), a third prototype was developed based on suggestions for revision derived from the try out. The prototype consisted of a teacher guide and student materials. Next, a field test was conducted in three senior secondary schools. Lesson observations using a curriculum profile instrument were conducted to collect data on the operational curriculum. Teacher logbooks were used and interviews were conducted to collect data on the perceived curriculum. Experiential data were collected from students via interview schedules.

7.2 SUMMARY OF THE MAIN FINDINGS

The summary of results presented in this section is based upon the final field test. These data are considered the most relevant to summary and discussion because they provide insights to the practicality of the last prototype of the exemplary materials.

Perceived curriculum

Teacher perceptions on the practicality of the exemplary materials referred to their clarity, congruence, complexity, and cost. With regard to these dimensions teachers reported that:

- they developed clarity of the exemplary curriculum materials and their intended practice;
- the intended practice, as represented by the exemplary curriculum materials, was incongruent with their current practice;
- the level of complexity of the exemplary curriculum materials was within their reach in terms of understanding how to translate the lesson plans into lesson activities and use them practice;
- in terms of the cost, implementation of the suggested learner-centred practice was possible within the limitations of available resources in the science laboratories. However, teachers perceived cost as a possible limiting factor especially in sustaining their motivation to change their practice.

Operational curriculum

Investigative practical work was more prominently visible in classroom practice than in formative assessment. The following patterns emerged.

First, in the investigative practical work orientation, the intention was to use the materials to guide teachers in organising resources, preparing students for the topic of the lesson, and guiding students during their practical work activities. Observed teacher activities, as regards investigative practical work, that were in line with the intended change included brainstorming exercises during lesson introduction, and attempts to help students think about the investigation in terms of planning and safety implications. However, teachers did not adequately engage students in 'inquiry thinking'. Instead, they tended to readily volunteer details about what students were expected to do during the experimenting stage. Specifically, teachers often provided groups with information on what procedures to follow and what equipment to use, contrary to the advice to allow students to make decisions themselves on experimental procedure and on what equipment to use. Therefore, in general, the lessons tended to be stronger on 'hands-on' and weaker on 'minds-on' experiences.

Second, teachers were not often observed to demonstrate the formative assessment orientations in terms of asking questions related to helping students to reflect critically on results they expected, activities they carried out, and results they obtained. Instructional advice on formative assessment was intended to help teachers guide students in making predictions about their work, in making decisions on what scientific knowledge was necessary for making choices about what resources to use and what evidence to look for during the experimentation. Teacher questions and questioning techniques during brainstorming activities tended to require more recall of information than engagement of students in inquiry thinking processes, in which the teacher could make decisions about the level of student understanding of conceptual and procedural knowledge. Correct answers were easily accepted and incorrect answers readily dismissed. Limited questioning as opposed to telling was also characteristic of the body of lesson phase. During planning and experiment stages, questioning and teacher guided discussions were limited in most lessons. Teachers were often observed to resort to instructing students on what they ought to do as opposed to providing support for students to think through their activities.

Third, teacher use of investigative practical work was more frequent in the body of the lesson (where students were supported with questions and probes to participate actively in planning and experimenting) than in the lesson introduction and lesson conclusion. In the body of the lesson, teachers were observed to move from group to group and to discuss activities with each group when necessary. In line with the intentions of the support materials, teachers also allowed students to work in their groups with limited advice or without unnecessary interventions. When teachers moved from one group to another, they asked questions and offered advice when asked. In contrast, lesson introductions tended to be rushed and lesson conclusions ran out of time and also ended up being rushed or not made at all.

Fourth, it was observed that some teachers had not read the teacher guide well, and as such, had not made adequate pre-lesson preparations. As would be expected with such a lack of adequate preparation, teachers were observed to frequently fail to follow the teacher guide, resulting in poor lessons. On the other hand, teachers who had their lessons prepared and ready at the start of the lesson tended to follow most of the teacher advice, resulting in good lessons. In addition, as was expected, in well-planned lessons there was often sufficient time for proper lesson conclusion.

Experiential curriculum

Students participated actively in the lessons. Student active participation also showed that they enjoyed the lessons, especially during lesson introduction when they actively took part in question and answer sessions with the teacher, as well as during the body of lesson when they were involved in planning and experimenting. Interviews showed that students also learned subject-specific knowledge and process knowledge in terms of investigation procedures.

7.3 DISCUSSION OF THE FINDINGS

7.3.1 Investigative practical work in practice

The central question in this study required investigating *how* exemplary curriculum materials composed of advice on teacher and student activities could support teachers in implementing formative assessment of investigative chemistry practical work. The quality of the curriculum materials designed and developed was investigated by examining their practicality for teachers and students. The conception of practicality - in terms of the four dimensions (4Cs): clarity, congruence with their practice, level of complexity, and cost implications - is in line with teachers' *practicality ethic* (Doyle & Ponder, 1977-78). The following patterns emerged.

The mismatch between how teachers perceived the intervention and the way they implemented the exemplary materials suggests that they had false clarity about the intended change. This might be due to the fact that the innovation exemplified in the materials was more complex and less congruent with their teaching practice than teachers thought at first sight. However, it is also conceivable that teachers provided the interviewer with socially desirable answers when reporting that they developed clarity of the materials and their intended practice.

In operationalising the curriculum, lessons tended to be more focused on 'hands-on' experiences than on 'minds-on' experiences. 'Hands-on' was mainly embodied in the 'practical work' component of investigative practical work. In promoting practical work teachers tended to put most effort in supporting the experimenting phase of the lessons at the expense of the accompanying activity of planning, which involved 'minds-on' (the 'investigative' component of investigative practical work). This contrasted the exemplary curriculum materials intended to support teachers in implementing a more learner-centred classroom practice in which both 'hands-on' and 'minds-on' would be equally promoted. So, as it was mostly characterised by 'hands-on' practical work, in this respect the observed classroom practice was less a learner-centred process than intended. The characteristics of a learner-centred classroom practice are that students be supported in: (i) planning and designing their activities, (ii) performing or implementing their plans and designs, (iii) carrying out analysis and interpretation of the results, and (iv) applying the knowledge they acquired as a result of taking part in investigative practical work (Lunetta, 1998). As regards the observed classroom practice, in relation to the implementation of investigative practical work, it is apparent that emphasis was placed on performing or implementing their plans and designs. Application of knowledge was limited, perhaps due to time constraints, especially in the lesson conclusion. In typifying the practice followed by most teachers, the model of Gott and Duggan (1995) shows that emphasis was placed on practical skills and procedural understanding at the expense of clear facts and conceptual understanding. Both processes are needed to get students to engage in cognitive processes that enhance their ability to solve problems (see chapter 3). Perhaps a more interesting question is why teacher actions seemed selective in implementing more practical work than embracing investigative practical work. One explanation could be that practical work, with its greater emphasis on 'hands-on,' was a more likely choice of emphasis over the more 'minds-on' investigative practical work in teacher practice because it was more congruent with their current practice. Another possible explanation is that teachers considered it more important that their students be engaged in 'hands-on' rather than 'minds-on' activities, e.g. because of constraints imposed by (still less innovative) examination demands.

Throughout most lessons, and especially in the lesson introduction, the facilitative role of the teacher was more limited than promoted in the teacher guide. In the lesson introduction and also during planning of the experiment by students, teachers were expected to play a bigger role in facilitating student reflections intended to promote 'minds-on' experience. The finding that the teachers' facilitative role fostered by the materials did not live up to its promise might be due to the fact that classroom practice is dominated by 'teaching to the examination'. The major influence of examinations is not surprising. In Botswana, as in most other countries, assessment and examination procedures serve as the cutting edge in teacher practice. When teaching to the examination, teachers often become preoccupied with completing the syllabus, which emphasises transmission of knowledge. Therefore, (sticking to) adopting a dominant role helped the teacher stay in control of the pace of lesson activities.

It could also be argued that the teacher's dominant role was (also) attributable to the way advice in the teacher guide was presented. Considering the rather traditional (i.e. teacher-centred) implementation context, the teacher guide deliberately contained statements on intended teacher actions only. Such a format and style, it was reasoned, would have a greater potential to relate the intended innovation to the teachers' zone of proximal development (Lazarowitz & Miller, 1992; van den Akker, 1994; Vygotsky, 1978). However, this might have led teachers to believe that they had to be in control of the lesson, limiting student involvement to 'hands-on' experiences. If so, it implies that the way investigative practical work support was structured to present the facilitative role of the teacher might have put teachers somewhat on the wrong track. Concerning problems related to the conclusion phase of the lesson, failure to conclude properly could be attributed to lack of time at the end of the lesson. This would seem a clear lack of proper planning for the lesson.

From the way lessons were run, it was evident teachers had not read and use the teacher guide to prepare for their lessons. Teachers who had not sufficiently prepared tended to be unaware of the details about the lessons. This was clear from the confusion that reigned in some lessons in terms of equipment not working or student lack of appropriate background knowledge-information that could be found in the teacher guide. This is a surprising outcome, because it contrasts with teachers' reported perceptions about the intervention, in which they claimed clarity, understanding of its incongruence, complexity, and cost implications in relation to their practice and context. This mismatch throws doubts on teachers' claims of having clarity, understanding incongruence, complexity, and cost implications. Evidence for the lack of reading was also apparent in the lack of preparedness and apparent uncertainty by some teachers about the essential steps to follow in implementing well-organised investigative practical work. If there was any reading of the teacher guide, it was a surface reading just before the lesson. Failure to read materials could be due to time constraints or to poor time management.

7.3.2 Formative assessment in practice

The exemplary materials also aimed to support teachers in monitoring how well students learned in the investigative practical work lessons. The purpose of assessment was formative, in guiding the remedial support of students during the lesson, and summative, in evaluating how well students learned in relation to the objectives of the lesson. In line with the teacher guide advice on formative assessment, most teachers started lessons with question and answer activities to focus student attention on important elements of the new lesson and making connections with the previous lesson. Lesson introduction was generally condensed into a set of instructions by the teacher (see 7.3.1). However, for a couple of cases in which adequate attention was paid to lesson introduction, formats of formative assessment used in the lesson introduction varied between teachers. While some teachers used brainstorming with only question and answer activities, at least one became more innovative by using short quizzes followed by class discussions. However, the majority of questions asked by most teachers in all the phases of the lessons did not encourage much thinking and could be labeled as recall type (for example, "What acids do you know?" and "What is the test for acids?").

Most of the formative assessment was observed during the body of lesson. The formative assessment script used by teachers in the body of lesson included observing what students did and asking students probing questions to help them reflect on their class activities. This type of assessment was also formative because it was informal and provided immediate feedback. Most of the teacher activities in this phase of the lesson consisted of supporting student work by asking them questions and encouraging them to discuss amongst each other. This approach - which was effective and interesting for students - was in line with the intentions of the teacher guide and had potential to (Black, 2001):

- help individual students develop their own models of learning;
- develop the capacity of the class as a whole to function as a community of learners.

These two statements serve as central to the constructivist theory of learning, on which the concept of learner-centeredness is premised. To achieve this, students were expected to engage in self and peer assessment. Self assessment can partly be assumed to take place when students reflect on their work. However, although a simplified approach to supporting and monitoring self and peer assessment was provided as part of formative assessment teacher guide, classroom practice for most teachers did not encourage self and peer reflection. Instead, the tendency of some teachers was to readily provide answers to student questions and compromise student opportunity to think deeply and reflectively about their activities.

In general, formative assessment was poorly done in the lesson conclusion. To compensate, teachers often provided students with instructions to make conclusions part of their homework. Teachers provided their students with homework, not only because homework was part of the teacher guide, but also because contextual constraints required a clear record of student achievements to be provided. Due to time pressure, teachers often skipped the suggestions in the teacher guide for in-class conclusion of lab report homework. This made the majority of the assessment outcomes during lesson conclusion summative. However, the expectation that the results of the lab report summative assessment would be available before a new lesson was not often easy to meet. Due to large classes, marking could not be completed in cases where the lab classes were on consecutive days. Therefore, this form of formative assessment was often limited in providing both teachers and students with feedback. This proved to be a major weakness because feedback is a defining element in formative assessment (Black & William, 1998).

