ENHANCING MATHEMATICS TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND SKILLS IN TANZANIA

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Introduction to the COSMAT study

This chapter presents the introduction to the peer COllaboration to Support Mathematics Teachers (COSMAT) study. Section 1.1 focuses on the study's background by looking at the role and position of mathematics in Tanzania and the efforts being made to improve its teaching and learning in schools through the TEAMS Project. Presented also in this chapter are the purpose, the research questions and the significance of the study (section 1.2). Section 1.3 offers an outline of the research approach, followed by a general overview of the chapters (section 1.4).

1.1 BACKGROUND OF THE STUDY

1.1.1 The role and position of mathematics

In Tanzania, mathematics occupies a high profile in the secondary school curriculum. There are a number of fundamental reasons for this. Mathematics is a language that helps us describe ideas and relationships drawn from our environment. As the science of patterns, mathematics enables us to make the invisible visible, thereby solving problems that would be impossible otherwise. Mathematics is not only used as a computational aid, but as a tool of science and technology, enabling scientists to explore concepts with idealised models before utilising them in the real world.

Because of its importance, the Tanzanian government is committed to ensuring the provision of high quality mathematics education. In this respect, a lot needs to be done. Of major concern are the consistently low achievement levels in mathematics among students at the secondary school level.

For many years the failure rate has been dramatically high in ordinary level (O-level) secondary schools. This is evident in the low scores of students' Certificate of Secondary Education Examination (CSEE) in the Basic Mathematics subject, taken at

the end of their fourth year at secondary school. For example, for the years 2000 and 2001, the percentage of those who failed mathematics was much higher than those who passed. In 2000, the percentage of those who failed was 71.3, whereas in 2001 the percentage was 75.5 (The National Examinations Council of Tanzania, 2002).

Many reasons have been advanced to explain this trend of poor performance (de Feiter, Vonk, & van den Akker, 1995; Kitta, 1994; Rubagumya, 1991; Sichizya, 1992; Stoll, de Feiter, Vonk & van den Akker, 1996). Schools are hit by a lack of resources such as books, equipment, and classrooms (MOEC, 1995). This problem is magnified by large classes that do not allow teachers to effectively interact with students or attend to those with learning difficulties. The students' understanding is also hampered by a low level of language proficiency (Galabawa, 1994; Kitta, 1994; Roy-Campbell, Makini & Qorro, 1997; Rubagumya, 1991; 1997). In Tanzania, the medium of instruction in primary schools is Kiswahili, which is quite different from the vernacular language most pupils speak at home. In secondary schools the medium of instruction is changed to English. Thus, it makes it difficult for students to follow the subjects, as they do not understand the language clearly. This also affects the learning of mathematics (cf. Howie, 2002).

Another problem is the quality of mathematics teachers. Due to the current expansion of student enrolment and the increase of secondary schools, there has been a shortage of qualified teachers. As a result, many schools have employed unqualified teachers such as ex-Form Six Leavers (students who have completed their advanced level education only) to teach. They have also employed people with backgrounds unrelated to teaching and have failed to secure employment opportunities relevant to their courses. There are cases in schools where teachers teach mathematics even though it is not their subject of specialisation. Finally, schools also employ under-qualified teachers such as Grade A's, who are qualified to teach at the primary school level only. Moreover, those who are qualified to teach at this level of education, have significant problems due to the poor teaching preparations they received in college (Chonjo, Osaki, Possi & Mrutu, 1996; Jarvis, 1990). The majority of these teachers lack substantial subject matter knowledge, the knowledge of what to teach, and how to teach the subject matter effectively (Pedagogy) (Chonjo et al., 1996; Mushashu, 1997; Sichizya, 1997). Subject matter knowledge and pedagogical knowledge blend to form what is referred to as pedagogical content knowledge (Shulman, 1986). Pedagogical content knowledge (PCK) is the knowledge of how to transform formal subject matter knowledge into something appropriate for a particular group of students.

Because of pedagogical content knowledge problems, as well as poor classroom conditions, there is an urgent need for comprehensive teacher support programmes to improve the quality of teaching. This is especially necessary in view of students' poor performance levels.

1.1.2 TEAMS project

The government recognises the need for teacher support for mathematics teachers in various ways. Through the Ministry of Education and Culture (MOEC), local institutions such as the University of Dar es Salaam (UDSM), the Tanzania Institute of Education (TIE), and the Mathematics Association of Tanzania (MAT) organise teacher support programmes enabling teachers to receive high quality mathematics education. Other efforts have established collaborative donor funded projects to receive support in these improvement efforts. Among these projects recently established in Tanzania are the Science Education in Secondary Schools (SESS) project and Science Teacher Improvement Project (STIP). SESS operates in 29 O-level government secondary schools in the Coast, Dodoma and Iringa regions. STIP operates in schools owned by the Christian Social Services Council (CSSC).

Another donor-funded inset project is the Teacher Education Assistance in Mathematics and Science Project (TEAMS). TEAMS, which is situated at UDSM, provides in-service education for mathematics and science teachers. This project started in 1996 within the framework of the MHO-programme for co-operation between UDSM and Dutch higher education institutions. (The MHO-programme is the Joint Financing Programme for Co-operation in Higher Education). The project, which focuses on science and mathematics teacher education, involves the Faculties of Education and Science at Tanzania's UDSM and Netherlands's University of Twente (UT) and Vrije Universiteit Amsterdam (VUA). The project's long-term goal is to establish a centre of expertise at UDSM in mathematics and science education, with an emphasis on teacher education.

The first period of the TEAMS-project, (between 1996 and 1999), was meant to initiate improvement in both pre- and in-service teacher education, as well as build the capacity to plan for more comprehensive changes and initiatives for the project's future phases. In general, the first main activities of the project included the following:

- the development of new courses in science and mathematics education for pre-service students;
- the organisation of in-service activities for teachers;
- staff development for junior staff.

With regards to organising in-service education, the TEAMS project is facing challenges. Because of the country's size, it is difficult to organise in-service education programmes that reach all mathematics teachers scattered in different schools throughout the country. One-shot in-service programmes may be possible, but it is difficult to organise follow-up sessions. In addition to this, current professional development literature indicates that one-short in-service education programme is not effective (Fullan, 2001) and the importance of follow-up in school level is widely recognised (Fullan, 2001; Showers & Joyce, 1996; van den Berg & Thijs, 2002). The TEAMS project is therefore exploring ways to provide teachers with school level support within the existing constraints. Peer collaboration, the practice of teachers supporting each other, has been seen as promising in this respect (Anderson & Sumra, 1996; Thijs, 1999). Subsequently, a study into peer collaboration within the framework of the TEAMS project was started. The main purpose of this peer COllaboration to Support Mathematics Teachers (COSMAT) study is described in the next section.

1.2 PURPOSE OF THE COSMAT STUDY

The purpose of the COSMAT study was to explore, design and evaluate peer collaboration; it is a school-based teacher professional development model that aims to provide ongoing support for mathematics teachers since literature indicates that peer collaboration has beneficial effects on teachers' professional development and continued growth (Fullan, 2001; Joyce & Showers, 1995; Showers & Joyce, 1996; Nias, 1998; van den Berg & Thijs, 2002). Peer collaboration means teachers working jointly to share their expertise and experience for the purpose of improving teaching, learning, and in this case, basic mathematics at the O-level secondary school. Presently, little is known in Tanzania about the potential of peer collaboration in relation to teacher professional development. The COSMAT study endeavours to explore the potential of this approach for mathematics teachers. More specifically, the study explores how peer collaboration can enhance teachers' PCK&S. In order to develop a teachers professional development programme, it is necessary to clarify its salient features, making it feasible for the target group. Therefore, the study attempts to answer two questions:

- *What are the characteristics of a school-based professional development programme that includes peer collaboration?*
- *How does it enhance mathematics teachers' pedagogical content knowledge and skills?*

Developing, organising and conducting effective professional development programmes for mathematics teachers can improve the teaching of the subject. The improvement of mathematics teaching means a lot to Tanzanian society. It may not only facilitate the learning of mathematics, but also subjects that employ it such as physics and chemistry. This situation may ultimately lead to the advancement of science and technology in the country, which is vital in fostering the country's social, political, cultural and economic development.

1.3 RESEARCH APPROACH

The COSMAT study followed a development research approach. Development research allows flexibility, step-by-step development of the programme, and sensitivity to the context. This is very important because peer collaboration is a relatively new paradigm in teacher professional development and, as of yet, little is known about how it works within a Tanzanian context. Van den Akker (1999) defines development research by its two-fold purpose: (i) supporting the development of prototypical products (including providing evidence for their effectiveness) and (ii) generating methodological directions for the design and evaluation of such products.

Development research, as articulated by van den Akker (1999) usually has the following research activities: *preliminary investigation*, which involves an intensive and systematic preliminary investigation of tasks, problems and context - this includes searching for accurate and explicit connections of that analysis with state-of-the-art knowledge from the literature. *Development of prototypes*, which becomes evident through iterative cycles of development and formative evaluation activities. And finally, *evaluation of the final product* after it has been implemented and put into practice.

The COSMAT study was based on van den Akker's (1999) developmental research characteristics, and is divided into three stages – the *foundation building stage,* the *development stage* and the *evaluation stage*. In the *foundation building stage,* the study's focus was to articulate tentative design guidelines for a potentially valid, practical and effective teacher professional development programme. Peer collaboration would be the main component to enhance the mathematics teachers' pedagogical content knowledge and skills (PCK&S). Validity, practicality and effectiveness are quality criteria for a sound professional development programme (Nieveen, 1997; van den Akker, 1999). That is, the components of the programme should be based on state-of-the-art knowledge (content validity) and consistently linked to each

other (construct validity). In terms of practicality, the COSMAT programme should be considered feasible by the target group and experts. Also it should be able to meet the needs of the teachers involved, the demands of the context in which they are working, as well as be consistent with the intentions of the developer. To be effective, the COSMAT programme should meet the expectations as expressed by the target group, improving mathematics teachers' PCK&S. To generate professional development guidelines appropriate to a Tanzanian context, preliminary investigation was conducted. The investigation included (a) a literature review on teacher knowledge, basics for teacher professional development, and support for teacher professional development, (b) an analysis of the context in which the COSMAT programme was to be implemented, (c) an analysis of the available data about other peer collaboration programmes to see how they worked, (d) and a consultation of experts for their appraisal of the programme. The preliminary investigation resulted in the initial components of the COSMAT programme. Chapter 4 gives a more detailed description of the formulated design guidelines that led to the identification of the COSMAT programme's main components.

The second stage of the COSMAT study centred on the development of the programme. In this stage, formative evaluation played an important role. According to van den Akker (2002), formative evaluation allows for judgements to be made on the strengths and weaknesses of an intervention in its development stages. Following the evaluation, suggestions are generated to improve the weak points. It is through formative evaluation that different draft evolutionary prototypes came about. These prototypes, which were subjected to a cyclic process, led to the establishment of reasonable programme components.

The third stage of the COSMAT study focused on determining the programme's impact. Information was collected to determine how teachers perceived the programme and how they put programme ideas into practice. The impact study served as a summative evaluation, which enabled the researcher to make overall judgements about the COSMAT programme's usefulness.

1.4 OVERVIEW OF THE FOLLOWING CHAPTERS

The following chapters present the activities and results of the study's different stages. Chapter 2 presents the context of the study, the United Republic of Tanzania, by looking at its geographical and demographic constitution as well as its education

system. Also in this chapter, the evolution of the mathematics programmes and the teacher education programmes are discussed. Finally, a brief description of teachers' learning needs is given whose aim is to form a part of the basis for formulation of the design guidelines of the study. Chapter 3 reports the outcomes of the literature review, which concerns basics for professional development such as foundational tenets and how to support the process. Chapter 4 describes the design and the development of the COSMAT programme based on design guidelines developed from the literature review and context analysis. Chapter 5 presents the outcomes of the formative evaluation of the COSMAT programme, which were used as the basis for redesigning the COSMAT-2 programme. Chapter 6 presents the results of the formative evaluation of COSMAT-2's impact. Chapter 7 presents discussions and conclusions of the study.

CHAPTER 2
The context of the study

This chapter analyses the context, the United Republic of Tanzania, in which the COSMAT programme was conducted. The primary aim of the context analysis was two fold: first, to better understand the context in which the study was conducted; second, to generate guidelines for the design of a programme where peer collaboration would be feasible in this context. Section 2.1 presents general background information about the country in terms of its composition, economy and population. Section 2.2 presents the education system and structure, which includes a historical overview of education and curriculum policies. Section 2.3 highlights mathematics education in Tanzania and gives an overview of ordinary level secondary school mathematics programmes and classroom realities. Section 2.4 explains briefly teacher education programmes. Section 2.5 reports mathematics teachers learning needs assessment and the processes involved in determining these needs. Section 2.6 presents the conclusions drawn from the context analysis.

2.1 THE UNITED REPUBLIC OF TANZANIA: GENERAL BACKGROUND INFORMATION

The United Republic of Tanzania emerged from the union of two countries, Tanganyika and Zanzibar. Tanganyika was under German occupation after the Berlin Agreement (Scramble for Africa, 1884-1885) until the end of the First World War, after which the League of Nations mandated Tanganyika to the British. Tanganyika won her independence on December 9, 1961, while Zanzibar, which won hers on December 10, 1963. Following the revolution on January 12, 1964, the two nations formed a union resulting in the birth of the United Republic of Tanzania on April 26, 1964. The former Tanganyika is popularly known as Tanzania Mainland or simply Tanzania, and Zanzibar is known as Tanzania Isles or simply Zanzibar. The country adopted a policy of Socialism and Self-Reliance after the Arusha Declaration in 1967.

Figure 2.1: The map of Tanzania

Source: *http://www.newafrica.com/maps*

After attaining its independence, Tanzania strived to eradicate what were earmarked as her major enemies - poverty, diseases and ignorance. However, the country was not very successful due to its economic realities. Tanzania is one of the least developed countries in the world. In 2001 it was estimated that the per capita income was $610 with an annual growth rate of 5%. This is one of the lowest per capita incomes in the world (The World Factbook, 2002). The economy is heavily dependent on agriculture, which accounts for half of the GDP, provides 85% of the exports and employs 80% of the workforce. Another important source of revenue are tourism and ???, which have shown steady growth in recent years.

Education is one sector that has been adversely affected by the economic situation, especially by the economic crisis and reforms of the 1980s. Because of the dwindling economy, especially with poorly performing per-capita income in the 1980s and 1990s, the Universal Primary Education (UPE) which was almost achieved and literacy rate, which reached 85% in 1970s, could not be sustained. Overall, education services are inadequate both in quantity and quality at all levels (MOEC, 1995).

Estimates from the 2002 census put the Tanzanian population figure at around 34.6 million with an annual rate of 2.9% (World Factbook, 2002). More than 80% of the people live in rural areas. Unlike most African countries, its population is not

dominated by any one of the more than 120 tribes occupying the country. Despite its size and ethnic diversity, Tanzania is one of the few African countries where language barriers do not exist among the people. This is due to the fact that Kiswahili has been accepted by all the country's inhabitants as its lingua franca. Any tribal vernaculars, which do exist, are largely confined to family circles.

The root of Kiswahili is the Bantu language, which is enhanced by vocabulary borrowed from Arabic, Portuguese, German and English. Since independence, the government has been instrumental in strengthening and consolidating Kiswahili as the lingua franca of Tanzania. Kiswahili, which is now one of the compulsory subjects in the country's schools, especially, primary and secondary schools, has also added it to the university syllabus. A special national council 'Baraza la Kiswahili' is working towards expanding and internationalising the language.

The most widespread and popular foreign language in Tanzania is English. It is used in offices and is the dominant medium of instruction in all secondary schools and other institutions of learning. Hindu, French, Greek, Italian and Arabic can be heard, but are confined to the ethnic groups concerned.

2.2 TANZANIA EDUCATION SYSTEM AND STRUCTURE

2.2.1 Historical overview of education

Pre-colonial period

Before German and British colonial rule in Tanzania, there was traditional education which emphasised principles of good citizenship, acquisition of life skills and the perpetuation of valued customs and traditions (MOEC, 1995). The indigenous curriculum operating during that time was propagated by oral tradition and focused on understanding and finding harmony with nature through knowledge of plants, animals, soils and environments around the community. Teaching was mainly informal, though there was a variation of a formal system (Osaki, 2002). In this formal system, local experts offered specialised life skills according to age and gender. The local experts included elderly men and women in the village or clan with expertise in a certain field. Apart from traditional rituals, girls at the age of puberty were taught how to take care of their families, whereas boys were taught how to become brave soldiers to protect their families and society, in general. These skills were offered at specialised places in the village such as a selected house and/or in the bush, and took place during specific periods of the year or years.