Poor formative assessment in practice could also be attributed to the extent to which the teacher guide provided support in implementing it. The field test findings show that the formative assessment support offered by the exemplary materials was not as adequate as intended. Although not expected at the start of the study, this conclusion does not come as a complete surprise, for two reasons. The first reason is that, in dealing with formative assessment during the iterative design, development and formative evaluation of the exemplary materials, it appeared harder than envisaged to find a proper balance between innovative ambitions conveyed in the BGCSE curriculum as regards formative assessment (of investigative practical work), operationalisations and exemplifications of this concept derived from the extensive literature review, and the rather traditional, teacher-centred and examination-oriented secondary science education setting in Botswana. Nevertheless, it is fair to say that the study has provided more insights on how to translate the concept of formative assessment in terms of teacher and student activities, in a context with many obstacles hindering the implementation of such a complex innovation. The second reason is that it is not realistic to expect exemplary materials alone to be sufficient in supporting teachers in implementing formative assessment (of investigative practical work). Teachers needed to read and discuss the exemplary materials composing the intervention. Without taking time to read and reflect on the intervention, there is little chance that understanding of change would be realised. To achieve this purpose the exemplary materials needed to be embedded in in-service education.

7.4 REFLECTIONS ON RESEARCH APPROACH

7.4.1 Teacher involvement in the development research approach

In science curriculum reform, the role of the teacher is (considered) crucial (Davis, 2003; Gunstone, 1996; Schneider & Krajcik, 2002; van den Akker, 1988). In line with this view, this study aimed at the iterative design, development, and formative evaluation of exemplary teacher support materials fostering a more learner-centred teaching approach, characterised by formative assessment of investigative practical work, in Form 4 chemistry classes in Botswana. The support materials, consisting of a teacher guide and accompanying student materials, are meant to exemplify and operationalise the intended BGCSE chemistry curriculum. In designing and developing these materials a development research approach was applied, with continuous involvement from the side of experts, teachers, and students. The special involvement of teachers in the design and development process was considered crucial as it could promote teacher ownership and voice.

However, getting teachers involved in the study was not an easy job. In a context where teachers feel the only way they can achieve better results is if the whole syllabus has been covered in preparation for the examination, there is often no room for outsiders. Gaining access in this study presented challenges in terms of the need to follow a 'hierarchy of consent', whereby the school administration had to grant permission, and leave the researcher to negotiate with teachers. More often than not teachers rejected any intrusion into their classrooms. Vulliamy (1990) reports of a similar experience and further notes that it "can lead to resentment, which can only be overcome by researchers through careful management of the researcher's role" (p. 40). In the end, some teachers accepted the invitation to participate in the study, while others declined. The situation was not helped by the fact that the proposed intervention, although falling within the syllabus the teachers taught, did not have the usual pressure to implement from the side of the ministry of education.

Access was also limited by physical geography. Therefore, the final choice of schools to participate was determined largely by such practicalities as travel distances as well as the willingness of the teachers to participate. In this study, it was evident that Botswana teachers were concerned with completing overloaded syllabuses, lack of equipment, uncertainty about the change itself, and the lack of clarity of what the contributed activities could make to achievement in national examinations.

7.4.2 The role of designer-researcher

Development research tends to involve the researcher in the role of both designer-developer and evaluator-researcher. Combining both roles often proves to be difficult because the tasks are not only challenging but also have the potential to present conflicting role demands. It is therefore essential that in both roles constant vigilance be exercised on what role one is playing at a particular time. This is important because (Lewin, 1990):

- the act of investigation changes that which is investigated. That is, observers, participants, or otherwise, cannot fail to influence what they see.
- unpredictable events will open up avenues of enquiry that were not anticipated. Educational policies may change, institutions may become more or less open, and chance meetings may create opportunities for deeper levels of insight into past events.

In this study the situation was made more challenging by the position of the researcher as the sole designer-developer and evaluator-researcher. When this happens, Putnam and Borko (2000, p. 13) argue for working towards transparency: "Rather than pretending to be objective observers, we must be careful to consider our role in influencing and shaping the phenomena we study. This issue is obvious when individuals take on multiple roles of researchers, teachers, teachers of teachers."

To address this delicate role balance, several checks and balances were built into the research process by involving others as a means of promoting quality standards, in terms of trustworthiness (Krathwohl, 1998; Miles & Huberman, 1994; Yin, 1994). In order to strengthen trustworthiness several measures were taken: (i) data collection methods and instruments were guided by a theoretical framework based on an extensive analysis of relevant state-of-the-art knowledge; (ii) triangulation of research methods (observation, interviews and logbook keeping) was applied; (iii) data collection followed a standard procedure; and (iv) design and research activities were documented as well as possible. Along with the research process, researcher actions evolved from a greater emphasis on the role of the designer-developer to an even greater emphasis on the role of evaluator-researcher. First, initial design specifications were compiled from a context analysis (reported in chapter 2) and literature review (reported in chapter 3). The initial design specifications were then used to develop a first prototype of the exemplary materials (reported in chapter 4). Next, a panel of science educationist was requested to carry out an expert appraisal of the first prototype in order to validate it against the BGCSE chemistry syllabus and state-of-the-art knowledge. This expert appraisal exercise led into revisions of the first prototype resulting in a second prototype. The second prototype was used in the try out. The try out was used to explore the practicality of the intervention composed of teacher advice and student lesson materials in limited sites (three schools). Formative evaluation during the try out involved the use of a classroom profile to observe teacher practice during lessons as well as post lesson interview protocols for teachers and students. At the same time, it was a pilot of the research instruments to be used during a final field test. The try out provided the researcher with necessary information to make revisions, resulting in a third prototype draft. A further check for accuracy of revisions against the expert advice was carried out on this draft by a panel of expert appraisers. This appraisal resulted in finer revisions, resulting in a third prototype of the exemplary product that was used in a final field test (reported in chapter 6).

7.5 CONCLUSIONS AND RECOMMENDATIONS

7.5.1 Quality and role of the exemplary curriculum materials

Change is often difficult and complex. Attempting change in the context of limited resources, time, and uncertainty can be a daunting task. Changes in teacher practice that can only be addressed by policy revision or major allocation of resources are often not easy to influence in the short term. However, it is often possible and desirable to support teacher change in adjusting their teaching repertoires with the aim of optimising the teaching and learning processes. With this in mind, and specifically basing on experiences from this study, recommendations are possible about how the exemplary curriculum materials could be made more effective. The following paragraphs present conclusions about how the exemplary materials were used and recommendations about how their potential could be improved (in addition to suggestions for improvement already made in sections 7.3.1 and 7.3.2).

Teachers who participated in the study showed that they were at different zones of proximal development in terms of their classroom practice concerning learner-centeredness. This was indicative of their uncertainty when attempting to implement. It is evident that most were still coming to terms with promoting student 'hands-on' experience. To overcome this challenge, teachers would need to learn to use new teaching approaches which involve the use of new curriculum materials and change their beliefs about how their students learn (Fullan, 2001; McLaughlin & Mitra, 2001). A holistic approach to curriculum implementation should also be followed to add impetus to the intended change. Holistic approach means avoiding fragmentation or atomisation of the concepts of investigative practical work and formative assessment. Since classroom dynamics make it difficult to separate investigative practical work from formative assessment, it is only sensible that while implementing in small incremental steps, both investigative practical work and formative assessment have to be promoted equally. This would reduce uncertainty on the part of the teachers concerning what needs to change. One area still lagging behind in the change process is the implementation of new assessment procedures that would require classroom practice, including formative assessment of investigative practical work. A more incremental approach that includes 'hands-on' with some parts focusing on 'minds-on' is needed. This would be different from the present study intervention approach, which sought to promote substantial content and skills with, 'hands-on' and 'minds-on' equally. Time is needed to achieve such purposes of the exemplary curriculum materials.

Most teachers did not prepare their lessons and showed poor management of time and resources. In order for the objectives of the syllabus to be achieved while addressing problems of large classes, preparation and management of time and resources is a necessity. Poor management also resulted in implementation that tended to concentrate on some sections of the lesson at the expense of others. In order to overcome this challenge, it is recommended that the exemplary materials also contain support on basic classroom practice such as management of time and resources, also emphasising adequate preparation. Management of class activities is a basic requirement in teacher practice and adequate pre-lesson preparation forms an indispensable element in the formula.

Teachers were overwhelmed by the amount of change they were expected to undertake in a limited period. As a result, teachers experienced cognitive overload due to the coupling of formative assessment and investigative practical work. This tended to raise the complexity and hence to widen the teachers' uncertainty about the intervention. To reduce this apparent cognitive overload, it is recommended that comprehensive developments of complete intervention composed of investigative practical work and formative assessment be maintained, but implementation through small steps. This approach would contrast what was followed in the study, where the learner-centred approach (as characterised by formative assessment of investigative practical work) was promoted as complete packages. With the intention still to promote formative assessment of investigative practical work, various permutations that target different parts of the learner-centred practice can be followed. The results of the study have shown that different parts of the lesson presented the teachers with different challenges. For example, lesson implementation varied in terms of lesson introduction, body of lesson, and lesson conclusion. Initially, paying particular attention to each phase while maintaining the holistic approach of coupling formative assessment and investigative practical work may reduce cognitive overload. Implications for such adaptations to the design of the exemplary materials are skills development, for example questioning, and giving feedback skills. This would allow time for the teachers to reflect on what they do. In this way assessment issues such as lab reporting could be explored significantly.

Teachers also had problems with formulating and using questions and comments meant to elicit reflection on the part of the students. To encourage teachers to use appropriate questioning techniques that would support efforts to achieve purposes of formative assessment, it is recommended that questioning techniques be made an essential part of the exemplary materials.

Reducing the cognitive overload in the way just mentioned and adding questioning techniques are some of the ways to improve the supportive potential of the exemplary materials. Other measures to be considered include the following:

- Presenting teacher advice on investigative practical work in such a way that the teacher focuses on one area of investigation, e.g., planning for an experiment and providing enough time to reflect on emergent issues such as addressing student questions and difficulties. In this way the teacher would be able to consolidate the facilitative role (see also section 7.3.1).
- Presenting teacher advice on formative assessment in such a way that each phase of the lesson (lesson introduction, body of lesson, and lesson conclusion) is distinctively explained and the teacher is warned about any challenges students are likely to meet, and how to go about addressing them (see also section 7.3.2).
- Embedding the exemplary materials in an in-service program, as the materials alone are not sufficient to support teachers in implementing the intended curriculum reform. In-service education should provide teachers with opportunities to interact with the materials. It should help teachers by providing a forum for clarifications of theory, for demonstration and practice of the intended change as exemplified in the materials, and for giving feedback on how much is being achieved in terms of understanding the change. Embedding the materials in an in-service program also has the potential to address the problems associated with teachers' tendency to ignore reading the teacher guide. To promote this purpose, such in-service program would include assignments to read and discus details of the intervention. Short and targeted in-service education has the potential to give teachers opportunities to widen their scope of professionalism in terms of the curriculum change intended.

7.5.2 Implementing formative assessment of investigative practical work in Botswana

The design specifications for exemplary materials to support teachers in implementing the intended curriculum change are based on formative assessment of investigative practical work, as recommended in the BGCSE chemistry curriculum. Although innovative practices in the form of learner-centred classroom practice are desirable and intended in the curriculum change, chemistry teachers in Botswana are also expected to help students perform well in the national examination. This has created a gap between policy intentions and actual teaching practice. To reduce this gap it is necessary to implement the change as intended in the BGCSE curriculum by changing teaching approaches and assessment procedures. Alternatively, the curriculum policy may also need to be changed to align more closely with what is realistic in the context. To achieve these purposes, teachers would need time to work with the suggested practice and reflect on its impact in their classroom practice. An important restriction, however, is that lesson time allocation in the school timetable is rarely alterable. As a consequence, the curriculum reform should be such that it can be put into practice within the allocated, and limited, amount of time. Time may be saved by reducing the amount of teacher and student activities to be covered and by focusing more on specific skills and concepts. Both require high levels of teacher commitment to change as well as clarity of the intended change. Therefore, overall attention to planning and time allocation is necessary to support teachers in implementing the curriculum change successfully.

Another, even more important prerequisite is the already mentioned embedding of the exemplary materials in an in-service education program. Such an embedding of the exemplary curriculum materials was not considered as part of the study because of lack of resources and time. Embedding the intervention in an in-service education programme is strongly recommended as it may provide teachers with opportunities to get a clearer picture of the intended curriculum change as exemplified in the materials, to prepare and conduct lessons using the materials, and to discuss their perceptions of and experiences with the teacher and student activities suggested, with guidance from external support. However, for such an in-service program to be effective other elements also need to be in place, including a realignment of policy and practice to work towards a more realistic implementation in the context. Also, to achieve any significant change, the adoption and implementation of the curriculum policy in schools science departments are also prerequisites. This requires adequate resources and time. A holistic curriculum implementation is more likely to compel teachers to implement a more learner-centred instructional approach characterised by formative assessment of investigative practical work.

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English summary

Supporting chemistry teachers in implementing formative assessment of investigative practical work in Botswana

Background and research question

Since 1998 Botswana has been implementing a learner-centred science curriculum in senior secondary schools. The Botswana General Certificate of Secondary Education (BGCSE) science curriculum is based on the format of the British GCSE science curriculum in which a learner-centred instructional approach is promoted. In the BGCSE chemistry syllabus this is exemplified through investigative practical work together with formative assessment of student work.

Before 1998 science teachers in Botswana used the Cambridge Overseas School Certificate (COSC) science curriculum in which learner-centeredness was not a main focus. As a consequence, the implementation of a more learner-centred instructional approach in the science curriculum is a major innovation in teaching and learning science in Botswana. With the aim of helping science teachers overcome problems of changing their classroom practice to more learner-centred instructional approaches, curriculum materials composing teacher advice and student activities were considered necessary. A basic assumption was that, especially during the initial stages of implementing a curriculum change, lesson materials that are exemplary of the intended curriculum change can: (i) provide teachers with theoretical background information on the meaning of the change; (ii) demonstrate for teachers the practical meaning of the intended change (through procedural specifications); (iii) provide teachers with opportunities to experiment with exemplary activities to get insight into the consequences of the change for their classroom practice; (and (iv) provide teachers with a frame of reference for the intended educational change and stimulate discussions among teachers who are using the materials.

With the assumption that exemplary curriculum materials have the potential to serve as an effective support for teachers implementing an innovative curriculum reform, this study was initiated in September 1999. Its aim was to investigate the characteristics of BGCSE exemplary curriculum materials (consisting of a teacher guide and students' materials) meant to support teachers in the implementation of formative assessment of investigative practical work in Form 4 upper secondary chemistry classes in Botswana. The study was guided by the following research question:

> *How can exemplary curriculum materials support senior secondary chemistry teachers in Botswana with the implementation of formative assessment of student investigative practical work?*

RESEARCH DESIGN

In order to answer this question, a development research approach was applied. This approach was characterized by a cyclic iteration of design, development, and formative evaluation activities. The study consisted of three related phases.

The first phase consisted of: (i) a front-end analysis consisting of a context study, an analysis of the problem, and a comprehensive literature review in the area of science curriculum reform, learner-centred practice, investigative practical work, and formative assessment; (ii) the formulation and refinement, based on an appraisal by three experts, of design specifications for exemplary curriculum materials, derived from the literature review as well as the context analysis; (iii) the development of a first prototype of the exemplary curriculum materials and their appraisal by four experts and three teachers for validity. The exemplary materials focused on the senior secondary pure chemistry topic of 'Acids, Bases, and Salts'.

The second phase consisted of the development of a second prototype (based again on an appraisal of four experts and three teachers) and a trial of this prototype in half class lessons in a limited number of sites. In the trial the research instruments to be used during the third phase of the study were also piloted.

The third and final phase involved the development and field test of a third prototype. Its development was based on implications for revisions derived from the trial. The field test was conducted in three senior secondary schools. Lesson observations using a curriculum profile instrument were conducted to collect data on the operational curriculum. Teachers' logbooks were used and interviews were conducted to collect data on the perceived curriculum. Experiential data were collected from students via interview schedules.

RESULTS

The final field test resulted in the following main findings.

Teachers' perceptions on the practicality of the exemplary materials *(perceived curriculum)* referred to the clarity, congruence, complexity, and cost implications of the curriculum materials. With regard to these dimensions, teacher interview results showed that: (i) they had clarity of the exemplary curriculum materials and their intended practice; (ii) they understood the intended practice as represented by the exemplary curriculum materials to be incongruent with their current practice; (iii) they understood the level of complexity of the exemplary curriculum materials to be within their reach in terms of ability to translate the lesson plans into lesson activities and use in practice; and (iv) they understood the cost implications of implementing the suggested learner-centred practice as feasible in the context of their science laboratories.

Investigative practical work was more prominently visible in classroom practice than formative assessment *(operational curriculum).* The following patterns emerged:

- In general, the lessons tended to be more 'hands-on' than 'minds-on'. Teachers engaged students in brainstorming exercises during lesson introduction, and made attempts to help students think about the investigation in terms of planning and safety implications, but they did not adequately engage students in 'inquiry thinking'. Contrary to the advice to allow students themselves to make decisions on experimental procedure and choices about what equipment to use, teachers often provided students with most information on what procedures to follow and what equipment to use.
- Teacher support of student activities showed that they used investigative practical work more during the body of the lesson than in either lesson introduction or lesson conclusion. Lesson-introductions tended to be rushed and lesson-conclusions ran out of time and also ended up being rushed or not made at all.
- Teachers had not read the teacher guide well in time and as such did not often make adequate pre-lesson preparations. Teachers who had their lessons prepared and ready at the start of the lesson tended to follow most of the teacher guide. This resulted in good lessons in terms of implementing the procedural specifications in the teacher guide.
- Teachers did not often demonstrate formative assessment orientations in terms of asking questions related to helping students reflect critically on results they expected, activities they carried out, and the results they obtained.

Students *(experiential curriculum)* participated actively in the lessons for all teachers, indicating that they enjoyed the lessons. Their answers to interview questions showed that they also learned subject specific knowledge and process knowledge in terms of investigation procedures.

DISCUSSION

The study originated from the need to design an intervention (in terms of exemplary curriculum materials) that could help upper secondary chemistry teachers in Botswana change their classroom practices from teacher-centred to more learner-centred instructional approaches through formative assessment of investigative practical work encouraging both 'hands-on' 'and minds-on' students' involvement in learning. The following patterns emerged as regards to how formative assessment of investigative practical work was put into practice.

As regards *investigative practical work* it seems that teachers developed false clarity about the intended change. This can be inferred from the mismatch between how they perceived the intervention and the way they implemented the exemplary materials. The occurrence of false clarity might be due to the fact that the innovation exemplified in the materials was more complex and less congruent with their teaching practice than teachers thought at first sight. Another explanation might be that teachers gave socially desirable answers when reporting that they developed clarity of the materials and their intended practice.
Lessons tended to be more focused on 'hands-on' experiences than on 'minds-on' experiences. 'Hands-on' was mainly embodied in the 'practical work' component of investigative practical work. So, in this respect, the observed classroom practice was less learner-centred than intended. In formulating an answer to the question of why teachers implemented more practical work than embraced investigative practical work, two explanations are possible. The first is that practical work, with more emphasis on 'hands-on', was a likely choice of emphasis over the more 'minds-on' investigative practical work because it was more congruent with their existing teaching practice. The second is that teachers considered it more important for their students to be engaged in 'hand-on' rather than 'minds-on' activities, e.g. because of constraints imposed by (still less innovative) examination demands.
Throughout most lessons and especially in the lesson introduction the facilitative role of the teacher was more limited than promoted in the teacher guide. This finding might be due to the fact that classroom practice is dominated by 'teaching to the examination'. It can also be argued that the teachers' dominant role was (also)

attributable to the way advice in the teacher guide was presented. Considering the rather traditional (i.e. teacher-centred) implementation context, the teacher guide deliberately contained statements on intended teacher actions only. Such a format and style, it was reasoned, would have more potential in relating the intended innovation to the teachers' zone of proximal development. However, this might have led teachers to believe that they had to be in control of the lesson, limiting student involvement to 'hands-on' experiences.
From the way lessons were run it was evident teachers did not often read and use the teacher guide to prepare for their lessons. Teachers who had not sufficiently prepared tended to be unaware of the details about the lessons. This is a surprising outcome, because it is in contrast with the teachers' reported perceptions about the intervention, in which they claimed clarity, understanding of its incongruence, complexity, and cost implications in relation to their practice and context. This mismatch throws doubts on teacher claims of having clarity, understanding incongruence, complexity, and cost implications.

Most of the *formative assessment* was observed during the body of the lesson. The formative assessment script used in the body of the lesson by teachers included observing what students did and asking students probing questions to help them reflect on their class activities. This type of assessment was also formative because it was informal and provided immediate feedback. Most of the teacher activities in this phase of the lesson consisted of supporting student work by asking them questions and encouraging them to discuss among each other. This approach - which was effective and interesting for students - was in line with the intentions of the teacher guide. In general, formative assessment was poorly done in the lesson conclusion. To compensate, teachers often provided students with instructions to make conclusions part of their homework. Teachers provided their students with homework not only because homework was part of the teacher guide, but also because contextual constraints required a clear record of student achievements to be provided. Due to time pressure teachers often skipped the suggestions in the teacher guide for in-class conclusion of lab report homework. This made the majority of the assessment outcomes during lesson conclusion summative.
In general, formative assessment was poorly practiced. This could partly be attributable to the extent to which the teacher guide provided support in implementing it. The field test findings show that the formative assessment support offered by the exemplary materials was not as adequate as intended. Although not expected at the start of the study, this conclusion does not come as a complete surprise, for two reasons. The fist reason is that, in dealing with formative assessment during the iterative design, development and formative evaluation of

the exemplary materials, it appeared harder than envisaged to find a proper balance between innovative ambitions conveyed in the BGCSE curriculum as regards formative assessment (of investigative practical work), operationalisations, and exemplifications of this concept derived from the extensive literature review, and the rather traditional, teacher-centred and examination-oriented secondary science education setting in Botswana. Nevertheless, it is fair to say that the study has contributed to providing more insights into how to translate the concept of formative assessment in terms of teacher and student activities in a context with many obstacles hindering the implementation of such a complex innovation. The second reason is that it is not realistic to expect exemplary materials alone to be sufficient in supporting teachers in implementing formative assessment (of investigative practical work). Teachers needed to read and discuss the exemplary materials composing the intervention. Without taking time to read and reflect on the intervention there is little chance that understanding of change would be realized. To achieve this purpose the exemplary materials needed to be embedded in in-service education.

RECOMMENDATIONS

Considering the findings of the study, some conclusions can be drawn about how the exemplary materials were used, based on which recommendations can be formulated about how their potential could be improved.

Teachers who participated in the study were overwhelmed by the amount of change they were expected to undertake in a limited period. As a result, they experienced cognitive overload due to the coupling of formative assessment and investigative practical work. This tended to raise the complexity and hence to widen their uncertainty about the intervention. To reduce this apparent cognitive overload, it is recommended that comprehensive developments of complete intervention composed of investigative practical work and formative assessment be maintained, but that the implementation be made through small steps. This approach would contrast what followed in the study, where the learner-centred approach (as characterised by formative assessment of investigative practical work) was promoted as complete packages. With the intention still to promote formative assessment of investigative practical work, various permutations that target different parts of the learner-centred practice can be followed.