Colonial Period

During the colonial period, especially the British colonial period, education provided was restricted to the few individuals earmarked to service colonial interests. In this period, there were three types of schools with different curricula. There were schools for Europeans, schools for Asians and schools for Africans. Curriculum for the European schools focused on academics and grammar, whereas the Asian schools focused on commercial studies. An integrated curriculum was offered to most African children. These involved the combination of related subjects to form general subjects. The curricula included gardening, agriculture, rural studies and general science which were aimed at teaching them practical skills of survival in the villages (Osaki, 2002). The curricula also included subjects such as woodwork, masonry and carpentry.

Post independence period (1961-1967)

Immediately after independence in 1961, the government passed the Education Act of 1962 to regulate the provision of education. This act repealed and replaced the 1927 Education Ordinance and was intended, among other things, to abolish racial discrimination in the provision of education; streamline the curriculum, examination as well as the administration and the financing of education to provide uniformity. This act was also intended to promote Kiswahili as a national language by making it the medium of instruction in schools along with English.

Despite these new policy measures such as abolition of racial discrimination in the provision of education and the streamlining of the curriculum, there were no significant changes in the goals and objectives of education (MOEC, 1995; Osaki, 2002). The same colonial system operated, but Africans were allowed to go to schools that were geared more towards European and Asian children. Here they came into contact with academic knowledge that was aimed at these two groups of children. Being in these academic schools made African children develop negative attitudes towards practical science knowledge and craft skills taught at the then African schools. This developed feelings of superiority among them as they claimed to be better than students from the more tradition-based African schools. Gradually, academic schools were considered superior to schools that offered practical skills subjects. To re-emphasise practical skills in 1967, the government introduced the philosophy of Education for Self-Reliance (ESR) to guide the planning and practice of education.

Period after 1967

The philosophy of ESR was a sequel of the Arusha Declaration and it underscored the weaknesses of an education system inherited from the colonial period. The

declaration spelled out the main pillars upon which the country's orientation towards socialism stands. They were respect for human dignity, hence equality of human individuals; co-operation in human endeavours for the welfare of all, hence sharing all vital necessities, and obligation to work and achieve for the good of all and for recognising one's role in the common good. This philosophy emphasised the need for curriculum reform in order to integrate theory with the acquisition of practical life skills. More specifically, ESR was education that would enable learners to be independent and creative thinkers, able and eager to combine knowledge with practice (Ishumi, 1976; MOEC, 1995).

The Education Act No. 25 of 1978 was passed to legalise education changes that were introduced in 1967 and 1978 following the implementation of ESR. Changes legalised by the act included making primary school enrolment and attendance compulsory for children of ages 7 to 13 and centralising school curricula and syllabi.

In 1981, a Presidential Commission on Education was appointed to review the existing system of education and propose necessary changes to be realised by the year 2000. The Commission submitted its report in March 1982, and since then, most of the recommendations have been implemented by the government. The most significant included the introduction of new curriculum packages at primary, secondary and teacher education levels; the establishment of the Faculty of Education (FOE) at the University of Dar es Salaam; the formulation of national policy of Science and Technology; and the expansion of secondary education.

In 1990, the government instituted a National Task Force on education to review the existing education system and recommend a suitable education system for the 21st Century. The Task Force's report, the Tanzania Education System for the 21st Century, was submitted to the government in November 1992. Recommendations of this report have been taken into consideration in the formulating the Tanzania Education and Training Policy (ETP) of 1995.

2.2.2 Education structure

Education and training in Tanzania is organised under the Ministry of Education and Culture; the Ministry of Science, Technology and Higher Education; and the Ministry of Regional Administration and Local Government. Other ministries are involved in sector-specific professional education and training (GURT, 2001a). In addition, formal and non-formal education is provided by communities, Non-Governmental Organisations (NGOs) and individuals in co-ordination with central government ministries.

The formal education system is predominantly academic and hierarchically divided, ranging from primary to tertiary level. The current structure of education is 2-7-4-2-3+, that is, two years of pre-primary education, seven years of primary education, four years of ordinary level secondary (O level) education, two years of advanced level secondary (A level) education and finally, a minimum of 3 years of university education (see figure 2.2). The following section describes formal education structure in Tanzania.

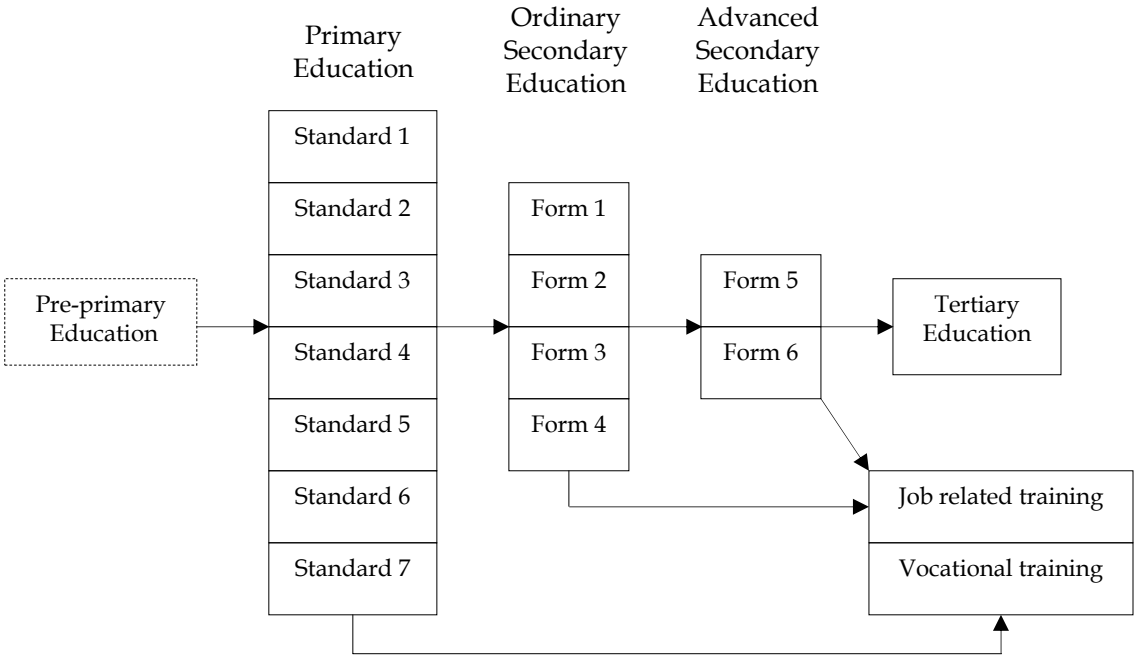

Figure 2.2: The formal education structure in Tanzania

Pre-primary Education

Despite the fact that the government recognises the importance of this level of education, it is not economically feasible to formalise and systematise the entire education spectrum of this age group (MOEC 1995). Thus the nursery, day care centres and kindergarten for ages 0 – 4 years have yet to become part of the formal education and training system. However, efforts and plans are underway to systematise pre-primary education of ages 5-6 years by introducing pre-schools at all primary schools.

Primary Education

This is a seven-year education cycle. It is compulsory in enrolment and attendance. The medium of instruction at this level is Kiswahili. At the end of the seventh year, pupils sit for the national examination known as the Primary School Leaving Examination (PSLE). Less than only 20% are selected to join public secondary schools. For example, of those pupils who sat for PSLE in 2000, only 12.42% were

selected to join public secondary schools in the year 2001 (cf. MOEC, 2001). Of those not selected, about 10% join private secondary schools while the rest can go to vocational training or enter the workforce.

Secondary Education

Tanzania secondary education is divided into two levels: ordinary level (O level) and advanced level (A-level). O-level lasts for four years. At this level, a student is supposed to take at least seven subjects depending on the school's bias. The seven subjects include mathematics, Kiswahili, English and Civics taken as compulsory subjects in all schools. At the end of the fourth year, students sit for examinations known as the Certificate of Secondary Education Examination (CSEE). Less than one percent of students who pass the CSEE are admitted to the two-year A-level education, which is comprised of Forms 5 and 6 (cf. MOEC, 2001). Those who are not admitted can get vocational training, professional training or join the workforce. A-level curriculum is more specialised with a minimum of three subjects per student. The subjects are based on a combination of choices the student can make depending on their level of performance in the CSEE. Those who complete the advanced level join either tertiary or higher education, training institutions or the workforce. The medium of instruction for both levels is English.

2.2.3 Curriculum policies

The Tanzania Education and Training Policy (ETP) is responsible for guiding curriculum policies in Tanzania. This policy was operationalised in 1995. The major purpose of this policy is to guide, synchronise and harmonise all structures, plans and practices; to ensure access, equity and quality at all levels; and to act as a mechanism for management and financing of education and training. Before 1995, the programmes and practices of education and training were based on and guided by short and long term development plans.

The policy document clearly stipulates that the government will continue to co-ordinate and supervise the preparation and delivery of curriculum for primary and secondary school levels and teachers colleges. The government undertakes these activities through the Tanzania Institute of Education (TIE). It is TIE's responsibility to design, develop, disseminate, monitor, and evaluate curricula for the fore mentioned educational institutions. This means that formal and centralised school curricula exist at various levels of education except at the pre-primary level. Until 1985, TIE was mandated to write books that would cover the prepared curricula and meet the needs of education for self-reliance (ESR) (Osaki, 2002). Thereafter, TIE was forced to stop writing books for a couple of reasons. The first was that

writing books was uneconomical for them because of the liberalised market that encouraged other publishers to write books for schools. TIE was advised to concentrate on curriculum design and development and the provision of in-service education. The second reason is that there was widespread criticism of its books for containing many editorial mistakes (Osaki, 2002) and misconceptions.

However, TIE continues to publish books, but on a smaller scale. Its existing books are popularly used in schools because of being in line with the syllabi.

Primary education curriculum

The primary school curriculum was revised in 1992, which lead to the reduction of compulsory subjects from thirteen to seven. These are Kiswahili, English, mathematics, social studies, science, life skills, and religious instructions. The curriculum at this level is expected to balance the requirements of the majority of children who do not proceed to secondary education with the requirements of those few who do.

Secondary education curriculum

As mentioned earlier, the students at the O Level secondary schools are supposed to take at least seven subjects, four of which are compulsory. The syllabi at this level emphasise factual information and there is little emphasis on practical skills. Thus, two major problems are associated with these syllabi. The first problem is that they are overloaded (Chonjo et al., 1996; MOEC, 1995). The second problem is that they are not relevant to students or today's world of work. MOEC acknowledges these problems, and through policy documents, urges TIE to emphasise merging theory and practice to enable students to undertake self-employment as well as direct employment in the formal and informal sectors upon completion of their studies. It also urges TIE to minimise overloading the syllabi.

Examinations

In Tanzania, national examinations are centrally designed, regulated, conducted and administered by the National Examinations Council of Tanzania (NECTA). NECTA was established in 1973. It followed the abolition of the Cambridge Overseas Certification Examinations, which were foreign examinations not relevant to the Tanzanian context. NECTA conducts two examinations at the primary school level. These are the Standard IV and Standard VII examinations. The Standard IV examinations are conducted at the regional level to determine pupils' mastery of the 3R's (Reading, Writing and Arithmetic) (MOEC, 1995). The examination's results are used for making decisions for promotion or repetition. The Standard VII examination is a Primary School Leaving Examination (PSLE), which marks the end

of the primary schools cycle and is used for selection of students for secondary education. At the secondary school level, NECTA conducts two examinations. The first one is the Form 2 examination, which is essential for diagnostic purposes and continuous assessment at the O-level secondary education. The second one is the Form 4 examination (CSEE), which marks the end of the four-year O-level education cycle. The last one is the Form 6 examination (ASCEE), which marks the end of the two-year A-level education cycle. The examination results of the two cycles are used to select students for furthering their education, training or direct employment.

2.3 MATHEMATICS EDUCATION

2.3.1 Overview of ordinary level secondary school mathematics programmes

Mathematics programmes in the United Republic of Tanzania reflect the political and social developments which have taken place in the country since the 1950s (Travers, 1985). Arabic influences as, seen in terms of the Kiswahili language for measure of length, capacity and time resulted from the slave trader, ruler or religious missionary whose caravans passed through both the coast and the interior. Also the 'business mathematics' of the Asian Merchant who set up shops in trading centres has left a remarkable impact on the country's culture. Mmari (1980) noted that it could be argued that commercial subjects were introduced in African secondary schools through Asian influences in East Africa. German colonisers who followed the missionaries established schools to prepare a cadre of African children for colonial service, for working on the plantations, or for serving in houses of business. After the First World War, The League of Nations placed Tanzania under the British as a Mandate territory, and the language of instruction changed from German to English. The metric system of measure, introduced by Germans, was abandoned and replaced by the imperial system. This change of language of instruction and mathematics created problems for the teachers who were then teaching mathematics, as well as for the students who were trying to learn the subject. Both teachers and students had no choice, however, as they had to accept the changes geared to the colonial masters. With the British system of education, though, preparing for English Examinations was extremely difficult as students struggled with material created for a British context. According to Mmari, studying for these exams entailed "many hours (spent) grappling with problems in journeys in the underground from tube section X to tube station Y, problems on the life expectancy of the local miner in Newcastle, and the results of cricket match in country of Southern England" (Mmari, 1980).

According to Sichizya (1992), since the mid 1960s, Tanzania has experienced remarkable changes in its mathematics programmes for primary schools, secondary schools and teachers' colleges. He further says that after independence in 1961, Tanzania continued to use a traditional mathematics programme (introduced by the British), which ceased in 1972. In addition to this programme, the Entebbe programme (modern mathematics) and the School Mathematics Project (SMP) were introduced in the 1960s. The two programmes were later abandoned in 1975 when a new mathematics programme and syllabi with contents taken from Traditional, Entebbe and SMP programmes, was introduced. This new programme, which is still used in O-level secondary school education and primary school education, is known as *basic mathematics.* At the O-level secondary school, which is the focus of this study, basic mathematics is taught as compulsory subject. Sichizya (1992) claims that this programme emphasises the understanding of a core of mathematics, active participation by the learner, and the practical use of mathematics. According to MOEC (1997), the main objectives of teaching basic mathematics are as follows:

i. to promote the development and application of mathematical skills in interpreting the world and solving problems in daily life;
ii. to provide pupils with mathematical tools and logical thinking, which they can apply in understanding other subjects better;
iii. to develop a foundation of mathematical knowledge, techniques and skills for studying mathematics and related subjects at higher levels of education.

The attainment of these goals depends on the qualification of teachers and their ability to synchronise different aspects of the mathematics curriculum (MOEC, 1997). However, despite these well-articulated objectives of teaching mathematics, students' poor performance has long been a subject of discussion among parents, teachers, educators, political leaders and students, themselves. As stated earlier, (see Chapter 1), students' performance in mathematics has been dramatically poor as shown in Table 2.1.

Table 2.1: Comparison between pass and fail percentage rates in mathematics in CSEE between 1996 and 2001

Year	Pass (%)	Fail (%)
1996	22.8	77.2
1997	30.1	69.9
1998	21.4	78.6
1999	26.8	73.2
2000	28.7	71.3
2001	24.5	75.5

Source: National Examinations Council of Tanzania*: Examinations Statistics, 2001,* Dar es Salaam, Tanzania.

Table 2.1 shows that for six consecutive years about 75% of the students failed in mathematics in their Certificate of Secondary Education Examination (CSEE). A number of reasons mentioned in Chapter 1 may have contributed to this kind of performance. The next section identifies another situation that might contribute to the poor performances, classroom realities.

2.3.2 Classroom realities

In the teaching of mathematics, there has been a huge gap between the intended curriculum, implemented curriculum and attained curriculum (Marsh & Willis, 2002). The intended curriculum is reflected in curriculum guides, course outlines, syllabuses, and textbooks adopted at the education system level. The implemented curriculum or enacted curriculum focuses on the classroom level, the level at which the intended curriculum is taught by the teacher. It talks about what form of mathematics is taught and how it is taught. The attained curriculum discusses what students have learned. There are a number of reasons for the gap between policy interventions and classroom realities. In terms of quality teaching, mathematics at ordinary secondary school is supposed to be taught by diploma and graduate teachers, the diploma being a minimum qualification (MOEC, 1995). Diploma teachers are expected to teach Forms 1 and 2, while graduate teachers are expected to teach Forms 3 and 4. In practice, however, this is not the case as there are presently more diploma teachers than graduate teachers in schools (see Table 2.2). Diploma teachers are also teaching mathematics in Forms 3 and 4 and in some schools there are no graduate teachers at all. This is true for both public and private schools. Furthermore, a considerable number of the diploma teachers lack substantial knowledge in terms of subject matter knowledge and teaching skills. They are unable to teach well topics they perceive as difficult (refer section 2.5.3).