Teachers also had problems with formulating and using questions and comments meant to elicit reflection on the part of the students. To encourage teachers to use appropriate questioning techniques that would support efforts to achieve purposes of formative assessment, it is recommended that questioning techniques be made an essential part of the exemplary materials. Reducing the cognitive overload in the way just mentioned and adding questioning techniques are some of the ways to improve the supportive potential of the exemplary materials. Other measures to be considered include the following:

- presenting teacher advice on investigative practical work in such a way that the teacher focuses on one area of investigation, e.g., planning for an experiment and providing enough time to reflect on emergent issues such as addressing student questions and difficulties. In this way the teacher would be able to consolidate the facilitative role;
- presenting teacher advice on formative assessment in such a way that each phase of the lesson (lesson introduction, body of lesson, and lesson conclusion) is distinctively explained and the teacher is warned about any challenges students are likely to meet and how to go about addressing them;
- embedding the exemplary materials in an in-service program, as the materials alone are not sufficient to support teachers in implementing the intended curriculum reform. In-service education should provide teachers with opportunities to interact with the materials. It should help teachers by providing a forum for clarifications of theory, for demonstration and practice of the intended change as exemplified in the materials, and for giving feedback on how much is being achieved in terms of understanding the change. Embedding the materials in an in-service program also has the potential to address the problems associated with teachers' tendency to ignore reading the teacher guide. To promote this purpose, such an in-service program would include assignments to read and discuss details of the intervention. Short and targeted in-service education has the potential to give teachers opportunities to widen their scope of professionalism in terms of the curriculum change intended.

NEDERLANDSE SAMENVATTING
Ondersteuning van scheikundedocenten bij de invoering van formatieve toetsing bij onderzoekspractica

ACHTERGROND EN ONDERZOEKSVRAAG

In 1998 is in Botswana een leerlinggericht natuurwetenschappelijk ('science') curriculum voor het voortgezet onderwijs ingevoerd. Dit zogenaamde Botswana General Certificate of Secondary Education (BGCSE) science curriculum bouwt voort op het Engelse GCSE science curriculum waarin een leerlinggerichte benadering wordt benadrukt. In de BGCSE syllabus ligt het accent in het bijzonder op onderzoekspractica en formatieve toetsing. Tot 1998 werd in Botswana gebruik gemaakt van het Cambridge Overseas School Certificate (COSC) science curriculum dat niet uitging van een leerlinggerichte benadering. De invoering van een meer leerlinggerichte benadering was dan ook een grote innovatie voor science leerkrachten. In de ondersteuning van docenten bij de omschakeling naar een meer leerlinggerichte lespraktijk bleek er behoefte te bestaan aan curriculummateriaal met voorbeeldactiviteiten voor leerlingen en advies voor de organisatie ervan door docenten. Een basisaanname, gebaseerd op eerder onderzoek, was dat dergelijk lesmateriaal, met name gedurende de initiële implementatiefase, een drietal functies zou kunnen vervullen: (i) verschaffen van theoretische achtergronden over de aard en betekenis van de vernieuwing; (ii) ondersteunen van docenten bij het in de praktijk brengen van de vernieuwing door het verschaffen van gedetailleerde aanwijzingen (procedurele specificaties), en (iii) geven van suggesties voor voorbeeldactiviteiten waarmee docenten kunnen experimenteren met de vernieuwing en zo inzicht krijgen in implicaties van de vernieuwing voor de praktijk.

Het doel van dit onderzoek, dat in september 1999 van start ging, was het exploreren van kenmerken van voorbeeldlesmateriaal ter ondersteuning van docenten bij de implementatie van formatieve toetsing bij onderzoekspractica. Het voorbeeldlesmateriaal zou moeten bestaan uit een docentenhandleiding en leerlingmateriaal. Het onderzoek richtte zich op het vierde leerjaar van het voortgezet scheikunde-onderwijs in Botswana. De volgende onderzoeksvraag stond centraal:

> *Hoe kan voorbeeldlesmateriaal scheikundedocenten in het voortgezet onderwijs in Botswana ondersteunen bij de implementatie van formatieve toetsing in de context van onderzoekspractica?*

ONDERZOEKSOPZET

Om de onderzoeksvraag te beantwoorden is een ontwerpgerichte onderzoeksbenadering gehanteerd. Deze benadering wordt gekenmerkt door een voortdurende wisselwerking tussen ontwerp- en evaluatie-activiteiten. Het onderzoek bestond uit drie fases. De eerste fase bestond uit: (i) een contextanalyse en een literatuurstudie naar de drie centrale concepten van het onderzoek, te weten leerlinggericht onderwijs, onderzoekspractica en formatieve toetsing; (ii) het formuleren van ontwerpspecificaties op basis van uitkomsten van de contextanalyse en het literatuuronderzoek, en het aanscherpen ervan door middel van een expertevaluatie, en (iii) het ontwikkelen van een eerste versie van het voorbeeldlesmateriaal en de beoordeling ervan door vier experts en drie docenten. Het voorbeeldlesmateriaal richtte zich op het onderwerp 'Zuren, basen en zouten'. De tweede onderzoeksfase bestond uit het ontwikkelen van een tweede versie van het voorbeeldlesmateriaal en een beproeving van dit prototype in een klein aantal scholen. De laatste onderzoeksfase besloeg de ontwikkeling van een derde versie van het voorbeeldlesmateriaal, op basis van uitkomsten van de beproeving, en evaluatie in de praktijk. Het veldonderzoek werd uitgevoerd op drie scholen en bestond uit lesobservaties met behulp van een curriculumprofiel, interviews met docenten en leerlingen, en logboeken voor docenten.

RESULTATEN

Uit het veldonderzoek (fase drie) kwamen de volgende bevindingen naar voren. Uit interviews met docenten bleek dat:

- het voorbeeldlesmateriaal en de beoogde didactische benadering duidelijk was voor de leerkrachten;
- de beoogde vernieuwing in hun ogen niet goed paste bij hun huidige lespraktijk;
- ze het niet te moeilijk vonden om de lesvoorstellen uit te voeren in de praktijk;

- ze van mening waren dat de invoering van de voorgestelde leerlinggerichte benadering met de beschikbare middelen in hun practicumlokalen uitvoerbaar was.

Uit de lesobservaties kwamen de volgende resultaten naar voren:

- De geobserveerde onderzoekspractica hadden meer het karakter van 'hands-on' dan 'minds-on' science. Docenten betrokken leerlingen weliswaar bij brainstormactiviteiten aan het begin van les en zetten hen aan om na te denken over de planning van de practica en te nemen veiligheidsmaatregelen, maar stimuleerde hen onvoldoende om zelf onderzoekend te werk gaan. Ondanks het uitdrukkelijk advies om leerlingen zelf te laten beslissen over hoe het experiment op te zetten en uit te voeren en welk practicummateriaal daarbij te gebruiken, voorzagen de docenten leerlingen vaak van de nodige aanwijzingen en informatie.
- De onderzoekspractica vonden vooral in het middendeel van de lessen plaats. Aan het begin en eind van de lessen werd er nauwelijks aandacht aan besteed. Tijdgebrek verhinderde docenten vaak samen met de leerlingen conclusies te formuleren aan het eind van lessen.
- De docenten hadden de docentenhandleiding niet van tevoren gelezen en waren derhalve vaak onvoldoende voorbereid. De docenten die hun lessen wel grondig hadden voorbereid volgden grotendeels de aanwijzingen in docentenhandleiding.
- Voorzover formatieve toetsing plaatsvond had het niet het karakter van leerlingen aanzetten kritisch na te denken over de verwachte resultaten, uitgevoerde activiteiten en behaalde resultaten. Formatieve toetsing vond voornamelijk in de kern van de lessen plaats. Docenten observeerde de practica en stelden vragen om leerlingen te laten reflecteren op de activiteiten die ze uitvoerden en moedigden hen aan om met elkaar te discussiëren. Dit type toetsing kan als formatief worden beschouwd, omdat het informeel is en onmiddellijk voorziet in feedback. Deze aanpak was in overstemming met de aanwijzingen in de docentenhandleiding. In het slot van de lessen waren elementen van formatieve toetsing echter nauwelijks terug te vinden. Wegens tijdgebrek negeerden de docenten regelmatig de suggestie uit de docentenhandleiding om de uitkomsten van de practica met de leerlingen te bespreken. In plaats daarvan kregen leerlingen vaak de opdracht als huiswerk een practicumverslag te maken.

Leerlingen namen actief deel aan de lessen en gaven aan dat ze de lessen met plezier hadden gevolgd. Ze waren van mening dat de lessen hen in staat hadden gesteld om vakinhoudelijk kennis op te doen en onderzoeksvaardigheden te ontwikkelen.

DISCUSSIE

Het onderzoek is ontstaan uit de behoefte een interventie te ontwerpen (in de vorm van voorbeeldlesmateriaal) ter ondersteuning van scheikundedocenten bij de invoering van een meer leerlinggerichte aanpak, en in het bijzonder van formatieve toetsing bij onderzoekspractica. Bij docenten lijkt er sprake te zijn van schijnduidelijkheid ('false clarity') over deze beoogde vernieuwing. Er was een groot verschil tussen percepties van docenten omtrent formatieve toetsing en onderzoekspractica en de feitelijke uitvoering ervan in de klas. Docenten waren van mening dat de vernieuwing helder en uitvoerbaar was, maar in de praktijk bleek dat ze slechts enkele kenmerken van de vernieuwing realiseerden. Het zou kunnen dat docenten sociaal-wenselijke antwoorden gaven op de vraag of de mate waarin de vernieuwing helder en uitvoerbaar was. Dit blijkt ook uit het feit dat docenten de docentenhandleiding zelden gebruikten bij de voorbereiding van de lessen. Leraren waren zich hierdoor niet bewust van de details van de lessen en de vernieuwing die daarin centraal zou moeten staan.

De geobserveerde onderzoekspractica hadden meer het karakter van 'hands-on' dan 'minds-on' science-onderwijs. Hiervoor zijn twee mogelijke verklaringen te geven. Allereerst zouden docenten voorkeur kunnen hebben voor 'hands-on' practica, omdat dit type practica meer overeenkomt met hun eigen onderwijspraktijk. Daarnaast zouden leraren het belangrijker kunnen vinden om leerlingen te betrekken bij 'hands-on' activiteiten, omdat deze activiteiten benadrukt worden in het centraal eindexamen.

Tijdens vrijwel alle lessen, en met name aan het begin van de lessen, speelden docenten een meer sturende (en minder begeleidende) rol dan gesuggereerd in het voorbeeldlesmateriaal. De lessen waren derhalve minder leerlinggericht dan beoogd. Dit zou kunnen komen door de dominante invloed van het eindexamen en de noodzaak die docenten voelen om zo snel mogelijk alle examenstof aan de orde te stellen. Anderzijds kan ook de vormgeving van de docentenhandeling een rol hebben gespeeld. Uitgaande van de tamelijk traditionele ('teacher-centred') onderwijspraktijk was ervoor gekozen om in de handleiding alleen aanwijzingen voor het handelen van de docent op te nemen. Dit kan de leraren echter op de gedachte hebben gebracht dat zij de regie moesten voeren en dat de inbreng van leerlingen zich zou moeten beperken tot 'hands-on' activiteiten.

Over het algemeen werd formatieve toetsing maar nauwelijks geïmplementeerd in de praktijk. Dit zou deels toegeschreven kunnen worden aan de mate waarin de docentenhandleiding ondersteuning verleende bij het invoeren ervan. Uit het veldonderzoek bleek dat het voorbeeldlesmateriaal docenten onvoldoende ondersteuning bood op dit punt. Hiervoor zijn twee mogelijke verklaringen te geven. Ten eerste bleek het in het ontwerpproces moeilijker dan gedacht om een goede balans te vinden tussen de innovatieve ambities van het BGCSE curriculum wat betreft formatieve toetsing en onderzoekspractica en de tamelijk traditionele, teacher-centred en examengerichte onderwijssetting in Botswana. Desalniettemin heeft het onderzoek tot meer inzicht geleid in de wijze waarop formatieve toetsing vormgegeven kan worden in een context met veel randvoorwaarden die de invoering van zo'n complexe innovatie belemmeren. Ten tweede is het niet realistisch te verwachten dat voorbeeldlesmateriaal alleen voldoende is om docenten te ondersteunen bij de invoering van formatieve toetsing bij onderzoekspractica. Docenten hebben tijd nodig om het voorbeeldmateriaal te lezen en te reflecteren op de vernieuwing die daarin centraal staat, en de implicaties van de vernieuwing voor de praktijk te doordenken en bespreken. Wanneer ze hier niet expliciet de tijd voor nemen, zoals het geval was in dit onderzoek, kan niet verwacht worden dat docenten een goed begrip van de vernieuwing ontwikkelen. Verankering van het voorbeeldlesmateriaal in een nascholingsprogramma is daarom wenselijk.

AANBEVELINGEN

Op basis van de onderzoeksbevindingen kunnen de volgende aanbevelingen worden geformuleerd wat betreft de aard van de voorbeeldmaterialen. De omvang van de vernieuwing was tamelijk overweldigend voor docenten. Met name de koppeling van formatieve toetsing aan onderzoekspractica resulteerde in een grote mentale overbelasting ('cognitive overload'). Dit vergrootte de complexiteit en daardoor tevens hun onzekerheid over het invoeren van de vernieuwing. Om deze mentale overbelasting zoveel mogelijk te beperken zou de implementatie van formatieve toetsing van onderzoekspractica meer stapsgewijs moeten plaatsvinden. De koppeling van formatieve toetsing aan onderzoekspractica zou daarbij gehandhaafd moeten worden, maar het voorbeeldlesmateriaal zou slechts op enkele aspecten van beide gericht moeten zijn.

Docenten waren niet goed in staat om leerlingen door middel van vragen aan te zetten tot reflectie. Omdat dergelijke vragen een belangrijk onderdeel vormen van formatieve toetsing, wordt aanbevolen meer aandacht te besteden aan vraagtechnieken in het voorbeeldlesmateriaal. Het terugdringen van de mentale belasting en het toevoegen van vraagtechnieken zijn twee manieren waarop de ondersteunende taak van het voorbeeldlesmateriaal kan worden verbeterd. Andere maatregelen die kunnen worden overwogen zijn:

- De aanwijzingen voor docenten voor het organiseren van onderzoekspractica zo presenteren dat docenten zich richten op één aspect van het onderzoek, bijvoorbeeld de planning van een experiment, en voldoende tijd overhouden om zich te richten op belangrijke zaken zoals het beantwoorden van vragen van leerlingen en het oplossen van problemen. Zo zou de docent zijn faciliterende rol kunnen versterken.
- De aanwijzingen voor docenten zo aanscherpen dat de rol van formatieve toetsing in de verschillende fasen van een les (inleiding, kern, slot) duidelijker naar voren komt en docenten weet hebben van mogelijke problemen die leerlingen kunnen ervaren en manieren waarop deze verholpen kunnen worden.
- Het voorbeeldlesmateriaal verankeren in een nascholingsprogramma, aangezien de materialen alleen niet voldoende zijn om docenten te ondersteunen bij het invoeren van een complexe curriculumvernieuwing. Dit programma zou de docenten moeten voorzien van: (i) theoretische achtergronden: (ii) een demonstratie van de beoogde vernieuwing; (iii) de mogelijkheid om te oefenen met het uitvoeren van de vernieuwing aan de hand van het voorbeeldlesmateriaal, en (iv) feedback op de mate waarin elementen van de vernieuwing gerealiseerd zijn in de praktijk. Een nascholingsprogramma waarin docenten het voorbeeldlesmateriaal gebruiken en bediscussiëren zorgt er ook voor dat docenten de docentenhandleiding voldoende bestuderen. Een dergelijke nascholing kan ervoor zorgen dat docenten hun professionaliteit op het terrein van de beoogde curriculumvernieuwing kunnen verruimen.

APPENDIX A1
Topic analysis

Acids, bases and salts

Specific objectives	Skills and processes being trained	Suggested activity	Resources needed
Define an acid as a hydrogen ion, H^+ donor. Define a base as a hydrogen ion, H^+ acceptor. Describe the meaning of weak and strong acids and alkalis. *Investigate the properties of strong and weak acids (CC)**	▪ Application of pre-knowledge of reaction rates, ▪ Follow instructions, ▪ Safe handling of apparatus and chemicals, ▪ Observation, recording, ▪ Use of variables (*volume, mass, concentration, surface area, strength*) and ▪ Draw conclusions.	**Activity 1** **Compare the strengths of some dilute acids**. In Davies, L. et al. (1976). Investigating chemistry. London: Heinemann. Pp. 79-81.	Worksheet, test tubes, measuring cylinder, 2 mol dm^{-3} solutions of hydrochloric, nitric, and ethanoic acids, magnesium ribbon and solutions of methyl orange and litmus.
*Investigate the properties of strong and weak alkalis (CC)**	▪ Application of pre-knowledge of reaction rates, ▪ Follow instructions, ▪ Safe handling of apparatus and chemicals, ▪ Observation, recording, ▪ Use of variables (*volume, mass, concentration, surface area, strength*) and ▪ Draw conclusions.	**Activity 2** Use the same procedure as for acids in Davies, L. et al. (1976). Pp. 79-81.	Worksheet, test tubes, measuring cylinder, dilute solutions of potassium hydroxide, sodium hydroxide, calcium hydroxide and ammonia solution, magnesium ribbon and solutions of methyl orange and neutral litmus.
	▪ Follow instructions, ▪ Safe handling of apparatus, ▪ Measurement, ▪ Observation, ▪ Recording and ▪ Drawing conclusions.	**Activity 3** **To Investigate how acids and alkalis affect indicators**. In Davies, L. et al. (1976). Investigating chemistry. London: Heinemann. Pp. 72-73 & 77.	Worksheet, test tubes, distillation condenser, round-bottom flask, retort stand and gauze, white tile (or filter paper), teat pipette, spatula, 100 cm^3 beakers, dilute solutions of hydrochloric, nitric, and sulphuric acids, tartaric or citric acid, sodium hydroxide, potassium hydroxide, calcium hydroxide and ammonia; brightly coloured petals, pestle and mortar, ethanol or propanone, solutions of methyl orange, neutral litmus, and phenolphthalein.

Specific objectives	Skills and processes being trained	Suggested activity	Resources needed
	▪ Application of pre-knowledge on indicators and acids, ▪ Follow instructions, ▪ Safe handling of apparatus and chemicals, ▪ Measurement, ▪ Observation, ▪ Recording, ▪ Analysis of data by comparison against a standard, and ▪ Draw conclusions	**Activity 4** **To show how a universal indicator can detect the pH of a solution**. In Davies, L. et al. (1976). Investigating chemistry. London: Heinemann. Pp. 81-82.	Worksheet, test tubes, commercial universal indicator solution, home made indicator (developed in the last activity), a range of solutions of known pH, common household materials such as bleach, toothpaste, detergents etc., deionised or distilled water.
Explain the difference between strength and concentration. Investigate the effect of acids and alkalis on indicators such as methyl orange, universal indicator and litmus.	▪ Follow instructions ▪ Safe handling of apparatus and chemicals, ▪ Observation, ▪ Recording, ▪ Testing of gases (hydrogen and carbon dioxide) ▪ Drawing conclusions	**Activity 5** **To investigate the behaviour of acids with (i) metals, (ii) carbonates and bases**. In Davies, L. et al. (1976). Investigating chemistry. London: Heinemann. Pp. 73-75 & 84-86.	Worksheet, rack of test tubes, Bunsen burner, dilute acids: hydrochloric, sulphuric, nitric, and tartaric or citric acids; metals: zinc, iron, magnesium and copper; carbonates: sodium carbonate, sodium hydrogen carbonate, calcium carbonate, etc; Bases: copper (II) oxide, Calcium Oxide, etc; alkalis: sodium hydroxide, potassium hydroxide, calcium hydroxide and ammonia solutions. Titration apparatus, phenolphthalein, 0.1 mol dm-3 solutions of sodium hydroxide and hydrochloric acid.
Describe pH as a measure of the degree of acidity or alkalinity of a solution. Determine the pH of a solution using universal indicator.	▪ Follow instructions ▪ Safe handling of apparatus and chemicals, ▪ Observation, ▪ Recording, ▪ Testing of gases (ammonia gas) ▪ Drawing conclusions	**Activity 6** **To investigate the action of alkalis on ammonium compounds**. In Davies, L. et al. (1976). Investigating chemistry. London: Heinemann. p. 79.	Worksheet, test tubes, Bunsen burner, test-tube holder, spatula, teat pipette; ammonium chloride, solution of sodium hydroxide.
*Investigate (including equations) the characteristic properties of acids in reactions with metals and bases (including alkalis and carbonates) (CC)** *Test for and identify hydrogen and carbon dioxide (CC)**	▪ Follow instructions ▪ Safe handling of apparatus and chemicals, ▪ Observation, ▪ Recording, ▪ Evaluate observations ▪ Drawing conclusions	**Activity 7 (a-d)** **Methods of preparing salts**: In Davies, L. et al. (1976). Investigating chemistry. London: Heinemann. Pp. 91-92 (acid on metal); Pp. 93 (acid on insoluble base); P. 84 (acid on alkali); P. 95 (Reaction of two salts – precipitation).	*Acid + Metal*: Worksheet, beakers, Bunsen burner and tripod stand, crystallizing dish, measuring cylinder, filter-funnel and filter paper, access to fume cupboard, iron filings and sulphuric acid, goggles). *Acid + Insoluble base*: Copper (II) oxide and apparatus as above. *Acid + Alkali*: 25 cm^3 or 10 cm^3 pipette, burette and stand, funnel, white tile, two 250 cm^3 beakers, a conical flask. Phenolphthalein indicator, 0.1 mol dm^{-3} solutions of sodium hydroxide and hydrochloric acid. *Salt +Salt*: Teat pipette, measuring cylinder, 100 cm^3 beaker, filter funnel and filter paper. 1 mol

Specific objectives	Skills and processes being trained	Suggested activity	Resources needed
			dm^3 solutions of sodium chloride and lead (II) nitrate.
*Investigate the characteristic properties of bases in reactions with ammonium salts [including reaction equations] (CC)**	▪ Solve problems ▪ Evaluate outcome ▪ Suggest improvements.	**Activity 8** Preparation of pure lead sulphate from a variety of possible of salts.	Samples of salts such as sodium chloride, sodium carbonate, lead (II) chloride, lead (II) nitrate, lead carbonate, magnesium carbonate and sulphuric acid.
	▪ Follow instructions ▪ Safe handling of apparatus and chemicals, ▪ Observation, ▪ Recording, ▪ Evaluate observations ▪ Drawing conclusions	**Activity 9** Tests to identify ions	Worksheet, test tubes, corked test-tube with a delivery tube, sodium hydroxide, ammonium hydroxide, silver nitrate, barium chloride, limewater, litmus paper and potassium manganate (VII) paper.
Give applications of acid/base reactions in daily life, e.g., treatment of indigestion, treatment of acidic soils, brushing teeth with toothpaste. Classify oxides as acidic, basic neutral or amphoteric *Prepare soluble salts from acid/base, acid/metal reactions (CC)** *Prepare insoluble salts by precipitation (CC)** *Purify salts by filtration and crystallization (CC)**			
Suggest a method of preparing a given salts from suitable starting materials, given appropriate information (CC)*			
Conduct tests for the following ions: Cu^{2+}, Fe^{2+}, Fe^{3+}, Zn^{2+}, NH_4^+ *(CC)*, Ca^{2+} *and* Al^{3+} *(EC)***; SO_4^{2-}, Cl^-, CO_3^{2-}, *(CC)**			

Note: * CC stands for core content, **EC stands for extended content.