Table 2.2: The number of secondary schools teachers for 2000

	Schools		
Qualifications	*Public*	*Private*	**Total**
Graduate	1033	1345	2378
Diploma	5905	3096	9001
Grade A	138	58	196
Others	179	1029	1208
Total	7255	5528	12783

Source: MOEC (2001). Basic statistics in education. Dar es Salaam: MOEC.

Another problem is the nature of the materials prepared for mathematics teaching and learning. The syllabus emphasises learners-centred teaching and learning (MOEC, 1997), while the curriculum materials used, particularly the textbooks, do

not reflect learner-centred ness. They focus more on the content, with little emphasis on the pedagogy. An additional problem hampering the learner-centred teaching is the large class size whereby it has been very difficult to advocate this approach.

2.4 TEACHER EDUCATION

2.4.1 Introduction

The emphasis of teacher education as a critical determinant of the quality of education is very much in keeping with the government's policy on prioritising basic education in its Education Sector Development Programme (ESDP) (GURT, 2001b). In its appraisal document, ESDP recognises that teaching, like other professions, is in a constant state of renewal and that initial, induction and in-service are different phases of the same generic process, namely teacher education.

The management and provision of teacher education programmes in Tanzania is the responsibility of at least three ministries: the Ministry of Education and Culture (MOEC) which is responsible for preparing certificate and diploma teachers; the Ministry of Science, Technology and Higher Education (MSTHE), which is responsible for preparing undergraduate and postgraduate teachers; and the Ministry of Labour and Youth, which is responsible for preparing vocational education teachers. Although, there are initiatives to liberalise the establishment, ownership, administration and financing of teachers colleges, the curriculum has remained centralised, whereby co-ordination and monitoring have remained under the government through TIE.

2.4.2 Pre-service programmes

The pre-service teacher education programmes are meant to supply well-trained teachers for the entire education system. Access to teacher education is currently open to all secondary school leavers depending on the level they want to train, and provided that they qualify for the programme they want to join.

Aims and objectives

According to MOEC (1995), the aims and objectives of teacher education are as follows:

- to impart to teacher trainees theories and principles of education, psychology, guidance and counselling;
- to impart to teacher trainees principles and skills of pedagogy, creativity and innovation;

- to promote an understanding of the foundations of school curriculum;
- to sharpen the knowledge of trainees' teachers and ensure their mastery of selected subjects, skills and technologies;
- to impart skills and techniques of educational research, assessment and evaluation.

Entry qualifications

Before 1995, the minimum entry qualification for the diploma teacher certificate was Division IV in the Advanced Certificate of Secondary Education Examination (ACSEE). In 1995 the government found it necessary to raise the entry qualification of prospective teacher trainees in order to improve the quality and competence of secondary school teachers. Currently, the minimum entry qualification is Division III.

Normally, the teacher education programme takes about two years. The two-year teacher education curriculum includes academic and professional components. The academic component focuses on improving content knowledge in the teaching subject. The professional component, on the other hand, focuses on the provision of foundation knowledge in the principles of education, child psychology and educational management. The pedagogy component focuses on the methods of teaching and micro-teaching. Field experience, referred to as block teaching practice (BTP) is also required. It normally lasts 6-8 weeks, during which students practice teaching in schools.

Constraints

One of the major problems of the pre-service teacher education programme in Tanzania is its financing. According to the Teacher Education Master Plan (GURT, 2001a), teacher education is one of the lowest financed sub-sectors compared to other sub-sectors in MOEC. The ad hoc funding makes the long term planning difficult at the institutional level. Due to the programme's under-funding and untimely delivery of monthly funds, colleges are forced to close earlier for vacations than scheduled and are forced to open late. Another problem facing the pre-service teacher education programme is the infrastructure. The majority of colleges are in poor conditions with deteriorating buildings, furniture, textbooks, and poorly equipped libraries (GURT, 2001a). Also noted is an imbalance between academic advancement and teaching and learning methods acquisition (Chonjo et al., 1996; Dasu, 2001; Jarvis, 1990). Too much time is spent covering academic topics, whereas the methodology aspect is covered in a very superficial manner. With these problems, we can say that teachers are not adequately prepared. In other words, pre-service education programmes do not adequately build strong teaching foundations among mathematics teachers in Tanzania. Thus, there is a need for ongoing in-service education programmes.

2.4.3 In-service education programmes

Teacher participation in the in-service education programmes is a way of supporting them to grow professionally. Professional inputs for teachers also has a substantial impact on students (GURT, 2001a).

Patterns of in-service education programmes

In most cases, the Ministry of Education decides on what goes into the in-service education programme. There are two ways in which they organise in-service programmes. The first is that teachers are brought from their regions to the centre say at the UDSM to be trained by lecturers from different Faculties of Science and Education departments, as well as TIE and MOEC officials. The second pattern is such that lecturers and officials are sent to train teachers in their respective zones or regions.

Constraints

As for the case of pre-service teacher education programmes, the in-service teacher education programmes are also with constraints. The two patterns of providing in-service education have not been very efficient or effective in achieving their objectives due to organisational problems and a lack of funds. First, because of the country's size (Tanzania is 27 times that of the Netherlands), it has been very difficult to organise in-service education programmes which impact all mathematics teachers. These teachers are scattered in secondary schools all over the country and the number of schools increase yearly for both public and private schools (see Table 2.3).

Table 2.3 Number of secondary schools in Tanzania

Year	**1996**	**1997**	**1998**	**1999**	**2000**
Number of Schools	656	721	781	864	927
Public	303	350	406	450	527
Private	353	371	375	414	400

Source: MOEC (2001). Basic statistics in education, Dar es Salaam.

Second, due to budget constraints facing the Ministry of Education, there have been very few in-service education programmes (Chonjo et al 1996). As for the case of pre-service education programmes, in-service programmes are allocated with very little funding, and depend mostly on foreign agencies and donors. For the few programmes that were conducted, very few teachers were involved (Chonjo et al., 1996; Kitta, 1997). Also, there has been no on the spot support to help teachers implement what they have learned from the in-service programmes. Thus, when teachers return to their schools, there is no further support to help them to implement what they have learned from the in-service education programmes.

TEAMS Project

The TEAMS project, which is situated at UDSM, has joined hands with other projects such as the Science Education in Secondary Schools (SESS) project and Science Teacher Improvement (STIP) project to support the Ministry of Education's efforts to provide in-service education. The aim is to support mathematics and science teachers enhance their pedagogical content knowledge and skills (PCK&S). The SESS and STIP projects are limited in terms of their coverage. SESS operates in public secondary schools in 3 out of 26 regions of the country. Its goal is to equip deprived schools with textbooks and science and mathematics apparatus, as well as run in-service education programmes for teachers. Their in-service education model uses both the training of the trainers (TOT) and the cluster workshops. An internal evaluation after the first phase revealed many achievements but also a number of problems (Osaki, 2002). Textbooks and apparatus were well distributed in schools but their use was limited in both classrooms and during the private reading time. As for the STIP, it operates in schools owned by the Christian Social Sciences Council. It also supplies books and runs workshops for teachers. Their workshop approach uses a philosophy called Starter Experiment Approach (SEA) which is designed to introduce every new science or mathematics topic or concept using a starter experiment to generate discussion and engage the students. However, no rigorous evaluation has been done yet to determine its impact in schools.

The TEAMS project has done a number of activities in relation to this issue. One of these was to prepare science teaching materials on different topics contained in both O-level and A-level syllabi to complement, as well as supplement, the scarce teaching materials available in schools. The project has also been involved in exploring more effective ways to support mathematics teachers through in-service education programmes. This had been done through the COSMAT study, which is described here. This study explored the potential of school-based peer collaboration in supporting mathematics teachers to enhance their PCK&S. This approach has been chosen due to its potential of ensuring continuous and on the spot support. An evaluation study done by Anderson and Sumra (1995) at one of the secondary schools in Tanzania has shown positive impacts of the approach. The COSMAT study was committed to explore peer collaboration as part of a professional development programme for mathematics teachers in various schools. As a baseline for the study, COSMAT began with the mathematics teachers learning needs assessment, which is discussed in the next section.

2.5 MATHEMATICS TEACHERS' LEARNING NEEDS

2.5.1 Design of the needs assessment study

Aim of the needs assessment

One of the first goals of the COSMAT programme was to gain more insight about the specific learning needs and problems mathematics teachers' face in teaching mathematics. Therefore, a needs assessment was conducted. A needs assessment is a systematic exploration of the ways things are and the way they should be (Stout, 1995). Literature suggests that, at least in relation to continuing professional development, learning is more likely to lead to change in practice when a need assessment has been conducted (Grant & Stanton, 2000). The intention of the needs assessment was to gather information to get a realistic picture of where teachers stand.

The focus of the needs assessment was to gain insight into the quality of mathematics teachers in schools, mathematics topics that teachers perceived difficult to understand and teach and teachers' perceptions of peer collaboration.

Participants

To collect mathematics teachers' perceived learning needs, several people were involved. First, there were 30 mathematics teachers from five secondary schools in three regions: one school from Arusha, three schools from Dar es Salaam and one school from Kilimanjaro. The schools were selected through purposive sampling. According to Denscombe (1998), this type of sampling is applied to those situations where the researcher already knows something about the specific people or events, and they are selected because they are expected to produce the most valuable data. Thus as a beginning, this study has to involve a few schools that are ready to participate in the programme. To begin with, a sample of 14 secondary schools from four regions was involved in an exploratory study conducted to gain more insight about schools. Almost all the schools involved in this exploratory study showed an interest in teacher professional development. Along with their interest in participating, five secondary schools had additional features that enabled them to qualify for the current study as the researcher expected to get reliable information. These features included the following:

- Administrative support;
- Existing teacher professional development efforts;
- Accessibility to the schools;
- A reasonable number of mathematics teachers.

Other people who also participated in the study are five heads of mathematics departments, four heads of schools, five mathematics teacher educators from teachers colleges and UDSM, two mathematics subject inspector and two officials from TIE.

Data collection instruments and methods

The primary instruments used for collecting data in this study were a questionnaire and interviews. The questionnaire (see Appendix A1) was used to collect data from mathematics teachers. It contained both close-ended and open-ended questions. It also contained 5-point and 4-point Likert-scale questions. The questionnaire was divided into three main parts: general information, mathematics teaching and peer collaboration. For general information, teachers were asked questions regarding their age, qualifications, teaching experience and attendance at in-service education programmes. For mathematics teaching, they were asked to indicate the mathematics topics that they would appreciate further support. They were also asked to pinpoint the teaching methodological skills they would like to have further support. Under peer collaboration, teachers were asked to express their feelings about collaborating with colleagues in terms of classroom observation and its usefulness. Interviews were used to collect information from the heads of mathematics departments, head of schools teacher educators school inspectors and officials from TIE. The major aim of conducting interviews with these people was to collect in depth information to supplement the information gathered from mathematics teachers regarding mathematics teaching and teacher professional development efforts taking place in schools and in the country as a whole. The interview schemes for heads of mathematics department, heads of school and mathematics educators are shown in Appendixes A2, A3 and A4 respecively.

2.5.2 Outcomes of the needs assessment

The outcomes of the needs assessment revealed that a majority of teachers (21 out of 30) did not get the opportunity to attend in-service education programmes since they joined the teaching profession. Most of these teachers have been in the teaching profession for more than 5 years (see Table 2.4).

Table 2.4: Teachers' working experience, qualifications and attendance to in-service education programmes

Working experience (years)	Qualification	Attended	Not attended	Total
Below 5	Diploma	1	4	**5**
	Degree	-	2	**2**
	Other	-	-	**-**
5-10	Diploma	3	6	**9**
	Degree	3	2	**5**
	Other	-	-	**-**
Above 10	Diploma	1	5	**6**
	Degree	-	2	**2**
	Other	1	-	**1**
Total		**9**	**21**	**30**

When interviewed, the heads of mathematics departments and the heads of school showed similar concern for teachers' lack of opportunities to attend in-service education programmes. Similarly, the heads of school also shared the same feelings with their mathematics teachers and the heads of mathematics department about the lack of in-service education programmes for mathematics teachers in Tanzania. As a result of this inadequacy, one school head said that they had to introduce what he called a 'semi-formal' teacher professional development programme. The programme included the following:

- in-house workshops and seminars.
- teacher development meetings (TDMs).
- Inviting resource persons.

However, these strategies were short lived because they did not address teachers' learning needs. There was also a lack of leadership skills to organise and co-ordinate the programmes so teachers had no clear idea on how to run the programmes.

For their part, teacher educators argued that the in-service education programmes do exist, but on a very small scale. This argument was supported by the mathematics subject inspectors, who said that the programmes are infrequent. As for the few programmes that do run, they cater to only a few teachers, most of who come from urban areas.

Quality of mathematics teachers and mathematics teaching

All the teacher educators admitted that the quality of mathematics teaching in Tanzania schools is very low. They mentioned several factors associated with this situation:

- Inadequacy of text- and reference books;
- Lack of teaching materials;
- Poor school leadership;
- Low motivation;
- Lack of regular in-service education programmes.

The school inspectors admitted that the quality of most mathematics teachers is poor, as they are both deficient in terms of subject matter knowledge and teaching skills. This emphasised the need for frequent in-service programmes. They associated teachers' inadequate training to poor backgrounds - while some teachers come from good colleges, others are coming from poor ones. They also admitted that teachers differ in their aptitude in mathematics. One inspector associated teachers' quality with the selection of teacher education candidates. He said that

> *Some teachers failed in mathematics in their A level examinations, yet they are selected to go to colleges to study mathematics which they would ultimately teach.*

Inspectors also found that a lack of induction programs for newly-employed teachers was linked to teachers' failure to teach mathematics properly They argued that, principally, a newly employed teacher is supposed to be under close supervision of an experienced teacher before he/she starts teaching per se.

The school inspectors also said that the quality of teachers differs from school to school. They argued that government schools tend to get qualified teachers. However, due to poor salaries and few incentives, their teaching quality has deteriorated in recent years, leading to poor achievements among pupils. Also some of them have moved to well paying private schools.

Private schools, which pay well, employ qualified teachers. Those that cannot afford to pay higher salaries employ unqualified and under-qualified teachers (see section 1.1.1). This problem is more pronounced in the rural schools.

Perceived difficult mathematics topics

Through the needs analysis process, teachers also indicate the topics in the Basic Mathematics syllabus that they perceived as difficult to teach and therefore needed further support (Table 2.5).

Table 2.5: Difficult mathematics topics as perceived by teachers (N = 30)

Topic	Responses (%)
Probability	83
Three-dimensional geometry	70
Circles and spheres	67
Matrices and transformation	43
Linear programming	40

Table 2.5 shows that a majority of teachers needed further support in probability followed by three-dimensional geometry. When asked to name the topics teachers had difficulties teaching, the heads of department, mathematics educators and the mathematics inspectors came out with the same topics identified by teachers.

Teachers' perceptions of peer collaboration

Teachers were also asked if they would like to participate in peer collaboration activities. All the teachers showed a positive response towards the idea. They said that participating in collaborative activities could facilitate mathematics teaching and learning in such areas as classroom observations and team teaching. In regard to classroom observation, they said that they were comfortable with both being observed and observing others. Most of them argued that it was easy to learn from how the colleague is teaching, for example, in the use of teaching aids and the capability for promoting student participation in the classroom. They claimed that from observing one will be in the position to discover something that would be useful to him or her. Through peer collaboration, teacher educators and inspectors agreed that teachers learn from each other quickly and can exchange ideas easily.

2.6 SUMMARY AND CONCLUSIONS

The primary aim of the context analysis was twofold: first, to better understand the background in which the COSMAT study was conducted; second, to determine the points of attention in order to generate guidelines for the design of a programme with peer collaboration that would be feasible in this context.

Information gathered through context analysis revealed many issues that need attention to facilitate mathematics teachers' professional development, ultimately improving students' achievement. It has been revealed that students perform very poorly in mathematics. Improving the performance is a complex process, as there are a number of factors that contribute to this situation. There is a gap between intentions and realities. Schools have unqualified and under qualified teachers, most

of whom have problems in PCK&S, while the teachers who are qualified often have problems teaching due to the poor teaching preparations they received in college.

It has also been revealed that schools do not have enough and relevant materials for teaching mathematics. In the syllabus, it is emphasised that mathematics teaching should be learner-centred but the materials available in schools, especially the textbooks, do not reflect this approach of teaching. Apart from a scarcity of materials, the schools must contend with large classes, which do not allow effective student-teacher interactions.

Bearing in mind the complexity of the problems mathematics teachers have, it was necessary to take small steps and carefully formulate the aims of a programme that could enhance their PCK&S. The context analysis pointed out teachers' lack of qualification in teaching mathematics. It was also noted that most of them have problems with the subject matter knowledge. This was confirmed through the learning needs assessment study. The study pointed out at more specific area in this respect. Teachers identified a number of topics they perceived as difficult to teach with probability and three-dimensional geometry being the two most difficult. In this regard, subject matter should be considered very important in the design of the COSMAT programme.