APPENDIX A2
Practical work problem activities

LESSON 1 ACIDS, ALKALIS AND INDICATORS

Background
Acids and bases have characteristic properties by which they can be identified. A simple way is by using indicators. Indicators are substances that change colour depending on whether they are in acidic or alkaline solution. Colour changes such as these take place at different concentrations with different indicators. Table 1 shows how various indicators change colour in the presence of acids and alkalis.
In this activity you will be required to plan and carry out experiments of your plan to solve the problem.

The problem
You are given solutions X, Y and Z. One is an acid, one is an alkali and one is a solution of the indicator phenolphthalein. You are not told which is which. Carry out the following activities:

What to do
(a) Plan tests which will enable you to find out which solution is which. Your plan will involve making mixtures of X, Y and Z.
(b) Carry out the plan you made for this experiment and identify solutions X, Y and Z.
(c) For your homework, make a report of what you did.

LESSON 2 WHAT IS THE SOLUTION?

Background Information
Acidic and alkaline solutions can be classified as strongly acidic/alkaline and weakly acidic/alkaline. The 'strong' description of an acid or alkali solution refers to the ability of the acid or alkali to readily release (dissociation) hydrogen ions (H^+) into aqueous solution. The 'weak' description of acid/alkali refers to the incomplete dissociation of the acid/alkali into the solution. A solution of hydrochloric acid is strongly acidic while ethanoic acid is weakly acidic. A solution of sodium hydroxide is strongly alkaline while ammonia solution is weakly alkaline.

The problem
You are given solutions A, B, C, D and E. They are solutions of acids, alkalis, and water. You are not told which is which. You have choice of indicators (solutions or paper): litmus, methyl orange, phenolphthalein and universal indicator.

What to do

(a) Think up a scheme and plan for identifying which solutions are strongly and weakly acidic; strongly and weakly alkaline or neutral. You may not use any other reagents. For guidance use the 'planning for an investigation' scheme in fig. 1.
(b) Carry out the experiment you have planned for solving this problem.
(c) For your homework make a report of what you did.

LESSON 3 STRENGTH OF AN ACID

Background information

When dilute hydrochloric and ethanoic acids are each reacted with magnesium ribbon, the hydrochloric reaction is faster than the reaction of ethanoic acid. The reason is that, hydrochloric acid has more hydrogen ions (H^+) in the acidic solution while ethanoic has less. Thus, in hydrochloric acid nearly all the acid molecules break up to form ions. Hydrochloric acid solution is called a *strong acid*. However, in ethanoic acid solution, only some of the acid molecules form ions, so it is called a *weak acid*. The strength of an acid can be expressed by pH values.

The problem

'Hydrochloric acid is a strong acid and ethanoic acid a weak acid'. You are asked to show your understanding of what is meant by this statement through a set of experiments that demonstrate properties of both a weak acid and a strong acid.

What to do

(a) Make a complete plan of activities you will use to demonstrate the statement. In planning use the list of apparatus provided to guide you in developing scientific investigations designs.
(b) Implement your plan as a laboratory experiments, collect and record your results.
(c) For your homework write report of what you did.

LESSON 4 ACIDS AND CARBONATES

Background information

Chalk is a form of calcium carbonate. Another form of carbonate is limestone. The blackboard chalk is not pure carbonate. It also contains calcium sulphate. Carbonates react with acids to give salt and water and releases carbon dioxide gas:

Carbonate + Acid ➔ Salt + Water + Carbon dioxide

The problem

You are provided with chalk (a carbonate) and dilute hydrochloric acid and an array of apparatus at your disposal to plan and carry out an experiment to collect 500 cm^3 of carbon dioxide gas produced.

What to do

(a) Make a plan for an experiment you would carry out to Collect 500 cm^3 of carbon dioxide using suitable apparatus.
(b) Carry out the activity of your plan and record your results and make conclusions.
(c) For your homework make a report of what you did.

LESSON 5 COMPARING INDIGESTION

Background information

Hydrochloric acid solution in a very dilute form is needed in our stomachs for digesting food. However, too much of it often leads to indigestion. Indigestion is a biological condition that results in high levels of acid in the stomach. Acid indigestion can be a major physiological discomfort for most people. We suffer from acid indigestion when there is more acid in our stomach than what is usually necessary for digestion.

To cure indigestion, you must neutralise the excess acid with a drink of sodium hydrogen carbonate solution (baking soda), or an acid indigestion tablet such as Rennies, Gaviscon mixture, Eno, etc that we can buy over the counter from. Thus, the cure for acid indigestion is typical reaction of acids and carbonates.

The problem

There is a dispute to settle about which acid indigestion remedy is more effective. You are approached as the knowledgeable chemical analyst to help in solving the dispute. Your task in this activity is to compare the effectiveness of three remedies for acid indigestion. That is, which indigestion remedy efficiently does the job of neutralizing the acid?

What to do

(a) Plan an activity to solve this problem. In planning activities for your laboratory analysis, use the scheme in fig. 1 and the list of available apparatus to guide your designs.
(b) Carry out the activities in your plans to find out if your plans give you expected results.
(c) For your homework make a report of what you did.

APPENDIX A3
Teacher interview protocol

The students' activities in this lesson series are intended to implement lab lessons in which students engage in learner-centred activities.

1. What is your opinion on these lessons in relation to supporting a learner-centred practice?
2. What do you think about the consistency between the students' activities and the BGCSE chemistry syllabus content that you teach?
3. What would be the benefits and challenges (or problems) of implementing the activities in your normal classes?
4. In what ways could the teacher guide help you in running students activities in lab classes in which the students' activities are used?
5. Do you have any additional comments you would like to make inn relation to making the teacher guide more helpful to your class practice? What advice would you like to have?

APPENDIX A4
Expert interview protocol

Note: Getting interview with experts proved to be difficult. So the following questionnaire was used:

This note is accompanied by a set of materials including:
The Field-Test research design guidelines
Exemplary curriculum on acids and bases based on the Botswana General Certificate of Secondary Education (BGCSE) chemistry syllabus in Botswana. These include (i) students' problem manual and (ii) Teacher-Guide book.
Research instruments including (i) teacher interview, (ii) students' interview, (iii) teacher logbook and (iv) Curriculum profile (User profile observation schedule.

My request is that you help me review/appraise the documents in (b) and (c) for consistency with the design guidelines in document (a): Field-Test Design. To guide the appraisal, the following questions can be used:

Is there consistency between items (in any of the documents:
- Curriculum Profile observation schedule (CPO),
- Teacher-Interview schedule (TI),
- Students-Interview schedule (SI)&
- Teacher-Logbook (TL)) on one hand and the
- Teacher Guide (TG) and
- Student Investigative Problems (SIP) on the other?

Are the various items in each document specific enough to convey the intentions of the developer to establish the level of practicality?
To what extent are the activities in a document (especially the CPO) topical for FA of IPW in LC design as exemplified by the TG support materials and the SIP?
Please use questions 1-3 above to make comments on the materials enclosed.

APPENDIX A5
Curriculum profile

A	Learner-centred *formative assessment* of investigative practical work	IPW/ FA	√/×	Critical incidents
Introduction	1. The teacher **discusses background of the problem**.	**IPW**		
	2. The teacher discusses the instructions of the activity to **clarify the problem question with students**.	**IPW**		
	3. The teacher **distributes problem sheets** and gives practical instructions.	**IPW**		
	4. The teacher **discusses objectives of lesson** with students.	**IPW**		
	5. The teacher **discusses the stages of the investigation** with a rough guide to time for each stage. [*Where applicable*]	**IPW**		
	6. The teacher **lists available apparatus** for students to choose what they decide they need.	**IPW**		
	7. The teacher **groups students for activities** they would do in the investigations.	**IPW**		
	8. The teacher **discusses safety precautions** aspects for the particular investigation.	**IPW**		
	9. The teacher **guides students through question/answer** session to help students to determine their readiness to the activity.	**FA**		
	10. The teacher **informs students about plan review** (*as a means of achieving peer assessment*).	**FA**		

Legend: √ denotes **yes** the action is observed; × denotes **not** observed.

B	Learner-centred formative assessment of investigative practical work	IPW/ FA	√/×	Critical incidents
Body of lesson	*1.* Teacher **uses effective groups of 2-4** students.	**IPW**		
	2. Teacher moves round groups as they start planning, and **encourage students' approach** to the problem.	**IPW**		
	3. Teacher moves round groups assisting with the planning if (or necessary) called, guides **by questions and not "telling".**	**IPW**		
	4. Teacher moves round groups and **encourages group collaboration** by instructing group members to divide tasks among themselves.	**IPW**		
	5. Teacher **monitors experimental set-ups for safety**.	**IPW**		
	6. Teacher moves around and **checks that plans specify safety**, complying with the particular problem safety requirements.	**IPW**		
	7. Teacher **ensures collection of apparatus is orderly**, either from the trolley or other designated area.	**IPW**		
	8. Teacher keeps a careful watch on timing and **encourages time self-management** by groups.	**IPW**		
	9. Teacher **asks students (groups) to specify assumptions** they make about the problem solution in their plans and draw the set up of apparatus they propose to use.	**FA**		
	10. Teacher **facilitates peer plan review** between groups or by whole class to encourage peer assessment.	**FA**		

Legend: √ denotes **yes** the action is observed; × denotes **not** observed.

C	Learner-centred formative assessment of investigative practical work	IPW/ FA	√/×	Critical incidents
Lesson conclusion	1. Teacher **ensures clear up before next lesson** is done in an orderly manner.	**IPW**		
	2. The teacher encourages and guides students to **discuss possible experimental discrepancies** in the results by asking the students to reflect on the activities.	**IPW**		
	3. The teacher **encourages groups to decide what format to adopt for presentation** of their group report.	**IPW**		
	4. The teacher **gives** students **homework** (e.g., in the science textbook) **to prepare for the next lesson**.	**IPW**		
	5. Teacher **reminds** students to make **conclusions** be **based on data collected** from the experiments they carried out.	**FA**		
	6. The teacher **reminds** students to draw **conclusions** that **relate to** their **specified assumptions** made earlier.	**FA**		
	7. Teacher actions/behaviour (attitude) **encourages students to ask questions** seeking clarification on their work.	**FA**		
	8. Teacher **asks for students' opinion when responding to class questions**.	**FA**		
	9. Teacher **makes sure students are clear before proceeding to the next point**.	**FA**		
	10. The teacher **encourages students to write a group laboratory report** about the plan and experiment they carried out.	**FA**		

Legend: √ denotes **yes** the action is observed; × denotes **not** observed.

APPENDIX A6
Teacher logbook

A. School data

Name of School: ______________________________

Lesson No.: _______

Lesson topic: ______________________________

Lesson date: ______________________________

Number of pupils in class: ______________________________

B. Experiences with the exemplary materials

1. Lesson preparation

1.1 Briefly outline for what purpose(s) you used the teacher guide (TG) for during lesson preparation.

1.2 Did the teacher guide provide enough information to help you understand what was expected of you in the lesson (tick√)?

Explain your response: | Y | N |

What challenges if any did you encounter during the preparations?

2. During the lesson.

How best can you describe your role during the lesson?

Why did you assume this role during the activity?

What problems/challenges if any did you encounter during the lesson?

C. Formative assessment of investigative practical work

Formative assessment of laboratory investigations

What *formative assessment* strategies were carried out during and after the lesson? Explain why these forms were preferred?

How did the teacher-guide support you make decisions on what formative assessment strategies to design and use?

What is your feeling about using these materials as part of your normal laboratory class?

Explain your response:

D. Additional comments

If you have any additional comments write them below:

APPENDIX A7
Teacher interview scheme

Semi structured teacher interview
Teacher perceived practicality *[also included are questions arising from class observations -* observed practicality to provide answer to research question:

How does the teacher perceive the practicality of the exemplary materials as used in the lesson in terms of its clarity, congruence to his/her practice, level complexity and cost of using it in class?

1. **General**
   a. What general statement can you make about the lesson series?
   b. Going through each lesson, what specific comments can you make?
   c. Did you use the Teacher Guide?
   d. How did you use the Teacher Guide?
   e. What group organisation (number/gender, etc.) did you make?
   f. Briefly describe what your pre-lesson preparations included.

2. **Clarity of the innovation**
   a. Do you feel the TG was clear about what was expected of you in the innovation? Explain.
   b. Through the TG what do you think was expected of you in terms of (i) *investigative practical work* and (ii) *formative assessment* of practical work?

3. **Congruence**
   a. Were the practices and materials suggested in the TG in line with what you expect your practice for implementing learner-centred teaching approach?
   b. In what way did the TG support you in (i) *getting students to carry out* investigative work? (ii) *Carrying out formative assessment* of students' investigative work?

4. **Complexity**
   a. How practical was the use of the TG in preparing and conducting a lesson?
   b. Was the TG format easy to follow and how much of this was a factor in supporting your preparation and helping students in the lesson?

5. **Cost**
   a. Do you feel the teaching approach suggested is sustainable when you consider what is available in your laboratory? Explain your response.
   b. Do you consider the time you have for teaching the syllabus enough to accommodate the suggested practice? Explain your response.

APPENDIX A8
Students' interview scheme

Student questionnaire

1. Was there anything in particular that you liked or disliked about the lesson?
   I liked:
   I disliked:

2. What did you like best about the lesson?
   Give a reason why.

3. What did you like least about the lesson?
   Give a reason why.

4. Was the lesson different from the usual chemistry lessons you are used to in your class?
   Yes/No
   If you answered yes, explain what the differences were.

5. Describe what you learned about *investigations* from the lessons.

6. Describe how what content (subject matter) you learned as part of the lessons.

APPENDIX A9
Results of individual cases

Results of the Field test
Operational curriculum: Lesson execution

Teacher T
Overall results

Table 6.2a Investigative practical work orientation

Lessons		1	2	3	4	5	Averages
Lesson introduction	(8/8)*	75	75	75	88	88	80
Body of lesson	(8/8)*	75	88	100	100	88	90
Conclusion	(4/4)*	50	50	75	50	50	55
Overall %		67	71	83	79	75	**75**

Legend: * denotes the maximum possible number of item indicators for IPW in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson.

Table 6.1 (b) Formative assessment orientation

Lessons		1	2	3	4	5	Averages
Lesson introduction	(2/2)**	100	50	100	50	50	70
Body of lesson	(2/2)**	50	100	50	50	50	60
Conclusion	(6/6)**	67	83	83	83	83	80
Overall %		72	78	78	61	61	**70**

Legend: ** denotes the maximum possible number of item indicators for FA in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson.

Details of lesson implementation

Table 6.3 Lesson introduction

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq. For* the series
1.	IPW	Discusses background of the problem		√	√	√	√	√	5
2.	IPW	Distributes problem sheets		√	√	√	√	√	5
3.	IPW	Groups students for activities.		√	√	√	√	√	5
4.	IPW	Clarifies problem question with students		√	√	√	√	√	5
5.	IPW	Lists apparatus		-	-	-	-	-	0
6.	IPW	Discusses safety precautions		-	-	-	√	√	2
7.	IPW	Discusses objectives of the lesson		√	√	√	√	√	5
8.	IPW	Discusses stages of investigation		√	√	√	√	√	5
9.	FA	Guides students through question & answers		√	√	√	√	√	5
10.	FA	Informs students about plan review		√	-	√	-	-	2
		Overall orientation % per lesson	**IPW**	75	75	75	88	88	**80%**
			FA	100	50	100	50	50	**70%**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Planning and experimenting

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq. For* the series
1.	IPW	Uses effective groups of 2-4		√	√	√	√	√	5
2.		Encourages students' approach		√	√	√	√	√	5
3.		Guides by questions not "telling"		√	√	√	√	√	5
4.		Encourages group collaboration		√	√	√	√	√	5
5.		Monitors experimental set-ups for safety		√	√	√	√	√	5
6.		Checks that plans specify safety		-	-	√	√	-	2
7.		Ensures collection of apparatus is orderly		-	√	√	√	√	4
8.		Encourages time self-management		√	√	√	√	√	5
9.	FA	Asks students (groups) to specify assumptions		√	√	√	√	√	5
10.		Facilitates peer plan review		-	√	-	-	-	1
		Overall % per lesson	**IPW**	75	88	100	100	88	**90**
			FA	50	100	50	50	50	**60**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Lesson conclusion

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq. For* the series
1.	IPW	Ensures clear up before next lesson		√	√	√	√	√	5
2.		Discusses experimental discrepancies		-	-	√	-	-	1
3.		Encourages groups to decide what format to adopt for presentation		-	-	-	-	-	0
4.		Assigns homework to prepare for next lesson		√	√	√	√	√	5
5.	FA	Reminds that conclusions be based on data collected		√	√	√	√	√	5
6.		Reminds students to evaluate results against specified assumptions for conclusion		-	√	√	√	√	4
7.		Encourages students to ask questions		√	√	√	√	√	5
8.		Asks for students' opinion when responding to class questions		√	√	√	√	-	4
9.		Makes sure students are clear before proceeding to the next point		√	√	√	√	√	5
10.		Encourages students to write a group laboratory report		-	-	-	-	√	1
		Overall % per lesson	**IPW**	50	50	75	50	50	**55**
			FA	67	83	83	83	83	**80**

Legend: * number of times the advice was observed used throughout the five lesson series.

Teacher U

Table 6.2a Investigative practical work orientation (curriculum profile data)

Lessons		1	2	3	4	5	Averages
Lesson introduction	(8/8)*	88	75	88	75	100	85
Body of lesson	(8/8)*	88	88	100	100	75	90
Lesson conclusion	(4/4)*	50	75	75	50	75	65
Overall %		75	79	88	75	83	**80**

Legend: * denotes the maximum possible number of item indicators for IPW in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson

Table 6.2b Formative assessment orientation (curriculum profile data)

Lessons		1	2	3	4	5	Averages
Lesson introduction	(2/2)**	50	50	50	50	100	60
Body of lesson	(2/2)**	50	50	50	50	50	50
Lesson conclusion	(6/6)**	50	67	50	67	100	67
Overall %		50	56	50	56	83	**59**

Legend: ** denotes the maximum possible number of item indicators for FA in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson

Details of lesson implementation

Table 6.3 Lesson introduction (curriculum profile data)

		Curriculum profile statements		**Lessons 1**	**2**	**3**	**4**	**5**	**Freq.* of item in lessons**
1.	IPW	Discusses background of the problem		√	√	√	√	√	5
2.	IPW	Distributes problem sheets		√	√	√	√	√	5
3.	IPW	Groups students for activities.		√	√	√	√	√	5
4.	IPW	Clarifies problem question with students		√	√	√	√	√	5
5.	IPW	Lists apparatus		-	-	-	-	√	1
6.	IPW	Discusses safety precautions		√	-	√	-	√	3
7.	IPW	Discusses objectives of the lesson		√	√	√	√	√	5
8.	IPW	Discusses stages of investigation		√	√	√	√	√	5
9.	FA	Guides students through question & answers		√	√	√	√	√	5
10.	FA	Informs students about plan review		-	-	-	-	√	1
		Overall % per lesson	**IPW**	88	75	88	75	100	**85**
			FA	50	50	50	50	100	**60**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Planning and experimenting (curriculum profile data)

		Curriculum profile statements	Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Uses effective groups of 2-4	√	√	√	√	√	5
2.	IPW	Encourages students' approach	√	√	√	√	√	5
3.	IPW	Guides by questions not "telling"	√	√	√	√	√	5
4.	IPW	Encourages group collaboration	√	√	√	√	√	5
5.	IPW	Monitors experimental set-ups for safety	√	√	√	√	√	5
6.	IPW	Checks that plans specify safety	-	-	√	√	-	2
7.	IPW	Ensures collection of apparatus is orderly	√	√	√	√	-	4
8.	IPW	Encourages time self-management	√	√	√	√	√	5
9.	FA	Asks students (groups) to specify assumptions	√	√	√	√	√	5
10.	FA	Facilitates peer plan review	-	-	-	-	-	0
		Overall % per lesson **IPW**	88	88	100	100	75	**90**
		FA	50	50	50	50	50	**50**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.5 Lesson conclusion (curriculum profile data)

		Curriculum profile statements	Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	**IPW**	Ensures clear up before next lesson	√	√	√	√	√	5
2.	**IPW**	Discusses experimental discrepancies	-	√	√	-	√	3
3.	**IPW**	Encourages groups to decide what format to adopt for presentation	-	-	-	-	-	0
4.	**IPW**	Assigns homework to prepare for next lesson	√	√	√	√	√	5
5.	**FA**	Reminds that conclusions be based on data collected	√	√	√	√	√	5
6.	**FA**	Reminds students to evaluate results against specified assumptions for conclusion	√	√	√	√	√	5
7.	**FA**	Encourages students to ask questions	-	√	-	√	√	3
8.	**FA**	Asks for students' opinion when responding to class questions	-	-	-	-	√	1
9.	**FA**	Makes sure students are clear before proceeding to the next point	√	√	√	√	√	5
10.	**FA**	Encourages students to write a group laboratory report	-	-	-	-	√	1
		Overall % per lesson **IPW**	50	75	75	50	75	**65**
		FA	50	67	50	67	100	**67**

Legend: * number of times the advice was observed used throughout the five lesson series.

Teacher W

Table 6.2a Investigative practical work orientation

Lessons		1	2	3	4	5	Averages
Lesson introduction	(8/8)*	63	63	63	75	-	66
Body of lesson	(8/8)*	75	75	63	75	-	72
Lesson conclusion	(4/4)*	75	75	50	50	-	63
Overall %		71	71	59	67	-	**67**

Legend: * denotes the maximum possible number of item indicators for IPW in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson.

Table 6.2b Formative assessment orientation

Lessons		1	2	3	4	5	Averages
Lesson introduction	(2/2)**	50	50	50	50	-	50
Body of lesson	(2/2)**	0	50	50	50	-	38
Lesson conclusion	(6/6)**	50	50	50	17	-	42
Overall %		33	50	50	39	-	**43**

Legend: ** denotes the maximum possible number of item indicators for FA in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson.