The context analysis further identified the lack of relevant teaching materials. Such materials are necessary considering teachers' pedagogical support and subject matter needs. Moreover, the existing materials contain editorial mistakes, misconceptions and a lack of pedagogical suggestions (see section 2.2.3). The need for materials was confirmed through the learning needs assessment. Providing teachers with relevant materials containing pedagogical suggestions is thus urgently needed. This should be taken into consideration in the design of the COSMAT programme.

The context analysis also pointed out that the majority of mathematics teachers do not get the opportunity to attend regular in-service programmes. This assertion has been confirmed by the needs assessment. The lack of in-service programmes has been due to two major problems. First, insufficient money is allocated for the programmes by MOEC. Second, because of the size of the country, it is extremely difficult to reach all teachers in schools. Yet it is vital to support teachers because of their problems with subject matter and pedagogy. Needs assessment has revealed that teachers have positive attitudes towards peer collaboration, which would create a conducive environment for organising school-based programmes as teachers could support one another and be provided an avenue for on-the-spot

support. Therefore, the design of the COSMAT programme should emphasise teachers working in a collaborative way and sharing ideas in study groups, co-planning of the lessons, and team-teaching.

The context analysis revealed that schools lacked people with proper leadership skills for running school-based in-service programmes. The programmes introduced in some schools through individual schools initiatives eventually collapsed and one of the major reasons for this was a lack of proper leadership skills. The designing of the COSMAT programme must include leadership skills to enable teachers to support one another and sustain the school-based programmes.

CHAPTER 3
Building blocks of teacher professional development: A review

This chapter presents the results of a literature study, aimed at gaining insight into building blocks for teacher professional development. These insights are expected to offer guidelines for the development of the COSMAT programme. Section 3.1 presents the major questions and sub-questions that guided the study. Section 3.2 focuses on pedagogical content knowledge as the basis for teacher professional knowledge. Section 3.3 highlights the basics for teacher professional development. Included in the section are definitions of teacher professional development and foundational tenets for designing teacher professional development programmes. Section 3.4 is about teacher professional development support, whereby insights into peer collaboration are highlighted. The benefits of peer collaboration and curriculum materials are also elucidated. The summary and conclusions drawn from the chapter are presented in section 3.5, where potential design guidelines for the COSMAT study are pinpointed.

3.1 INTRODUCTION

The preceding chapter explored a number of factors that lead to the consistently poor performance in mathematics among O-level secondary school students in Tanzania. The report highlighted a gap between intentions and realities. This gap has been created by, among other things, schools being occupied by unqualified and under qualified teachers that have problems with pedagogical content knowledge and skills (PCK&S). Even those who are qualified have similar problems with PCK&S because of their poor training received in colleges. To improve student performance in mathematics, these teachers need support through professional development to enhance their PCK&S. The literature study presented in this chapter explores the pertinent characteristics that make professional development more effective. The study sought current practices of teacher professional development from both developed and developing countries

(particularly Africa) to gain insight into characteristics of effective professional development programmes relevant to a Tanzanian context. The insights obtained were to help in generating guidelines for designing the COSMAT programme. The literature study was guided by the following overall question:

What characterises effective teacher professional development?

With reference to the general research question, three more specific questions were pinpointed. First, the study aimed at exploring what constitutes teacher knowledge. This issue is particularly important, as it would help to give focus to the professional development programme being designed. Thus the first question was:

1. What constitutes teacher pedagogical content knowledge and skills (PCK&S)?

Second, the study aimed at gaining insight into specific issues influencing the designing of a professional development programme that would enhance the identified knowledge base of teachers. This led to the second study question:

2. In designing a professional development program, what are the most promising building blocks in enhancing teachers' PCK&S?

Third, the study aimed to find out how a teacher professional development programme (to be designed) can be supported with peer collaboration so as to make it more effective in enhancing teachers' knowledge. This resulted in the third study question:

3. How can collaborative forms of teacher professional development enhance teacher PCK&S?

3.2 ON LEARNING PEDAGOGICAL CONTENT KNOWLEDGE

In any profession there is a specialised professional knowledge that makes it unique and distinct from other professions. This also applies to the teaching profession. One of the characteristics of good teachers is that they possess a substantial amount of specialised knowledge for teachers known as *pedagogical content knowledge* (PCK), which is the intersection between *pedagogy* and *content* (Shulman, 1986) (see Figure 3.1).

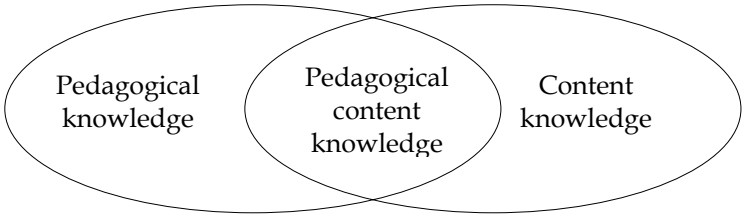

Figure 3.1: Knowledge base of the teaching profession

Pedagogy, which has been the focus of most teaching research between the 1960's and mid 1980's (cf. Grossman, 1990) consists of general knowledge, beliefs, and skills related to teaching. It includes knowledge and beliefs of learning and learners, knowledge of principles of instruction such as small group instruction (Cohen, 1986), knowledge and skills related to classroom management (Doyle, 1986) and knowledge and beliefs about the aims and purposes of education (Grossman, 1990). The content is a discipline perspective, which is based on the breadth and depth of the subject matter (Shulman, 1986). It is the understanding of the organisation of concepts and principles a discipline (basic to the subject matter to be taught) and the strategies within the discipline to generate new knowledge. This area of teacher knowledge had been ignored until the 1980's (Shulman, 1986). It has been revealed that having a flexible, thoughtful conceptual understanding of subject matter is critical to effective teaching (Borko & Putnam, 1996; Darling-Harmond, 1998).

In short, PCK refers to how teachers blend content and pedagogy to determine the most effective means to teach particular topics or problems consistent with the students' interest and ability (Shulman, 1986). Teachers need to be aware of topics that are problematic for students (Shulman, 1986; Wilson, Shulman & Richert, 1987). Emphatically, Ball (1997) says, teachers need ways to see into the subject matter through the eyes, hearts and minds of learners. Their task is to transform the content in ways that make it accessible to students (Wilson et al., 1987) while maintaining its integrity (Ball, 1993; Lampert, 1992). Moreover, knowledge changes with time and context, so teachers must learn to adapt to changes.

Teachers' learning constitutes a very important part of their professional development and growth. Borko and Putnam (1996) and Loucks-Horsley et al. (1998) argue that for a teacher education programme to be successful it should consider teachers as learners in ways that are consistent with the student's perspective of learning. Teachers should be given experience with teaching approaches that are similar to those being used in classrooms. If, for example, teachers are expected to teach in a learner-centred way, then they should be

exposed to this approach of teaching. According to contemporary cognitive theories, learning is situated in a particular context and is an active constructive process that is heavily influenced by the individual's existing knowledge and beliefs (Borko & Putnam, 1996). Research on learning to teach shows that teachers' existing knowledge and beliefs are critical in shaping what and how they learn from teacher education experiences. It is argued that prospective and experienced teachers' knowledge and beliefs serve as a filter through which their learning takes place (Borko & Putnam, 1996). It is through these existing conceptions that teachers come to understand new practices.

3.3 BASICS FOR PROFESSIONAL DEVELOPMENT

Professional development plays a crucial role in successful education reform. Professional development serves a bridge between where teachers are now and where they will need to be tomorrow to meet new challenges in guiding students to achieve higher standards of learning and development. What is professional development then? The next section steers us towards definition.

3.3.1 Working towards a definition of professional development

There are a number of definitions of professional development given by different scholars. According to Fullan (2001), professional development is the sum total of formal and informal learning experiences throughout one's career from pre-service teacher education to retirement. For Loucks-Horsley et al. (1998), professional development means the opportunities offered to educators to develop new knowledge, skills, approaches, and dispositions to improve their effectiveness in classrooms and organisations.

For his part, Guskey (2000) considers professional development as those processes and activities designed to enhance professional knowledge, skills and attitudes of educators so that they might in turn improve students' learning. He adds that the process involves learning how to redesign educational structures and cultures.

From these definitions, it can be said that teacher professional development involves all processes and designed activities that enable teachers to acquire knowledge, skills, attitudes and behaviour enhancing their ability to function effectively in their classrooms. The next section discusses foundational tenets, focusing on views that influence the design of teacher professional development programmes.

3.3.2 Foundational tenets on professional development

The collective opinions on learners and learning, teachers and teaching, the nature of the content, and principles of effective professional development programmes influence the design of professional development programmes.

Conception of learners and learning

Teachers' conceptions of learners and learning shape the kind of instruction they provide (Bruner, 1996; Loucks-Horsley et al., 1998). People share different views of learners. One perspective sees the student as an imitative learner, and focuses on passing on skills and 'know-how' through examples and demonstrative action. This view, which is based on a behaviourist theory of learning, considers the learner's mind as *tabula rasa* (an empty container in which to pour knowledge). The proponents of this view (Bloom, 1956; Gagné, 1967) emphasise talent, skills, and expertise, rather than knowledge and action.

In some contexts, behaviourism is used synonymously with 'objectivism' because of its reliance on objectivist epistemology. The objectivist approach in learning believes in the existence of reliable knowledge about the world and the learner's goal is to gain this knowledge, as transmitted by teachers (Jonassen, 1991).

Current theories stress the influence of a student's prior knowledge, beliefs and attitudes on their learning (Cobb, 1994; Kieren & Steffe, 1994). This view, which is labelled constructivism, contends that students actively construct meaning through interaction with existing knowledge and ideas provided by others students and teachers. Constructivists view students as bringing their own beliefs, ideas, and experiences, to the classroom, which in turn, actively affect how they understand and learn new materials (Borovcnik & Peard, 1996). Students interact with others to make sense of experiences and phenomena, and then reflect on this process, reconceptualising their existing knowledge structures. Learning is thus perceived as a social process in which interaction with others is of prime importance (Wenger, 1998). Through interaction with peers and teachers, students share their personal meanings and, based on this 'negotiation' process, reconceptualise their initial knowledge structures. The new knowledge's meanings to students depend on its context. Therefore, the social and cultural context of students should be an important part of the teaching and learning process.

It is widely accepted that promoting student learning in a constructivist way requires teachers to adopt new pedagogical approaches (Loucks-Horsley et al., 1998; Putnam & Borko, 2000). In other words, the conception of the teacher and

teaching will be different from the traditional one. So, what is the conception of the teacher and teaching in the constructivist paradigm?

Conception of teachers and teaching

Conceptions about teachers and teaching shape the way professional development programmes are prepared. In order to support students to construct their own knowledge, teachers are not expected to continue with their traditional role of transmitting knowledge. With a constructivist approach to teaching, teachers play the role of a "midwife in the birth of understanding" as opposed to being "mechanics of knowledge transfer" (von Glasersfeld, 1995). Teaching is not to dispense knowledge but to provide students with the opportunities and incentives to build it up (von Glasersfeld, 1996). Teachers holding a constructivist view are expected to adopt a teacher-student interaction mode of instruction by creating a stimulating learning environment that allow students to explore and investigate as teachers act as facilitators (Gergen, 1995). According to Thompson (1992), problem-solving is central to teaching for constructivist teachers; purposeful activities stem from problem situations that require reasoning, creative thinking, discovering, inventing, communicating, testing ideas, and gathering and applying information.

Teachers must also be aware that the practice of teaching is complex. They have to understand that teaching occurs in uncertain circumstances and requires constant decision-making. It encompasses deep, flexible knowledge and the ability to apply that knowledge to students, content, the curriculum, instruction, assessment, and the school and local communities (Fullan & Hargreaves, 1992; Loucks-Horsley et al., 1998; Shulman, 1987). Nevertheless, it is believed that teachers can practice in this way - in part by building on their own classroom experience and, in part, by learning from the collected wisdom of others (Loucks-Horsley et al., 1998). This will eventually help them become more effective teachers. Being an effective teacher is ultimately judged in terms of imparting knowledge and values that students can comprehend and relate to. Effective teaching, according to Arends (1994), Stephens and Crawley (1994), and Loucks-Horsley et al., (1998) includes the following:

- making the subject exciting, and linking it, whenever possible, to issues students can relate to in their world;
- unashamedly loving the subject and getting the students to know that they love it;
- making complex issues understandable;
- listening to the students and thereby avoiding too much 'chalk and talk';
- setting work that the students can realistically handle;
- realising that initial teacher training is only one phase of long-term professional development.

Teaching in a constructivist way depends on the teachers' conception of the nature of the content before they can help the students to learn it (cf. Swafford, Jones & Thornton, 1997). Teachers have different conceptions about the nature of the subject matter that they teach. The forthcoming discussion presents these differences with specific reference to mathematics (in view of the focus of COSMAT).

Conception of the nature of content

It is argued that a person's understanding of the nature of the subject content shapes their view of how teaching should take place in the classroom (Hersh, 1986). Research indicates that mathematics teachers' conceptions about mathematics influence their actions in the classroom (Pepin, 1999; Teo, 1997).

Associated with teachers' conceptions of mathematics are beliefs aligned with the traditional, absolutist view and a non-traditional, constructivist view of mathematics (Roulet, 1998). Although there are others, absolutist and constructivist views are distinguished here because of their observed occurrence in mathematics teaching (Thompson, 1992), and because they are apparent in teachers' conceptions of mathematics (Ernest, 1996). Teachers' with an absolutist conception of mathematics describe the subject as a vast collection of fixed and infallible concepts and skills (Romberg, 1992) and a useful but unrelated collection of facts and rules (Ernest, 1996). For them, mathematics represents "the unique realm of certain knowledge". Absolutist views of mathematics are not concerned with 'describing' mathematics or mathematical knowledge (Ernest, 1996). They view mathematical knowledge as timeless, superhuman, value-free and culture-free.

In contrast to the view of mathematics as a formal system of concepts and rules that one has to adapt through learning, advocates of realistic mathematics education (RME) conceive mathematics as human activity, so that learning mathematics is doing mathematics or mathematising (Gravemeijer, 1994). This view of mathematics is related to constructivism. Constructivism is one alternative view to traditional instruction. Hersh (1986) lists two main properties of mathematical activity or knowledge which adhere to constructivist view of mathematics and challenge the basic assumption that mathematical knowledge is infallible. These properties are:

1. Mathematical objects are invented or created by humans.
2. They are created, not arbitrarily, but arise from activity with already existing mathematical objects, and from the needs of science and daily life.

The properties indicate that Hersh (1986) emphasises the notion of practical mathematics and challenges the assumption that mathematics is absolute and certain. The constructivist view emphasises the practice of mathematics and the

reconstruction of mathematical knowledge. Teachers holding a constructivist view of mathematics perceive the subject as a language developed by humans to describe their observations of the world. The teachers see mathematics as continually growing, changing and being revised, as solutions to new problems are explored by the learners with the teachers as facilitators.

Practising teachers should be supported to adhere to this new paradigm whereby: learners are viewed as constructors of knowledge and not just accumulators of existing knowledge; teachers are viewed as facilitators and not just transmitters of knowledge; and content is created and does not exist as an absolute reality. In this regard, views of professional development should adjust to fit this new paradigm. Since this paradigm views mathematics as a creative human activity, and that mathematical learning occurs as students develop effective ways to solve problems (de Lange, 1996; Streefland, 1991), mathematics teaching should focus on the following issues as addressed by de Lange (1996) and Hadi (2002), using Cobb's (1994) description:

1. The starting point of instructional series should be experientially real to students so that they can immediately engage in personally meaningful mathematical activities.
2. In addition to understanding students' current mathematical ways of knowing, the starting point should also be justifiable in terms of the potential end points of the learning sequence.
3. Instructional sequences should involve activities in which students create and elaborate symbolic models of the informal mathematical activity.
4. The first three issues can only be effective if they are realised within an interactive teaching environment: explaining and justifying solutions, understanding other students' solutions, agreeing and disagreeing, questioning alternatives, reflection.
5. Real phenomena in which mathematical structures and concepts manifest themselves lead to the intertwining of learning strands.

Views on principles of professional development

It has been noted that many authors have reviewed research on professional development. For example, Colbe and Koballa (1996) reviewed professional development for science teachers, while Clarke (1994) did so for mathematics teachers. The aim was to discover principles that could guide professional development. Loucks-Horsley et al. (1998) describe a common vision of professional development in science and mathematics through examining efforts to develop standards to guide reform. They noted that a variety of different

institutions agreed with this. Some of the organisations were interested in improving mathematics and science, whereas others were interested in professional development, itself. In their work, they identified what they conceived as indicators of effectiveness for teacher development programmes in science, mathematics and technology. They identified seven principles that are addressed in effective professional development experiences (Loucks-Horsley et al., 1998):

i. They are driven by a well-defined image of effective classroom learning and teaching.
ii. They provide opportunities for teachers to build their knowledge and skills. For example, they help teachers develop in-depth knowledge of their disciplines as well as pedagogical content knowledge; they also help in choosing and integrating curriculum and learning experiences.
iii. They use or model with teachers the strategies teachers will use with their students. For example, they start where teachers are and build from there; provide ample time for in-depth investigations, collaborative work, and reflection; and connect explicitly with teachers' professional development experiences and activities.
iv. They build a learning community. For example, because continuous learning is a part of school norms and culture, teachers are rewarded and encouraged to take risks and learn; teachers learn and share together.
v. They support teachers to serve in leadership roles such as supporters of other teachers, as agents of change, or as promoters of reform.
vi. They provide links to other parts of the education.
vii. They are continuously assessed to ensure a positive impact on teacher effectiveness, student learning, leadership, and the school community.

To be effective, professional development efforts should take these principles into account. Teachers sharing, teachers supporting each other and the building of learning communities are among the most important features addressed in the principles of effective professional development. These features suggest the need for teacher collaboration to support their professional development. The next section presents a discussion about how to support teacher professional development.

3.4 SUPPORTING TEACHER PROFESSIONAL DEVELOPMENT

3.4.1 Towards collaboration in teacher professional development

Research on teacher professional development programmes gained momentum in the 1970s. Much of this research was based upon the work of Joyce, for example,

Joyce & Peck (1977); Joyce & Showers (1983, 1985, 1988, and 1995); Showers & Joyce (1996). Sparks and Loucks-Horsley (1989) summarised major studies and several effective practices. They organised their review of the staff development literature into a number of basic models of professional development activities. According to them, these models describe the range and variety of experiences commonly found in schools. One of the models is *individually guided professional development programmes*, which allows the teacher to design his or her own learning activities (Guskey, 2000; O'Sullivan et al., 1988; Sparks & Loucks-Horsley, 1989). An assumption of this model is that individuals are motivated by being able to select their own learning goals and means for accomplishing those goals (Guskey, 2000). A belief that underlies this model is that self-directed development empowers teachers to address their own problems and by so doing, creates a sense of professionalism (Sparks & Loucks-Horsley, 1989). According to Guskey (2000), the model is flexible and gives opportunities for personal choice and individualism. It also provides an excellent format for self-analysis, personal reflection, and thoughtful decision making. Despite these advantages, this model has profound shortcomings. When teachers design their own learning, a lot of what Sparks and Loucks-Horsley (1989) call 're-inventing the wheel' takes place. Also, this model reinforces teacher isolation.

Current literature on teacher professional development emphasises the shift from individualised forms to more collaborative forms of professional development programmes (Guskey, 2000; Fullan, 2001; Loucks-Horsley et al., 1998; Pugach & Johnson, 1995; Showers & Joyce, 1996). Teacher collaboration can take place inside or outside the classroom, depending on the nature and the purpose of the activity to be carried out. Inside the classroom, teachers can collaborate in different ways. They can collaborate through *mentoring and classroom observation* or through *team teaching*. According to Loucks -Horsley et al. (1998) and Guskey (2000) mentoring and classroom observation involves pairing an experienced and successful teacher with a less or equally experienced colleague. They are then provided with regular opportunities for discussions of professional goals, sharing of ideas and strategies on effective practice, and reflection on current methods. Sparks and Loucks-Horsley (1989), Joyce and Showers (1995) and Guskey (2000) contend that these two approaches can benefit both individuals involved. Having someone else in the classroom to view instruction and provide feedback has a powerful impact on classroom behaviour. They further contend that the person acting as another set of 'eyes and ears' for the teachers also learn as they view their colleagues in action.

Team teaching can be defined as a group of two or more teachers working together to plan, conduct and evaluate the learning activities for the same group of learners

(Goetz, 2000). Team teaching can take different forms depending on the nature of the content and activities to be carried out in the classroom (Robinson & Schaible, 1995). Teachers can actively share the instruction of content and skills to students at the same time. Team teaching can also occur in such a way that when one teacher instructs the entire class, the other circulates the room and monitors student understanding and behaviour.

Outside the classroom, teachers can also collaborate in different ways. They can, for example, collaborate through *study groups*, doing *action research (inquiry)*, or being involved in a *development/improvement process.*

According to Loucks-Horsley et al. (1998) and Guskey (2000), study groups offer teachers the opportunity to meet and address issues of teaching and learning. The issues to be discussed may vary from current issues in mathematics to school reform. The groups may be composed of a small number of teachers or an entire department, depending on the issue to be pursued. Loucks-Horsley et al (1998) asserts that study groups provide a forum in which teachers can be inquirers and ask questions pertaining to their classroom practices.

Through inquiry or action research, teachers examine their teaching and students' learning by engaging in a research project in their classrooms (Loucks-Horsley et al., 1998; Guskey, 2000). Inquiry involves the identification of a problem, data collection (from the research literature and classroom data), data analysis, and changes in practice followed by the collection of additional data. Sparks and Loucks-Horsley (1989) claim that the model is built on the belief that the mark of a professional teacher is the ability to take 'reflective action'.

According to Sparks and Loucks-Horsley (1989), involvement in a development/improvement process refers to systemic school improvement processes. This involves assessing current practices and solving problems whose solution will improve student outcomes. The solution might include developing new curricula, designing programmes, or changing classroom practices. In this case, new skills or knowledge may be required and can be attained through reading, discussion, observation, training and experimentation (Kwakman, 2003; Sparks & Loucks-Horsley, 1989). Consequently, involvement in the improvement process can result in many skills, attitudes, and behaviours. The advantage of this model is that participants not only increase their specific knowledge and skills, they also enhance their ability to work collaboratively and share in decision-making (Guskey, 2000).

Despite the fact that both individual and collaborative models are widely used to address teacher professional development, there is a growing call for more collaboration to facilitate teacher learning (Hargreaves, 1997; Kwakman, 2003; Lieberman, 1996; Little, 1993; McLaughlin, 1997; Pugach & Johnson, 1995; Thijs, 1999). The reason for this is new information or ideas spring from dialogue and interaction with other people, rather than through individual learning (Kwakman, 2003). Moreover, collaboration is assumed to create a learning culture and helps to build a community in which further learning is supported and stimulated. The next section presents a detailed discussion about the benefits that can be gained through collaboration.

3.4.2 Teacher collaboration: benefits and limitations

Benefits

Literature shows that the continuing growth and professional development of teachers may be substantially enhanced by opportunities to collaborate with others (Fullan, 2001; Joyce & Showers, 1995; Nias, 1998; Showers & Joyce, 1996). The opportunity to take advantage of the expertise of others, and be recognised for their own, can provide teachers with important reinforcement and incentives for continuing growth and development. It can also enhance the personal status and respect that comes from being part of a 'community of learners' with their professional colleagues (Hixson & Tinzman, 1990). Cohen (1988) and Rosenholtz (1989) argue that working together has the potential to raise morale and enthusiasm, while opening the door to experimentation and an increased sense of efficacy.

Collegiality among teachers, as Inger (1993) and Fullan (2001) contend, breaks up the isolation of the classroom and allows teachers a rewarding career with daily satisfaction. Instead of grasping for a single dramatic event or the special achievements of a few children, as their main source of pride, teachers are more able to detect and celebrate a pattern of accomplishments within and across classrooms (Little, 1987). Teachers who work closely together on matters of curriculum and instruction find themselves better equipped for classroom work (Anderson & Sumra, 1995; Inger, 1993). They take considerable satisfaction from professional relationships that withstand differences in viewpoints and occasional conflicts. Another perceived benefit of collegial practice in schools has been introduced by Fullan (2001), who maintains that educational change is more successful when teachers work collaboratively. The acceptance of new ideas is encouraged through what he terms 'the primacy of personal contact' amongst teachers. Taking the argument further, the educational outcome of students can also be improved by the successful adoption of this new teaching practice.

Furthermore, complexities that accompany a new curriculum or arise from an existing curriculum are challenging for teachers (Loucks-Horsley et al., 1998). Teacher teamwork makes these complex tasks more manageable, stimulates new ideas, and promotes coherence in the school's curriculum and instruction. Together, teachers have the organisational skills and resources to attempt innovations that would exhaust the energy, skills or resources of an individual teacher. Thus, the accomplishments of a proficient and a well-organised group are widely considered to be greater than the accomplishments of isolated individuals (Little, 1987).

Limitations

Despite the fact that collaboration has often been hailed as the solution to individualism and the isolation of teachers, it has some limitations. One of the limitations of teacher collaboration is an organisational setting that allows teachers the time to collaborate (Pugach & Johnson, 1995; Thijs, 1999). This is because teachers are often confronted by pressure of work; they are responsible for heavy workloads and have limited time (Kwakman, 2003; Stuart, 1997) within the limited time in their schedules. Among other things, they have to prepare tests, mark students' exercise books and participate in other extracurricular activities such as supervising sports and games.

Also, collaboration is criticised for suppressing some of the important qualities of teachers as human beings associated with individualism. Fullan and Hargreaves (1992) caution that collegiality can suppress individuality and subject teachers to 'group-think', depriving them of independent thinking. Caution must be taken not to suppress all teacher individualism. Some of the aspects of teacher individualism such as caring, individuality, creativity and solitude are important for teacher effectiveness and confidence. Overemphasising collaboration may lead to the creation of 'group dependence syndrome' among teachers, whereby they may develop the tendency to rely solely on the group for solving problems. This tendency may delay finding a solution to a problem that needs immediate attention.

Implementation challenges

Apart from limitations, there are some challenges facing teacher collaboration. To be able to support each other to enhance their PCK&S, teachers should have a sufficient knowledge base. The majority of teachers in schools are not fully prepared in this respect, though (Ball & Cohen, 1999; Fullan, 2001). This, of course, makes realising the benefits of collaboration difficult.

Another challenge for implementing collaboration in schools is building collaborative cultures among teachers. Pugach and Johnson (1995) contend that

collaborative interactions are not always easy as it involves a change of behaviour. Fullan (2001) argues that there is no single answer for this and suggest that changes require some impetus to get started. He proposes to begin with small groups of people, and if successful, build momentum.

The identified challenges and limitations may hamper teachers' benefits of collaborative learning endeavours. Thus, a number of fundamental steps should be taken to promote it. One of the steps is the provision of the exemplary materials to stimulate the process. The materials can provide teachers with a shared frame of reference. The next section presents the essence of the exemplary materials for teacher professional development.

3.4.3 The role of exemplary materials

Exemplary materials play a vital role in teacher professional development, as they are considered an important support tool for teachers attempting to change their teaching practice (Ball & Cohen, 1996; Gray, 1997; Ottevanger, 2001; Tilya, 2003; van den Akker, 1988).
Curriculum materials, referred to by Loucks-Horsley et al. (1998) as 'curriculum replacement units' can be used in different ways in professional development:

- They can be used to stimulate teacher reflection and discussion on a concrete experience with the new teaching method.
- They can help in the process of changing the curriculum by allowing teachers to learn gradually content and a new way of teaching.
- They can help to stimulate and inspire teachers to collaborate with colleagues in formal, as well as informal ways (Thijs, 1999).

Several studies that have been conducted in both developed and developing countries have shown that the use of new curriculum materials is seen as an agent for instructional change, provided that they give concrete information about the teacher's role in executing a lesson. This concrete information and directions can be offered through 'procedural specifications': accurate how-to-do-it advisement, focused on essential but apparently vulnerable elements of curriculum (van den Akker, 1988; 1998). The use of procedural specifications has been necessitated by four implementation problem areas many teachers face (van den Akker 1988): lesson preparation, which is often time consuming and difficult; subject matter knowledge, which many teachers lack; lack of pedagogical knowledge; and assessment of learning which is also considered difficult.

In a study conducted by Voogt (1993) to support teachers in the use of courseware in an inquiry-based science curriculum in Dutch secondary schools, she designed and evaluated teacher materials using procedural specifications. Although her study indicated that a teacher's use of printed materials kept their lesson approaches closer to the designer's intentions, teachers often used student materials for the preparation rather than teacher materials. She noted that teachers who did this performed considerably poorer than their colleagues who used the teacher materials. These teachers were less actively involved in supporting their students during the lessons and ran into technical problems with the courseware. Another study done by van den Berg (1996) indicated that using procedural specifications enhances the effects of in-service education on the implementation efforts of teachers. She noted that the integration of materials with procedural specifications into an in-service programme stimulates teachers to try new things and provide them with successful first-time experiences. Furthermore, she found that procedural specifications made lesson planning less complicated and time consuming compared to planning a lesson without them.

Similarly, several studies have been conducted in developing countries, especially in Southern Africa to determine the suitability of exemplary materials with procedural specifications in supporting mathematics and science teachers in their professional development (Gray, 1997; Ottevanger, 2001; Stronkhorst, 2001; Thijs, 1999; Tilya, 2003). Results from these studies showed the materials had positive effects in supporting teachers' efforts to implement learner-centred learning, though in varying levels of effectiveness. Thijs (1999) concluded that the materials could provide teachers with a clear picture of how the innovation can be used in a real context and support them during their first implementation trials. Also, the materials could offer a focus on the innovation, stimulating peer collaboration activities. Findings from Thijs (1999), Ottevanger (2001) and Stronkhorst, (2001) concur with the observations by van den Akker (1988) and van den Berg (1996) that for the materials to be effective, they should contain procedural specifications on how to implement the innovation.

Thijs (1999) cautions that the selection of the topic for developing the material is very crucial. She suggests that the materials should address subject topics that are part of the syllabus, but not adequately covered in common textbooks. The topic should also fit to the scheme of the teachers' work.

From these findings it appears evident that exemplary curriculum materials are of paramount importance for a teacher professional development. Among other

things, they can stimulate teacher collaboration, which is very important for teacher learning. Moreover, exemplary curriculum materials coupled with collaboration can support teacher professional development in situations where teachers have the opportunity to meet regularly in school on a formal or informal basis. The next section presents the importance of school-based teacher professional development, whereby the role of leadership is highlighted.

3.4.4 School-based professional development and leadership

School-based support is regarded highly in both developed countries (Borko & Putnam, 1996; Fullan, 2001; Joyce & Showers, 1995; Kwakman, 2003; van den Berg, 1996) and developing countries (Anderson & Sumra, 1995; Dalin, 1994; Stol, de Feiter, Vonk, & van den Akker, 1996; Thijs, 1999). The school-based setting is considered to be sustainable, ongoing and allows teachers to talk with their peers about changes and improvements in their practice (Powell, Goldenberg & Cano, 1995). This setting inspires collaboration and engages teachers as both learners and as teachers (Darling-Harmond & McLaughlin, 1995; Saunders, Goldenberg & Hamann, 1992). According to Guskey (2000), school-based designs offer several advantages. One is that because the decisions about professional development goals, content, and models, are made at the school level, efforts are more likely to be contextually relevant. Another advantage is that the consensus on issues related to professional development is easier to reach because fewer individuals are involved.

To support work effectively in this setting, there must be a supportive leadership in schools that understands the importance of teacher professional development. First, such leadership must allow the restructuring of the school so that collaboration among teachers is feasible (Thijs, 1999). The study done by Anderson and Sumra (1995) showed that involvement of school leadership in a teacher professional development programme, specifically in coaching activities, was a key factor in establishing a climate of trust among teachers. Moreover, they insisted that the activities should be separated from evaluation. Also, as part of leadership at school level, there has to be demonstrated expertise and practical experience in the area under consideration (Loucks-Horsley, et al 1998; Pugach & Johnson, 1995; Sparks & Loucks-Horsley, 1990). These instructional experts serve as coaches or facilitators (either formally or informally).

The amount of in-service education programmes is not necessarily related to the quality of implementation, but it can be if combined with pre-implementation training with assistance during implementation (Fullan, 2001). Borko and Putnam

(1996) contend that teachers require considerable and sustained support integrating the pedagogical content knowledge and beliefs they acquire from in-service programmes into their current practices in the classrooms. The essence of facilitators is to render support to teachers on a daily basis when they have problems during the implementation. It is argued that teachers learn best from other teachers, but research shows that they interact with each other infrequently (Lortie, 1975). Having facilitators within the schools may make teacher interaction possible by being the source of inspiration, where teachers can get day to day support. When teachers are trained as staff developers, they can be very effective in working with other teachers (Fullan, 2001).