Details of lesson implementation

Table 6.3 Lesson introduction

		Curriculum profile statements	Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Discusses background of the problem	√	√	√	√		4
2.	IPW	Distributes problem sheets	√	√	√	√		4
3.	IPW	Groups students for activities.	√	√	√	√		4
4.	IPW	Clarifies problem question with students	√	√	-	√		3
5.	IPW	Lists apparatus	-	-	-	-		0
6.	IPW	Discusses safety precautions	-	-	-	-		0
7.	IPW	Discusses objectives of the lesson	√	-	√	√		3
8.	IPW	Discusses stages of investigation	-	√	√	√		3
9.	FA	Guides students through question & answers	√	√	√	√		4
10.	FA	Informs students about plan review	-	-	-	-		0
		Overall % per lesson **IPW**	63	63	63	75		**66**
		FA	50	50	50	50		**50**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Body of the lesson: planning and experimenting

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Uses effective groups of 2-4		√	√	√	-		3
2.		Encourages students' approach		√	√	-	√		3
3.		Guides by questions not "telling"		√	-	√	√		3
4.		Encourages group collaboration		√	√	√	√		4
5.		Monitors experimental set-ups for safety		√	√	√	√		4
6.		Checks that plans specify safety		-	-	-	-		0
7.		Ensures collection of apparatus is orderly		√	√	√	√		4
8.		Encourages time self-management		-	√	-	√		2
9.	FA	Asks students (groups) to specify assumptions		-	√	√	√		3
10.		Facilitates peer plan review		-	-	-	-		0
		Overall % per lesson	**IPW**	75	75	63	75		**72**
			FA	0	50	50	50		**38**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.5 Lesson conclusion

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Ensures clear up before next lesson		√	√	√	√		4
2.		Discusses experimental discrepancies		√	√	-	-		2
3.		Encourages groups to decide what format to adopt for presentation		-	-	-	-		0
4.		Assigns homework to prepare for next lesson		√	√	√	√		4
5.	FA	Reminds that conclusions be based on data collected		-	√	√	√		3
6.		Reminds students to evaluate results against specified assumptions for conclusion		√	-	√	-		2
7.		Encourages students to ask questions		√	-	-	-		1
8.		Asks for students' opinion when responding to class questions		-	-	-	-		0
9.		Makes sure students are clear before proceeding to the next point		√	√	√	-		3
10.		Encourages students to write a group laboratory report		-	√	-	-		1
		Overall % per lesson	**IPW**	75	75	50	50		**63**
			FA	50	50	50	17		**42**

Legend: * number of times the advice was observed used throughout the five lesson series.

Teacher X

Overall results

Table 6.2a investigative practical work orientation (curriculum profile data)

Lessons		1	2	3	4	5	Averages
Lesson introduction	(8/8)*	38	63	63	50	63	55
Body of lesson	(8/8)*	75	63	63	88	63	70
Lesson conclusion	(4/4)*	50	50	75	25	25	45
Overall %		54	59	67	54	50	**57**

Legend: * denotes the maximum possible number of item indicators for IPW in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson.

Table 6.2b Formative assessment orientation (curriculum profile data)

Lessons		1	2	3	4	5	Averages
Lesson introduction	(2/2)**	50	50	50	0	50	40
Body of lesson	(2/2)**	0	50	50	50	50	40
Lesson conclusion	(6/6)**	33	33	33	67	50	43
Overall %		28	44	44	39	50	**41**

Legend: ** denotes the maximum possible number of item indicators for FA in the curriculum profile instrument that the teacher was expected to show by his actions in the course of the lesson.

Details of lesson implementation

Table 6.3 Lesson introduction (curriculum profile data)

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Discusses background of the problem		√	√	√	√	√	5
2.	IPW	Distributes problem sheets		√	√	√	√	√	5
3.	IPW	Groups students for activities.		√	√	√	√	√	5
4.	IPW	Clarifies problem question with students		-	-	-	-	-	0
5.	IPW	Lists apparatus		-	-	-	-	-	0
6.	IPW	Discusses safety precautions		-	-	-	-	-	0
7.	IPW	Discusses objectives of the lesson		-	√	√	-	√	3
8.	IPW	Discusses stages of investigation		-	√	√	√	√	4
9.	FA	Guides students through question & answers		-	√	√	√	√	4
10.	FA	Informs students about plan review		-	-	-	-	-	0
		Overall % per lesson	**IPW**	38	63	63	50	63	**55**
			FA	0	50	50	50	50	**40**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Planning and experimenting (curriculum profile data)

		Curriculum profile statements	Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Uses effective groups of 2-4	√	√	√	√	√	5
2.		Encourages students' approach	√	√	-	√	√	4
3.		Guides by questions not "telling"	-	-	√	√	√	3
4.		Encourages group collaboration	√	√	-	√	√	4
5.		Monitors experimental set-ups for safety	√	-	√	√	-	3
6.		Checks that plans specify safety	√	-	√	-	-	2
7.		Ensures collection of apparatus is orderly	√	√	-	√	√	4
8.		Encourages time self-management	-	√	√	√	-	3
9.	FA	Asks students (groups) to specify assumptions	-	√	√	√	√	4
10.		Facilitates peer plan review	-	-	-	-	-	0
		Overall % per lesson **IPW**	75	63	63	88	63	**70**
		FA	0	50	50	50	50	**40**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Lesson conclusion (curriculum profile data)

		Curriculum profile statements	Lessons 1	2	3	4	5	Ratio per Item
1.	IPW	Ensures clear up before next lesson	√	√	√	√	√	5
2.		Discusses experimental discrepancies	-	-	√	-	-	1
3.		Encourages groups to decide what format to adopt for presentation	-	-	-	-	-	0
4.		Assigns homework to prepare for next lesson	√	√	√	-	-	3
5.	FA	Reminds that conclusions be based on data collected	√	√	√	√	√	5
6.		Reminds students to evaluate results against specified assumptions for conclusion	-	-	-	√	-	1
7.		Encourages students to ask questions	-	-	-	√	√	2
8.		Asks for students' opinion when responding to class questions	√	√	-	-	-	2
9.		Makes sure students are clear before proceeding to the next point	-	-	-	-	-	0
10.		Encourages students to write a group laboratory report	-	-	√	√	√	3
		Overall % per lesson **IPW**	50	50	75	25	25	**45**
		FA	33	33	33	67	50	**43**

Legend: * number of times the advice was observed used throughout the five lesson series.

Teacher Y

Table 6.2a Investigative practical work orientation (curriculum profile data)

Lessons		1	2	3	4	5	Averages
Lesson Introduction	(8/8)*	88	88	88	100	75	88
Body of lesson	(8/8)*	88	88	100	100	100	95
Lesson conclusion	(4/4)*	75	75	75	50	100	75
Overall %		74	79	87	83	90	**86**

Legend: * denotes the maximum possible number of item indicators for IPW in the curriculum Profile, Instrument that the teacher was expected to show by his actions in the course of the lesson.

Table 6.2b Formative assessment orientation (curriculum profile data)

Lessons		1	2	3	4	5	Averages
Lesson introduction	(2/2)**	50	50	50	50	50	50
Body of lesson	(2/2)**	50	50	50	100	50	60
Lesson conclusion	(6/6)**	83	83	83	83	100	86
Overall %		67	67	67	83	72	**65**

Legend: ** denotes the maximum possible number of item indicators for FA in the curriculum Profile, Instrument that the teacher was expected to show by his actions in the course of the lesson.

Details of lesson implementation

Table 6.3 Lesson introduction (curriculum profile data)

		Curriculum profile statements		Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Discusses background of the problem		√	√	√	√	√	5
2.		Distributes problem sheets		√	√	√	√	√	5
3.		Groups students for activities.		√	√	√	√	√	5
4.		Clarifies problem question with students		√	√	√	√	√	5
5.		Lists apparatus		√	-	-	√	-	1
6.		Discusses safety precautions		-	√	√	√	-	3
7.		Discusses objectives of the lesson		√	√	√	√	√	5
8.		Discusses stages of investigation		√	√	√	√	√	5
9.	FA	Guides students through question & answers		√	√	√	√	√	5
10.		Informs students about plan review		-	-	-	-	-	0
		Overall % per lesson	**IPW**	88	88	88	100	75	**88**
			FA	50	50	50	50	50	**50**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.4 Planning and experimenting (curriculum profile data)

		Curriculum profile statements	Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Uses effective groups of 2-4	√	√	√	√	√	5
2.		Encourages students' approach	√	√	√	√	√	5
3.		Guides by questions not "telling"	√	√	√	√	√	5
4.		Encourages group collaboration	√	√	√	√	√	5
5.		Monitors experimental set-ups for safety	√	√	√	√	√	5
6.		Checks that plans specify safety	-	-	√	√	√	3
7.		Ensures collection of apparatus is orderly	√	√	√	√	√	5
8.		Encourages time self-management	√	√	√	√	√	5
9.	FA	Asks students (groups) to specify assumptions	√	√	√	√	√	5
10.		Facilitates peer plan review	-	-	-	√	-	1
		Overall % per lesson **IPW**	88	88	100	100	100	**95**
		FA	50	50	50	100	50	**60**

Legend: * number of times the advice was observed used throughout the five lesson series.

Table 6.5 Lesson conclusion (curriculum profile data)

		Curriculum profile statements	Lessons 1	2	3	4	5	Freq.* of item in lessons
1.	IPW	Ensures clear up before next lesson	√	√	√	√	√	5
2.		Discusses experimental discrepancies	√	√	√	√	√	5
3.		Encourages groups to decide what format to adopt for presentation	-	-	-	-	√	1
4.		Assigns homework to prepare for next lesson	√	√	√	-	√	4
5.	FA	Reminds that conclusions be based on data collected	√	√	√	√	√	5
6.		Reminds students to evaluate results against specified assumptions for conclusion	√	√	√	√	√	5
7.		Encourages students to ask questions	√	√	√	√	√	5
8.		Asks for students' opinion when responding to class questions	√	√	√	√	√	5
9.		Makes sure students are clear before proceeding to the next point	√	√	√	√	√	5
10.		Encourages students to write a group laboratory report	-	-	-	-	√	1
		Overall % per lesson **IPW**	75	75	75	50	100	**75**
		FA	83	83	83	83	100	**86**

Legend: * number of times the advice was observed used throughout the five lesson series.

APPENDIX A10
Design specifications

Table 7.1 Design specifications of exemplary teacher support materials in Botswana

Teacher support function	Design specifications
Support for lesson preparation	*General description of lesson* ▪ Description of concepts: investigative practical work and formative assessment – this would present teachers with clarity of what the change involved. ▪ Description of what the lesson looks like – this was used to exemplify what change was expected. ▪ Aims of the lesson (based on the BGCSE syllabus) – the purpose of the exemplary materials was to support teachers' implement the BGCSE syllabus learner-centred teaching approach. *Lesson preparation* ▪ Necessary background knowledge students should know to provide scaffold for learning new knowledge in the lesson activities. ▪ Lesson plan with timing – suggestions for timing were important to indicate how time could be used efficiently. ▪ Possible difficulties during the lesson – it was important to provide teachers with dynamics of a learner-centred practice. ▪ Materials (apparatus) required during the lesson – advice on how the materials should be distributed – this was important because the resources were used strategically to support learner-centred procedures through problem solving, which included planning investigations.
Support for subject knowledge	*Subject content* ▪ Factual information on subject (acids & bases, see section 4.3 for reasons of choosing topic). ▪ Knowledge about science practical skills. ▪ Possible students' questions and answers – to reduce uncertainty it was necessary to provide teachers with solutions to problems that may develop during the lesson and these included preparing teachers for possible students' questions.
Support for teaching methodology	*Teaching strategies* ▪ Suggestions for sequencing of activities, including start up and finishing of the lesson – sequencing lessons was necessary to show teachers that students need background knowledge acquired from previous lessons to expect less support from the teacher. ▪ Exemplary materials presented as structured problems (with aim implied through the title but requiring its articulation, requiring decisions on apparatus, procedure, variable manipulations and conclusions). ▪ Suggestions on how to conduct IPW (lessons fit in a double period) ▪ Suggestions on how to carry out FA as part of IPW. ▪ Suggestions for grouping students – grouping suggestions were made to guide teachers in using groups to promote effective learning. ▪ Suggestions on how to hand out materials (apparatus) – same as bullet 3 under lesson preparation. ▪ Concrete suggestions for the role of the teacher in supporting investigations ▪ Concrete suggestions for the role of the teacher in carrying out assessment for formative purposes during and after the lesson. ▪ Suggestions for homework
Suggestions for monitoring students' learning.	*Monitoring students' learning (learning effects)* ▪ Suggestions on how to conduct FA during group activity ▪ Suggestions for marking and analysing students' lab reports. ▪ Suggestions on how to give back feedback. ▪ Suggestions for using students feedback class-work and lesson preparation