3.5 SUMMARY AND CONCLUSIONS

3.5.1 General overview

Teacher learning constitutes an important part of teacher professional development and continued growth. It involves active construction processes that are heavily influenced by an individual's existing knowledge and beliefs, and is situated in a particular context. Teachers' existing knowledge and beliefs are critical in shaping what and how they learn from teacher education experiences. This chapter explored what constitutes teacher knowledge. It has been noted that to be a professional teacher, one is expected to possess a substantial amount of pedagogical content knowledge. This knowledge, which is an intersection of subject matter and pedagogy, enables the teachers to know what to teach and how to teach it effectively to a particular group of students. In order to improve and consolidate teacher knowledge, teachers must be supported through teacher professional development programmes. The chapter indicates that there are a number of teacher professional development models. Some models focus on individual teachers such as individually guided professional development programmes. Despite their benefits, these programmes have limitations, such as encouraging teacher isolation. They are not consistent with the current strategies of teacher professional development approaches, which emphasise teacher collaboration. Hence, there are models that emphasise teacher collaboration either inside or outside the classroom. Inside the classroom teachers can collaborate through mentoring, classroom observation or team teaching. Outside the classroom teachers can collaborate through study groups, action research or being involved in the development/improvement process. Studies show that peer collaboration has the potential of enhancing teacher professional development and continued growth. It

has been revealed that working together has the potential of raising morale and enthusiasm, creating readiness for experimentation and increased sense of efficacy.

In order to stimulate more effective implementation and bring outside knowledge into the collaboration process, teachers need to be provided with curriculum materials that address topics not adequately covered in the regular textbooks and that fit into the teachers' schemes of work. To stimulate and promote the use of materials, school-based settings are said to be more appropriate because teachers can get on-the-spot support, provided that there is supportive leadership.

3.5.2 Implications

From the literature study, a number of issues have been taken into consideration for the COSMAT study. First, in view of the potential of peer collaboration in supporting teachers' professional development and continued growth, the COSMAT study should consider peer collaboration as a central component in professional development programmes aimed at enhancing mathematics teachers' pedagogical content knowledge (PCK). In Chapter 2, it was revealed through context analysis that O-level mathematics teachers in Tanzania have problems in terms of content and pedagogy due to the poor training they received in the colleges or inadequate qualifications to teach at this level. So there is an urgent need to support them in enhancing their PCK&S through professional development.
Second, it has been noted that PCK&S include pedagogy and content, both of which are extremely important for teachers. The COSMAT study explores the possibilities of supporting mathematics teachers through professional development programmes enhance their PCK&S. The approach should focus on the constructivist conceptions of the learner and learning; teacher and teaching; and the nature of mathematics.

Third, the importance of curriculum materials for teacher professional development has been acknowledged. In Chapter 2, the question of materials was touched upon too. In Tanzanian schools, there is a scarcity of relevant curriculum materials. Those that are available and popularly used are full of editorial mistakes and misconceptions. They contain a lot of content with very little pedagogical support. So in designing the COSMAT programme, materials should be considered critical. More specifically, they should be developed and incorporated into the programme to help teachers know what to teach and how to teach it effectively. The materials should consider the syllabus requirements of mathematics, as well as fit into the teachers' scheme of work.

Fourth, for curriculum materials to be more effective in stimulating collaboration, school-based settings should be used. It is within this setting that the intensive use of materials is being made. It has been learned that a school-based setting is more conducive for peer collaboration. It is at this setting where sustainable and ongoing support for teachers can be guaranteed. Therefore, in designing the COSMAT programme, school-based settings should be considered to support the entire group of mathematics teachers.

Finally, it has been noted that school-based collaboration and curriculum materials alone does not guarantee success in supporting teachers. Teachers also require considerable and sustained support, as well as and opportunities to implement their pedagogical content and beliefs. There is a distinct need for leadership abilities among selected teachers to organise and support their colleagues in a school-based teacher development programme. Therefore, the design of the COSMAT programme should include the component of leadership skills.

CHAPTER 4
COSMAT programme: design and development

This chapter discusses how insights gained from the context analysis (Chapter 2) and the literature study (Chapter 3) have been used to design and develop teacher professional development programme. The programme, which is labelled COSMAT programme, is aimed at enhancing O-level secondary school mathematics teachers' pedagogical content knowledge and skills (PCK&S). Section 4.1 formulates the programme's design guidelines and section 4.2 highlights the programme's aims and development process. Section 4.3 describes and justifies the development of exemplary curriculum material, one of the most important components in the programme. Section 4.4 presents activities involved in the development of the school-based seminar, which is another important component of the programme. Section 4.5 describes peer collaboration, a component that plays a central role in the programme, whereas section 4.6 describes the facilitators, a group of teachers expected to assume a leadership role in organising the programme at school level. In the last section (4.7), a brief synthesis of the chapter is presented.

4.1 THE COSMAT PROGRAMME DESIGN GUIDELINES

The COSMAT programme aimed to enhance O-level secondary school mathematics teachers' pedagogical content knowledge and skills (PCK&S) in the teaching and learning of mathematics. This section presents design guidelines that were used in the development of the programme. The guidelines were based on the information gathered through a context analysis (Chapter 2) and literature review (Chapter 3). The context analysis gave an elaborate picture of the quality of mathematics teachers in Tanzania and their learning needs. The chapter also reported on in-service education programmes aimed at fostering teachers' professional development, as well as their potential limitations in meeting teachers' learning needs. The literature review gave an overview of important characteristics of professional development programmes. It also highlights the central role that peer collaboration plays in the process.

Combining information from chapters 2 and 3, the following preliminary design guidelines for the COSMAT programme were formulated:

1. Bearing in mind the complexity of the problems Tanzanian mathematics teachers have in terms of content and pedagogy (see sections 2.4.2 & 2.5.3), it is necessary to take small steps and carefully formulate the aims of the programme that could support teachers in enhancing their PCK&S.
2. To enhance teachers' PCK&S in the teaching of mathematics, peer collaboration is considered important, as it has the potential to stimulate and support teacher learning (see sections 3.4.1 and 3.4.2). This peer collaboration should also focus on a variety of collaborative activities (see section 2.5.3).
3. To stimulate teacher collaboration, exemplary curriculum materials are considered important because they can inspire teachers to collaborate with colleagues in formal as well as informal ways (see section 3.4.3). The aim of the material should not only support teachers with subject matter knowledge, but show them how to teach in a learner-centred way, as well. In order to do this, the materials should include specific guidance about the following:
   - suggestions on lesson preparations;
   - suggestions about teacher's and students' activities;
   - suggestions on how to address subject matter knowledge;
   - suggestions for student assessment tools.
4. For more effective collaboration with the use of the exemplary materials, a school-based seminar is considered important (see section 2.4.3). The seminar's aim is to introduce teachers to the main characteristics of the exemplary materials and of peer collaboration. In order to achieve this, the seminar should consist of the following components:
   - demonstration lessons conducted by facilitators using the exemplary materials; this enables teachers to gain the subject matter knowledge and learn how to teach it in an activity-based way;
   - group work in which teachers discuss lessons in detail to gain activity-based teaching skills and insight into the subject matter knowledge;
   - co-planning of lessons whereby teachers get the opportunity to share ideas on how to prepare lessons with the exemplary materials;
   - micro-teaching sessions, through which teachers practise the teaching of probability in a training situation and receive feedback from facilitators and their colleagues.
5. In order to facilitate the implementation of peer collaboration at the school-level it is considered important to give teachers a clear picture of what peer collaboration is (see section 2.5.3). Teachers can be furnished this information through small pamphlets containing the rationale, guidelines and examples of how to conduct peer collaboration.

6. To further stimulate peer collaboration in school-based settings, leadership is considered important (see section 2.5.3). As the role should be fulfilled by teachers, some must be identified and prepared for leadership roles as facilitators. These teachers are expected to support and encourage their colleagues to conduct collaborative activities.

4.2 DEVELOPMENT OF THE COSMAT PROGRAMME

This section describes the development of the COSMAT programme in the broadest terms. Before describing the programme's design and different components in detail in sections 4.3 to 4.7, the section provides a brief introduction to the overall development process. It gives an overview of the activities involved in the programme's development and discusses its primary aims.

4.2.1 Overview

The development of this programme, which is labelled the COSMAT (COllaboration to Support MAthematics Teachers) programme, was based on the design guidelines given in section 4.1. The programme consisted of the following main components:

- exemplary curriculum materials;
- school-based seminars;
- peer collaboration guidelines;
- facilitators.

The programme's components were developed concurrently based on the design guidelines. All cycles of development included formative evaluation to determine the practicality of the programme, to detect its shortcomings and to generate ideas for improvement (cf. Nieveen, 1997). During the process, an expert appraisal was performed within each cycle and exemplary materials were tried out. The researcher was involved in all activities. For a detailed description about formative evaluation activities, see section 4.3.3 for the exemplary materials; section 4.4 for the school-based seminar programme; and section 4.5 for peer collaboration guidelines. Figure 4.1 gives an overview of the development of different programme components and the formative evaluation activities involved.

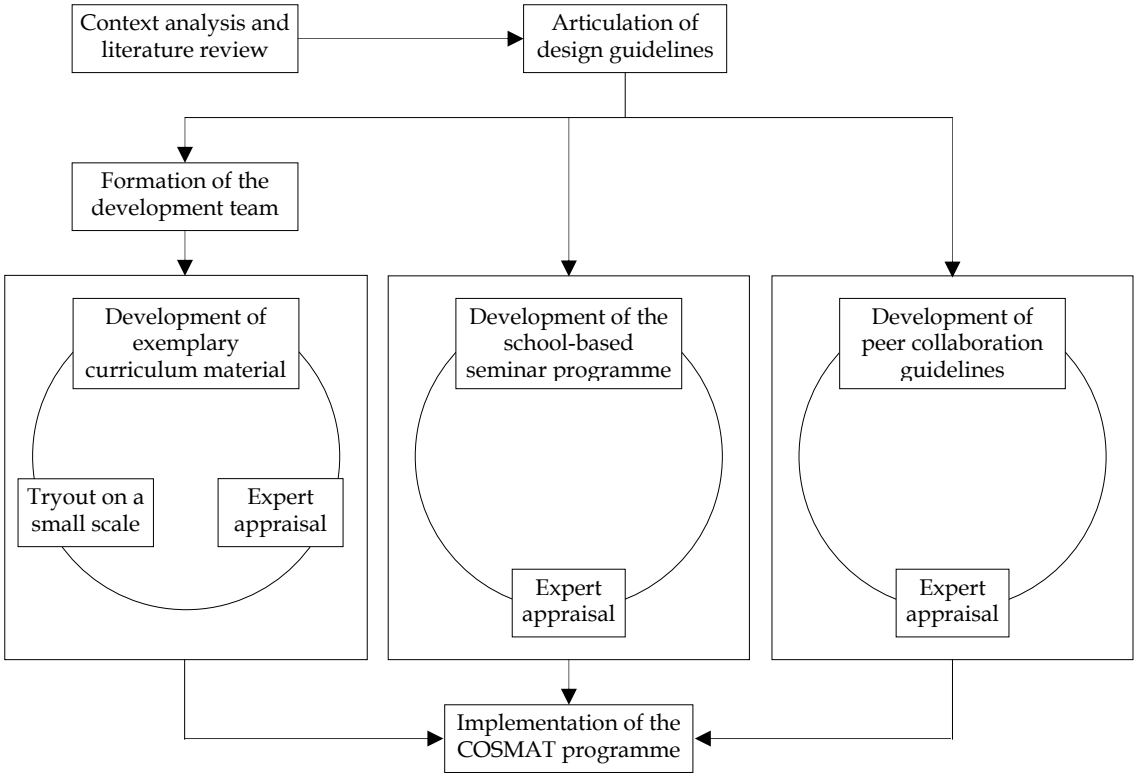

Figure 4.1: Schematic development of the COSMAT programme

The development of the programme involved three schools right from the beginning. This was done to fit the programme to teachers' needs, (cf. Fullan, 2001) as well as developing a sense of ownership of the programme for teachers. These schools were selected for two main reasons. First, they had school leaders that supported the programme. Second, they were already some ongoing professional development efforts in these schools. From each of the three schools, two teachers who were expected to be facilitators were selected. The selection was based on two conditions. First, one of them had to be a head of mathematics department. By virtue of his position, he was expected to help in a number of issues that needed administrative support, such as timetable matters with regards to implementing the programme and the organisation of programme activities. The second condition was that the facilitator had to be an expert in the teaching of O-level secondary school basic mathematics. These facilitators were also part of a development team (DT) that developed the exemplary material in the five-day workshop conducted in June 1999. Other members of the DT were four teacher education college mathematics tutors and two TEAMS project members (including the researcher). The main reason for involving teachers in the DT was based on the assumption that they are closest to the curriculum implementation and could help develop materials that are applicable to the classroom (Loucks-Horsley et al., 1998). They know what material is feasible in the classroom and what best fit the needs of

their students. Another reason for having teachers on the team was to remain consistent with school-based professional development, which stresses that teachers should take ownership of the programme and become responsible for the quality of their teaching practice (Pugach & Johnson, 1995). By participating in the exemplary materials development workshop, it was expected that these facilitators could increase their understanding of both content and pedagogy (cf. Loucks-Horsley et al., 1998). As a result, they would be in a better position to support their colleagues in the school-based seminar as well as implement the programme ideas. The developed exemplary materials consisted of seven activity- based lessons: four in probability and three in three-dimensional geometry. These two topics were selected because they were perceived as the most difficult to teach of the O-level secondary basic mathematics syllabus. However, for this programme, only probability was pursued further. Detailed reasons for choosing probability and activity-based teaching are given in section 4.2.2.

The facilitators were also involved in the development of the school-based seminar programme. Being teachers in their respective schools, they could give a good picture as to where the COSMAT programme could fit into their schools' programmes and timetables. With regard to supporting teachers in conducting peer collaboration, an outline of peer collaboration guidelines was prepared by the researcher. In the course of making sure that things would go as planned, there was continuous collaboration between the researcher and facilitators.

The next section presents the aims of the programme. Thereafter, a detailed description of the design and development of the COSMAT programme's main components are presented in the next sections of the chapter, starting with the development of the exemplary curriculum materials in section 4.3.

4.2.2 Aims of the programme

The major aim of the COSMAT programme was to support mathematics teachers in enhancing their PCK&S. In order to achieve this goal, peer collaboration took an important position in the process. For teachers to have proper guidance in conducting collaborative activities, the programme also aimed at furnishing teachers with important information about peer collaboration (see design guideline five).

With reference to the first design guideline, the COSMAT programme was expected to take small steps and carefully formulate their aims that could help mathematics teachers enhance their PCK&S. To support mathematics teachers in this regard, the

programme intended to focus mainly on subject matter knowledge. This is because many teachers in Tanzania displayed a need for support in this area as revealed through the learning needs assessment (see section 2.5.3). It was expected that if the teachers have sufficient subject matter knowledge, then it would be easy to support them in terms of pedagogical knowledge. The decision was made to focus the COSMAT programme on probability, one of the topics in the O-level mathematics syllabus. By definition, probability is the branch of mathematics concerned with analysing the chance that a particular event will occur (Wheeler, 1988). The basic purpose of probability theory is to predict the likelihood that something will or will not happen. By studying probability, children are expected to develop critical thinking skills and interpret the probability that surrounds us daily. The choice of topic was made by the development team (DT) on the first day of the materials development workshop. This topic was chosen because it had been noted that of the branches of mathematics, probability is a clear branch demanding a fundamentally different style of conceptualisation (De Corte, Greer & Verschaffel, 1996). It contains a number of potential misconceptions which, if not challenged, will become deeply rooted. It is important to support teachers in dealing with these misconceptions so as to be able to teach better. The decision to deal with only one topic was made to have in-depth coverage of one topic, as opposed to superficial coverage of many topics.

To support teachers teaching probability in a learner-centred way as articulated in the current O-level Basic Mathematics syllabus (cf. MOEC, 1997), the COSMAT programme focused on the activity-based approach of teaching (see section 4.3.2). This is an approach to teaching mathematics which involves active participation by learners rather than passive compliance (Martin, 1994; Triadafillidis, 1996).

The activity-based approach would be used to help teachers/students develop a relational understanding to construct knowledge and mathematical concepts (Van de Walle, 1995). In order to achieve this, it was thought worthwhile to develop an activity-based approach, connecting thinking and mathematics and designing to more mathematically significant instructional learning experiences. These learning experiences are as follows:

- *Hands-on*, that is, involving students in actually doing mathematics – experimenting first hand with physical objects in the environment and having concrete experience before learning abstract mathematical concepts. This means that by using the materials, students are expected to do different activities/experiments that would help them overcome misconceptions that are associated with it.

- *Authentic*, which means, allowing students to do probability activities that are related to real life situations. Through doing these activities, students are expected to come up with principle(s) and formula(s) for finding probabilities of different events within the real life events.

To allow flexibility in the use of the approach, it was decided to present teachers with a variety of teaching and learning activities in which discussion between students and teachers is encouraged. Both the supports for subject matter knowledge and activity-based teaching would be included within the exemplary curriculum materials. The next section presents the development of curriculum material.

4.3 DEVELOPMENT OF THE EXEMPLARY CURRICULUM MATERIALS

In this study, exemplary curriculum material was considered an important tool for supporting mathematics teachers to enhance their PCK in the teaching of probability. The major aim is to increase their confidence and competence in the teaching of the topic. This section describes and discusses the materials development workshop; format and characteristics of the first draft of the materials; and the formative evaluation of the materials, which includes the expert appraisal and try-out.

4.3.1 Material development workshop

In order to provide the development team with an environment conducive to exemplary materials, a 5-day workshop was organised by the researcher. The aim of the workshop was to develop a first set of exemplary materials on probability that would support mathematics teachers in enhancing their PCK&S on this topic.

Plan and organisation

To familiarise the members of DT with the task ahead of them, they were first informed of the suggested format of lesson organisation (see Table 4.1).

Table 4.1: Format of the lesson plan

The organisation of the lessons is in such a way that each is divided into the following subsections:

1. *Lesson title*: This indicates the major title of the lesson.
2. *What are we trying to achieve in this lesson?* This subheading refers to the specific objectives that are to be achieved by the lesson.
3. *What does this lesson look like?* This section gives a general overview of the lesson.
4. *References:* This indicates the textbooks and other reference materials that have been referred to when preparing the lesson.
5. *Lesson plan and timing***:** This section shows the approximate time that is expected to be spent in each section of the lesson.
6. *Lesson preparation*: this describes s things that are to be prepared for the lesson by either the teacher, students or both.
7. *Teaching materials needed*: These are the things that are required for facilitating the teaching and learning of a particular lesson.
8. *Execution of the lesson:* This section indicates the steps to be followed and activities to be carried out in teaching the lesson of interest.
9. *What has been learnt from the lesson?* This section gives general overview of what students might have learnt in a given lesson
10. *Suggested homework ideas*: These are assignments that a student may be required to do at home after the lesson. Part of it may be done in the classroom if the teacher wishes
11. *Teacher notes*: This is a summary of the important ideas a student is supposed to learn from the lesson
12. *Suggested test questions:* These are sample questions which teachers may use to prepare a test at the end of the lesson and/or at the end of the whole topic.
13. *Answers*: In the last pages of the material, answers for suggested homework ideas and test questions are given.

This format was adopted from the TEAMS project in-house format and it has been built on formats used in studies done in Namibia (Ottevanger, 2001) and Botswana (Thijs, 1999). The researcher gave an introduction and clarification of each section of the lesson. Much emphasis was placed on the section 'What are we trying to achieve in this lesson?' which represents the objectives to be achieved in each lesson. Without clearly stated objectives, it would be very difficult to assess students' achievement. Therefore, examples of well-stated objectives were given and then participants were asked to state objectives, which were evaluated in terms of clarity and specificity. Also, emphasis was put on how to design classroom activities. In this area, the participants were asked to design activities that would reflect students' daily lives, as well as their abilities.

After the preliminary information, the participants divided themselves into two groups. These groups were formed for convenience so as to avoid having one big group where effective discussion about lessons would be difficult. The groups were

formed so that an equal number of people were distributed on each side. The researcher was allocated to one group and the other TEAMS member was allocated to the other group. Two college tutors and three secondary school teachers were also put in each group. Teachers from the same school were advised to sit in different groups. The groups existed until the end of the workshop.

In developing the materials, it was agreed to follow the series of subtopics indicated under the two topics in the current Basic Mathematics syllabus as the major headings of the lessons. Each group was given a task of preparing two lessons. Then towards the end of each day, the two groups assembled together for the presentation of lessons already prepared. After each presentation, all participants, including the researcher, discussed the lessons by giving comments, suggestions and corrections. This procedure was followed until the end of the workshop.

Besides probability, participants also prepared lessons for three-dimensional geometry. This was done for of two main reasons. First, it was considered the second most challenging topic among ordinary level mathematics teachers; the lessons that would be developed could also help simply its teaching and thus be useful in future programmes. Second, of the 5-day workshop, 4 days were spent intensively preparing probability lessons. Therefore, there was one more day, which the participants thought it would be worthwhile to spend for preparing lessons on this topic. However, in this study the topic was not pursued further.

Outcomes of the workshop

At the end of the workshop, a total of seven lessons was developed: four lessons on probability and three lessons on three-dimensional geometry (see Table 4.2).

Table 4.2: Lessons for probability and three-dimensional geometry

Topic	**Lesson**	**Lesson title**
Probability	Lesson 1	Probability of an event
	Lesson 2	Combination of probabilities
	Lesson 3	Mutually exclusive events
	Lesson 4	Independent events
Three-dimensional geometry	Lesson 5	Drawings using oblique projections
	Lesson 6	Angle between a line and a plane
	Lesson 7	Angles between two planes

At the end of the workshop, participants' opinions, and especially those of the facilitators, were sought about the usefulness of the workshop in their work by means of a questionnaire. Generally, all the participants perceived the workshop as very useful. They agreed that the workshop enabled them to share their expertise

and experiences in the teaching of probability and three-dimensional geometry. Facilitators found that developing lessons collaboratively helped them enhance their subject matter knowledge and ability to teach it in an activity-based way. Furthermore, they argued that developing the activity-based lessons taught them how to ensure full student participation in the teaching and learning process. The facilitators noted that this was one of the most important aspects of their professional development as a direct result of the workshop. It gave them the opportunity to challenge the mathematics curriculum materials currently used in schools. They contended that the materials need to be reviewed to suit the requirements of the current learner-centred approach. The tutors, through informal discussion, remarked that the idea was useful and that the move should be continued for other topics also to further support teachers.

4.3.2 Formative evaluation of the material

Expert Appraisal

After being developed, compiled and typed, the lessons on probability were taken to two mathematics experts. These experts were as follows:

- A mathematics lecturer from the Department of Mathematics of UDSM.
- The head of Mathematics Department at the Tanzania Institute of Education (TIE).

The aim of sending the lessons to these experts was to have their opinions, comments and suggestions to improve the validity of the content, organisation and practicality of the materials, taking into consideration the realities of the Tanzanian classrooms.

Throughout the interview, the experts were asked to give comments, criticisms, and suggestions that could improve the lessons. They were asked to look at the objectives and whether they were achievable; the relevance of the content and the designed classroom activities and if they were appropriate to the intended group of students; the assignments and tests; and the organisation of the lessons in general. Commenting on the lessons in general, they said that they were satisfactory in terms of content coverage. They said that they sufficiently covered the probability content for the O-level secondary school mathematics syllabus and that the level of difficulty had been reduced so that they could be used to teach probability, enabling teachers and students to understand the concept and its applicability.

Since they were aware of many teachers' having problems teaching due to insufficient knowledge, the experts acknowledged the idea of having exemplary materials to support teachers. They added that the materials are important and address teachers' needs. Also, they were of the opinion that teachers ought to be familiarised with teaching the topic by using the new activity-based approach to

help them promote student-centred teaching and learning. They said that if the materials are embedded in a seminar, teachers might get adequate knowledge that can help them teach the topic without much trouble. They acknowledged that the objectives were clear and activities were practical thus feasible within the classroom. In general, they said that the materials reflected learner-centeredness, and that they covered the syllabus requirement of a basic mathematics programme for ordinary level secondary school.

No major improvements were recommended on the objectives, teaching activities or content. They did, however, add suggestions for improvement on the following sections of the lesson:

- The section 'Ending the lesson' should reflect exactly what the teacher will do and for what purpose.
- The section 'Lesson preparation' appeared to be too general; it should clarify who should prepare what – teacher, student or both.

After receiving the comments from the experts, the probability lessons were revised by incorporating all the necessary corrections and suggestions. Then the trial of the material took place.

Trial of materials

The tryout involved two mathematics teachers and Form 4 students at one of the secondary schools. The purpose of the exercise was to explore the practicality of the material, that is, to see whether teachers would be able to use the materials as intended (Nieveen, 1997). Each teacher taught all lessons as the try-out coincided with the teachers' schemes of work on the topic. However, only two lessons were observed for each teacher, whereby events focusing on teacher-student interaction, as well as activity-based teaching with the exemplary materials were recorded. At the end of the try-out, the responsible teachers were interviewed so as to get their opinions about the usefulness of the exemplary materials, in general; objectives; content; classroom activities; lesson duration; and suggested homework and test ideas.

Throughout the observation it was noted that student participation was not very prevalent. The major reason for this could be associated with the type of teaching practice teachers were used to. Teachers argued that using activity-based approach is relatively new, as they were used to the chalk-and-talk method. It was also noted that some of the suggested teaching aids like playing cards and using a die were not familiar to some students. This situation was revealed to be a problem related to exposure, rather than the exemplary materials.

Despite the fact that teachers could not implement the activity-based lessons, as the approach appeared to be too novel for them, they considered the materials useful for mathematics teachers as long as they receive support**.** They said the materials could help to ensure student participation in the classroom and lessen time spent on lesson preparation. They also argued that due to lessons being activity-based, a sense of co-operation could be developed among students. This sense of co-operation may be realised through the lessons' group activities whereby learning can be a shared process rather than individualistic one. The sense of co-operation could also be extended between students and teachers. If teachers trust that their students can perform activities from the exemplary materials given proper guidance, students, in turn, may develop an understanding of teaching and learning as a process, rather than a teacher-centred one.

As for the instructional objectives, teachers said they were clear and achievable, and the lesson contents were relevant. They added that the lessons could fit into teachers' schemes of work though the size of the classes could hamper proper execution of the lesson activities.

Regarding homework and test ideas, they noted that they had no answers prepared for them. They contended that this could limit their use of the materials. They argued that if the materials were to help teachers improve their knowledge in probability, then they should have the answers to questions which would enable them to check whether they are right or wrong. These revisions were taken into account.

4.4 SCHOOL-BASED SEMINAR

To support mathematics teachers enhancing their PCK&S in the teaching of probability, a 5-day school-based seminar was considered an important component of the COSMAT programme. The aim of the seminar was to introduce teachers to exemplary materials on probability, as well as an activity-based teaching approach. Also, the seminar was aimed at introducing teachers to peer collaboration as a means of enhancing their PCK&S. At the seminar, it was expected that teachers would get the opportunity to enhance their PCK&S through the following:

- demonstration lessons;
- group work;
- co-planning of the lessons;
- micro-teaching sessions.

In terms of learning, teaching and professional development, it was expected that the seminar would achieve to:

- expand teachers' knowledge of probability and how to teach it;
- provide teachers with time away from their classrooms and the opportunity to reflect, argue alternative explanations, interact with their colleagues, and practice new ideas and techniques in safe settings. It is in this setting where teachers can freely express their areas of deficiencies and thus get support from their colleagues (Joyce & Showers, 1995; Showers, 1985).

The first outline of the five-day school-based seminar was prepared by the researcher in collaboration with the facilitators of the three schools for two main reasons. First, because they are all teachers and heads of department at their respective schools, they could give information as to what would an appropriate time for the seminar to take place at the school. Second, it was one step towards making them assume a leadership role in the programme. This does not mean that each school had a different seminar programme, but rather a different timetable for the programme. This was due to the fact that the schools differed in terms of their operational programmes. Two of the three schools, for example, had double sessions per day, so, during school hours it was not possible to organise the seminar because mathematics teachers from the two sessions could hardly meet. Moreover, the agreement was made between the school administration and researcher to sandwich the seminar programme between school hours.

The outline was prepared with reference to the insights given in design guideline four. The decision on the duration of each activity in the outline was based on the importance of the activity and the number of the participants. The outline included the following:

- a presentation about the meaning of activity-based teaching in relation to the learner-centred teaching learning approach;
- a presentation and discussion on the peer collaboration guidelines;
- a subject matter presentation whereby facilitators would teach of all the lessons;
- a discussion of taught lessons (20 minutes for each lesson);
- a micro-teaching session whereby all participating teachers would practice teaching activity-based probability lessons by preparing short 20-minute lessons.

The outline was then taken to two experts: one from the University of Twente (UT) and the other one from the University of Dar es Salaam (UDSM). The experts suggested that there should be a session where teachers could become familiarised with the materials as well as the activity-based lessons. They also suggested that for

the subject matter presentation, facilitators should demonstrate one lesson only so that the participants could discuss the remaining lessons for clarity. These suggestions were taken into account. A detailed description of the seminar is given under the seminar programme design.

Seminar programme design

At each of the three schools involved in the study, a 5-day seminar of two hours a day was planned. The first 3 days were to be used for introducing the programme and the exemplary materials; demonstration lessons; group discussions; and co-planning of the lessons. The last two days were spent on micro-teaching sessions. Table 4.3 shows the seminar programme.

Table 4.3: Seminar programme

Day	Title	Activity
1	The meaning of the activity based lessons (25 min.)	Presentation and discussion of the activity based lessons in relation to the learner-centred teaching/learning approach
	Introduction to the exemplary teaching material (20 min.)	Description of the exemplary materials
	Collaboration guidelines (45 min.)	Presentation and discussion of the peer collaboration guidelines and the observation checklist
2	Demonstration lessons (60 min.)	One facilitator conducts a lesson on 'probability of an event' from the exemplary materials for other participants
3	Group work (80 min.)	Teachers discuss the remaining lessons in the exemplary teaching materials in groups. Plenary sessions on the discussed lessons arranged
	Co-planning of the lessons (40 min.)	In groups of two, teachers plan lessons on a combination of probabilities, mutually exclusive events and independent events.
4 & 5	Micro-teaching sessions (20 min. for each teacher)	Each teacher teaches a co-planned lesson from the exemplary materials to a group of teachers while other teachers observe by using the observation checklist
	Plan for implementation of the seminar activities (55 min.)	Planning the implementation of the activities learned from the seminar in a real classroom situation.

The major components of the seminar are described in more detail below:

(i) *A demonstration lesson* was to be conducted by facilitators. They were to use one of the lessons from the materials. The aim of this exercise was to support mathematics teachers in acquiring subject knowledge in probability. Also the demonstration lesson was aimed at showing teachers how the teaching of probability lessons using activity-based approach, which is relatively new to many mathematics teachers in Tanzania, is conducted in practice (see Joyce & Showers, 1995; Showers, 1985).

(ii) *Group discussion*. In this session, teachers were to have opportunity to discuss the remaining lessons in the materials in detail. It is argued that learners' learn best when they are actively involved in the process (Davis, 1993). Tobin (1993) asserts that explaining something to a peer usually leads one to see things more clearly and spot inconsistencies in one's own thoughts. In small groups of 3-4, teachers were expected to discuss the following lessons: *probability of combined events*; *mutually exclusive events*; and *independent events*. The aim of this exercise was to enable teachers to gain more insight about the lessons. Through the exercise, teachers would point out areas that were not clear, as well as those that appeared difficult. This would be supplemented by a plenary discussion whereby teachers would express their opinions about the areas that were noted unclear and difficult.

(iii) *Co-planning of the lessons*. In this exercise, it was planned that teachers would form into pairs. Each pair would then co-plan two 20-minute lessons, one for each member of the pair. The aim of this practice is to give teachers an opportunity to share ideas on how probability could best be taught using the activity-based approach, given the prevailing conditions in their schools, such as large classes, lack of appropriate teaching aids, and so on. It was also aimed at giving teachers collaboration experience.

(iv) *Micro-teaching*. Micro-teaching sessions were aimed at enabling teachers to practise the teaching of probability in a simplified situation (see Joyce & Showers 1995, van den Berg, 1996). Each participant would present his/her co-planned lesson, which would then be followed by discussion. In this exercise, the participants would switch roles, participants –teacher, observer and student. The observer would note the events during the lesson. The events recorded were used as the basis for discussion after the lesson. This exercise was expected to help teachers gain experience on how to conduct classroom observation.

4.5 PEER COLLABORATION

Peer collaboration plays an important role in the COSMAT programme. In order to support mathematics teachers gain more insight into conducting collaborative activities, a pamphlet with essential guidelines for peer collaboration was prepared by the researcher. Insights about the guidelines were gained from different sources (Pugach & Johnson, 1995; cf. Robbins, 1991; Thijs, 1999). The guidelines consisted of the following ideas:

- Definition of peer collaboration.
- Rationale for peer collaboration.
- Examples of peer collaboration activities.
- Guidelines for collaboration.

The guidelines were to support mathematics teachers in conducting different kinds of collaborative activities to enhance their PCK&S. The first draft of the guidelines was taken to two experts: one in mathematics education and the other in teacher education with vast experience in conducting in-service programmes. Experts were asked to comment on the relevance of the guideline's contents and the pamphlet's structure in general.

Regarding the content, the experts said that guidelines should focus more on guiding teachers in conducting peer collaboration in general terms rather than classroom activities such as observation and mentoring. This is due to the fact that teacher collaboration does not take place inside the classroom only. It takes place outside the classroom, as well. They added that since the programme involves the facilitators, a section addressing their role in the peer collaboration should be included in the pamphlet. Thus a broader definition of peer collaboration was made. Among the collaborative activities suggested were as follows:

a. *Co-planning of the lessons:* In this exercise, teachers were encouraged to co-plan their lessons together to share ideas as to how probability could best be taught, given the prevailing conditions in their respective schools.
b. *Classroom observations:* Mathematics teachers were to visit each other's classrooms, especially when teaching probability lessons. The classroom observation was to be followed by feedback. Feedback about the performance helps improve the teaching approaches by reinforcing mastery and providing hints for reinforcement (Showers & Joyce, 1996; Gottesman & Jennings, 1994). In short, the main function of coaching is to reinforce the teaching approaches acquired in the seminars. During prior classroom observations, there would be a follow-up meeting between the researcher and teachers in their respective

schools about how to conduct collaborative activities. During the meeting, they would receive and refine collaborative skills.

c. *Team teaching*: Teachers at each school would be encouraged to conduct team teaching. This exercise was expected to give all mathematics teachers in the department the opportunity to teach lessons after the seminar. This is because probability is taught in Forms 4, so those teaching other forms have to wait for a year or two before they teach the topic. The aim of the exercise was to enable teachers to teach the topic right after the seminars to consolidate the knowledge and skills they gained. It may also foster collegiality and build motivation and shared responsibility for implementation (Sparks, 1993)
d. *Study groups*: Mathematics teachers at each school were expected to form small groups that would discuss problems in the teaching and learning of mathematics in their respective schools. Also the groups would be the basis of supporting one another in implementing probability lessons in an activity-based way.

After the seminars, teachers were expected to implement programme ideas by actually teaching the probability lessons in real classroom situations and conducting collaborative activities.

4.6 FACILITATORS

The essence of facilitators in the COSMAT programme is to fulfil the leadership role as emphasised by design guideline six. From each of the three schools, two teachers were to be selected as facilitators. They would be members of the development team (DT), play a role in the seminar and were expected to role-play later in peer collaboration. To select the facilitators among teachers from schools, two conditions were used as explained in section 4.3.1. The first task of the facilitators was to participate in the exemplary materials development workshop as members of the development team (see section 4.3.1). After the workshop, facilitators were asked about its benefits. All of them valued the workshop as very useful enhancing their subject matter knowledge, as well as their knowledge of teaching mathematics in an activity-based way (see section 4.3.2).

As facilitators, their major role is to help their colleagues enhance their PCK&S through demonstration lessons during the seminar and provide them with on-the-spot support as they implement the programme ideas in a real classroom situation. Their other role was to organise and co-ordinate collaborative activities.

4.7 SYNTHESIS

In this chapter, a presentation was made of the COSMAT programme's design and development with reference to insights gained from the context analysis and literature study pinpointed in the design guidelines. The development of the programme, which involved different groups, focused on mathematics teachers. The programme aimed at supporting O-level secondary school mathematics teachers to enhance their PCK&S in teaching the subject. Moreover, emphasis was placed on the subject matter knowledge because of teachers' need for support in this area. To avoid superficial coverage of many topics, probability was selected to be the main focus of the programme. This topic was selected because many teachers perceived it as difficult to understand and teach as it created many misconceptions that needed to be addressed.

Schools were involved right from the beginning in the programme's development. The main purpose of this was to meet teachers' learning needs and help them develop a sense of ownership of the programme among teachers. Teachers brought in their own experiences from the classroom during the development of different programme components.

Peer collaboration was considered an important component of the programme in this improvement effort as teachers could support one another by using different strategies throughout the programme. To support teachers with peer collaboration, an outline of peer collaboration guidelines was prepared. The guidelines were intended to help teachers conduct peer collaborations both inside and outside the classroom.

The exemplary materials formed another important component of the programme. The materials contained four activity-based lessons that covered the probability content of the O-level syllabus requirement. The lessons were prepared in an activity-based way to support teachers with a learner-centred approach. The materials also contained procedural specifications to help teachers execute lessons in a step-by-step, logical way. The intention was to facilitate student participation in the classroom. The materials were developed by a development team (DT), which was composed of six O-level mathematics teachers from three schools; four teacher education college mathematics tutors; and two TEAMS project members (including the researcher). By involving teachers in the development team, they could enhance their subject matter knowledge in probability and learn how to teach it in an activity-based way. The materials were then subjected to expert

appraisal and tryout on a small scale, which subsequently led to its improvement. This is different from how materials are usually developed in Tanzania, where they are taken to schools for use without been subjected to intensive formative evaluation process. It is useful to have this kind of formative evaluation to get suggestions and opinions that would improve the materials.

Although the content of the exemplary materials was highly appreciated by teachers, a major problem was noted during the execution of the activity-based lessons. Although care was taken not to involve other complex forms of learner-centred teaching, few teachers could handle an activity-based approach due to the large class size and a difficulty deviating from the chalk-and-talk method. The activity-based approach appeared quite innovative to them. This shows that the exemplary materials alone were not enough; the seminar coupled with peer collaboration was critical to support the teachers in gaining insight on how to conduct activity-based teaching.

The school-based seminar was another important component of the COSMAT programme. The seminar aimed at introducing teachers to peer collaboration as well as supporting them to acquire subject matter knowledge through demonstration lessons and group work. The seminar was also aimed at introducing teachers to activity-based lessons.

Despite the fact that facilitators were used in supporting their colleagues through demonstration lessons and in organising collaborative activities such as co-planning and team-teaching, there was no special support activity for them. It was expected that their teaching experience and participation in the materials development workshop would be sufficient in supporting their colleagues. Their primary focus was to support mathematics teachers in acquiring subject matter knowledge first, bearing in mind the time constraints of the programme.

CHAPTER 5
Formative evaluation and revision of the programme

This chapter presents the results of a formative evaluation study and the revision of the COSMAT programme. The programme was aimed at enhancing mathematics teachers' PCK&S in teaching probability. The focus of the study was exploring teachers' reactions to the programme, specifically to the school-based seminar where teachers were first exposed to it. The study also focused on teachers' use of programme ideas in practice, both individually and collaboratively. Section 5.1 presents the study's design, where research questions, participants of the study, and data collection methods and instruments are described. While section 5.2 describes the implementation of the school-based seminar, section 5.3 presents the study's results focusing on teachers' reactions to the school-based seminar. Section 5.4 presents the results of teachers' use of the programme ideas in practice. Section 5.5 presents students' experiences and opinions of the programme. The conclusions and recommendations for the improvement of the programme are presented in section 5.6 while section 5.7 describes the development of the revised COSMAT-2 programme.

5.1 DESIGN OF THE STUDY

The major purpose of the COSMAT programme was to support O-level secondary school mathematics teachers in enhancing their pedagogical content knowledge and skills (PCK&S) in teaching mathematics, specifically probability. In achieving this, the programme consisted of the following components: a school-based seminar; exemplary curriculum materials; and peer collaboration. This section presents the design of the formative evaluation study of the programme. Included in the section are research questions that guided the study, participants, data collection methods and instruments, and data analysis methods.

5.1.1 Aims and research questions

The purpose of the formative evaluation study was to find ideas that would help to improve the COSMAT programme. The study used three levels of evaluation of the professional development programme, inspired by Guskey's (2000) levels. They are as follows:
Level 1: Participants' reactions to the programme.
Level 2: Participants' use of programme ideas in practice, whereby the focus is on individual use (2(a)) and collaborative use (2(b)).
Level 3: Students' experiences and opinions about probability lessons.

Evaluation at the first level allowed for insight into the participants' initial reactions to the programme. Guskey (2000) argues that measuring participants' initial satisfaction with the experience provides information that can help improve the design and delivery of programmes or activities in valid ways. He adds that positive reactions from the participants are usually necessary prerequisites to higher level evaluation results. In exploring teachers' reactions to the programme, the study focused on teachers' general impressions about the seminar and its components, and teachers' perceptions of the seminar in enhancing their PCK&S and promoting peer collaboration. Thus on determining teachers' reactions to the programme, the study was guided by the following questions:

What are teachers' general impressions about the school-based seminar and its components?
What are teachers' perceptions of the school-based seminar in enhancing their PCK&S when teaching probability?
What are teachers' perceptions of the school-based seminar in promoting peer collaboration among teachers?

The evaluation at the second level was aimed at exploring how teachers used the programme ideas in practice. It helped to gather information about whether or not programme ideas were used, and how well they were used (cf. Guskey, 2000). This is expected to improve students' performances in the long run. It specifically focused on exploring teachers' use of programme ideas individually when teaching probability lessons in the classroom and the extent to which they used the exemplary materials introduced to them in the seminar. In the seminar, teachers taught a short lesson (micro-teaching) in a simplified situation by using the exemplary materials. That is, they taught part of a probability lesson involving 1-2 classroom activities to a small group of students or colleagues for about 20 minutes. In preparing themselves for the micro-teaching lessons, they chose the areas they would be comfortable teaching. However, in practice, in the real

classroom situation, they had to teach the whole topic, which included several activities to be covered within one lesson. It was considered important to explore whether the programme had helped enhance their PCK&S in teaching probability in this more complex and challenging, real classroom situation. That is, to see whether they could handle a number of activities in the lessons, ensuring maximum participation of the students, while taking into consideration the large size of the classes. Also the study is interested in getting information on the extent to which teachers used exemplary materials in teaching. This situation leads to the following research question:

How do teachers perceive and use exemplary materials?

The second level also focused on the use of programme ideas collaboratively. The aim of the programme was to help teachers organise and conduct collaborative activities with the expectation that it would help them enhance their PCK&S. In this case, the study is guided by the following:

How do teachers collaborate in their school context?

What are teachers' perceptions of peer collaboration?

Sometimes the impacts of change or innovation are not directly observable. In such cases, useful information can be gained through those individuals who are most directly affected by the change or innovation, such as the students (cf. Guskey, 2000). Students are known to be keen of changes in the classroom practices and can provide important information on both the levels of use and differences in practice. In this perspective then, the study is guided by the following research question:

What are students' experiences with and opinions about the probability lessons?

5.1.2 Participants

In the school-based seminar there were 26 participants drawn from three O-level secondary schools. These were the schools from which the facilitators (members of development team (DT)) were drawn. The reasons for selecting the schools were given in section 4.2.1. Table 5.1 shows the number and qualification of mathematics teachers from the three schools who participated in the school-based seminar.

Table 5.1: Participants of the school-based seminar

	Qualification		
Gender	*Diploma*	*Graduate*	*n*
M	21	2	23
F	3	–	3

From Table 5.1 it can be seen that the majority of participants (n = 24) of the seminar were male diploma teachers, which is typical of mathematics teachers in Tanzania.

After the school-based seminar, two out of the three schools were explored putting programme ideas into practice. The two schools were selected for a number of reasons. One of the schools is located in Dar es Salaam where the researcher lives, so it was easy for him to monitor and follow-up the progress of the programme. This school also had a considerable number of mathematics teachers (n=12). The second school had an administration that was very supportive of the programme and teachers that showed a great deal of interest in it. Therefore, it was expected that they would contribute in-depth information that would help improve the programme. The third school was omitted because the school leadership, of late, was not very supportive in facilitating the implementation of the programme because of other organisational commitments. Due to this situation, it was not feasible to continue with the programme at this school because it would have been very difficult to secure co-operation from both teachers and school leadership.

At the two schools all mathematics teachers participating in the seminar were involved in all collaborative activities such as co-planning of the lessons, classroom observation, team-teaching and study groups. It was during this stage that the influence and contribution of facilitators supporting their colleagues and organising peer collaboration was explored. At the two schools, one had 10 participants (8 teachers and 2 facilitators) and the other one had 5 participants (3 teachers and 2 facilitators). All the participants were male except one female. Table 5.2 gives the summary of the participants' profile.

Table 5.2: Summary of the participants' profile

Characteristic	**Mean**	**SD**	**N**
Age (years)	36	7.1	15
Teaching experience (years)	10	9.0	15

Apart from teachers, a total of 27 students from the two schools, 13 (out of 47) students from one school (6 boys and 7 girls) and 14 (out of 49) from the other (7 girls and 7 boys) were involved in the study. From both schools, students were selected randomly in such a way that an equal of number of boys and girls were selected. The summary of the students' profile is given in Table 5.3.

Table 5.3: Summary of students' profile

Gender	**Mean age (years)**	**SD**	**n**
Boys	18	1.2	13
Girls	17	0.9	14

From Table 5.3 it can be seen that the mean age of boys is 18 and that of girls is 17. The variation between their age is not very big though it appears that the boys' age is more spread out than that of the girls.

5.1.3 Data collection methods and instruments

Different data collection methods and instruments were used depending on the nature of the programme activity to be carried out and the research question to be answered (see Figure 5.1).

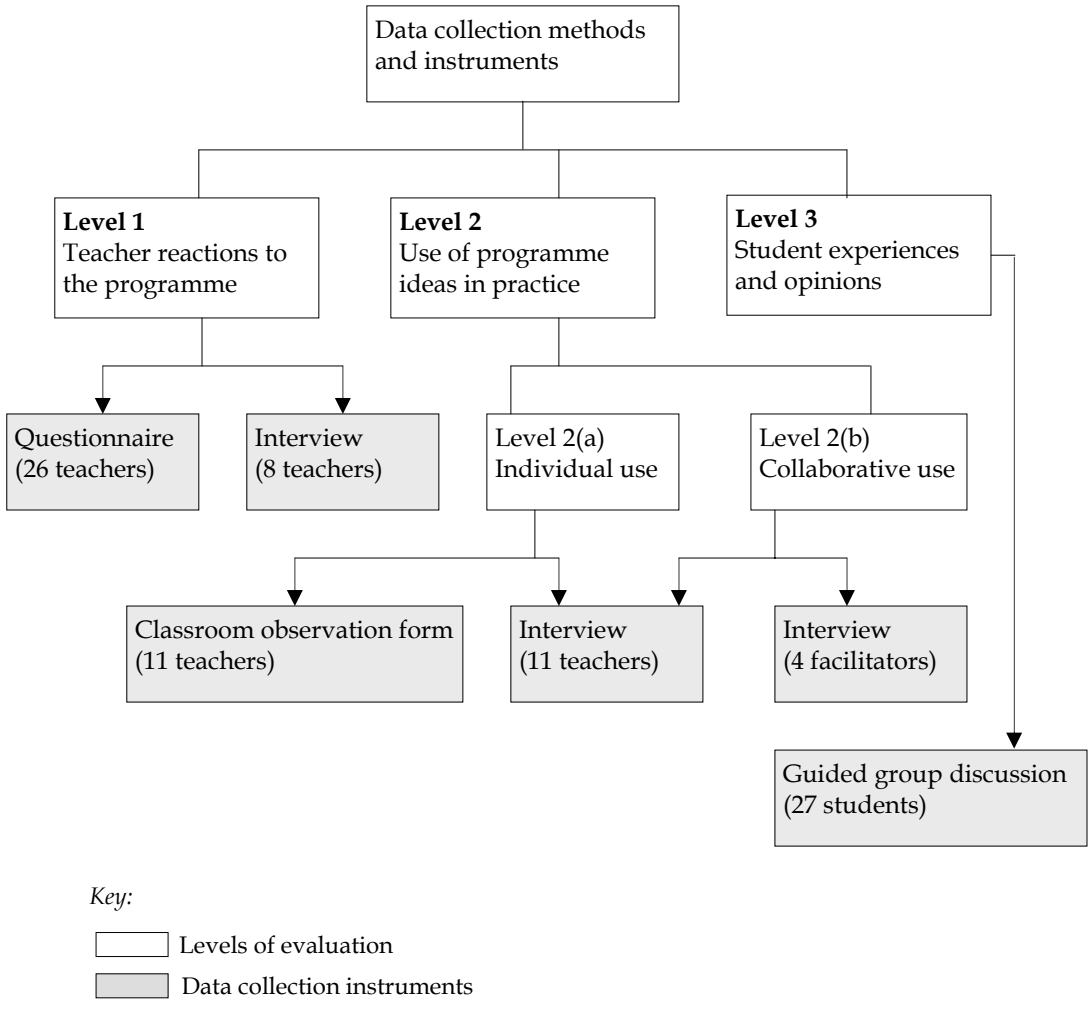

Figure 5.1: Overview of data collection methods and instruments

Questionnaire

The questionnaire was used to collect teachers' reactions about the programme after the seminar. It consisted of both close-ended and open-ended questions **(see Appendix B)**. The close-ended questions included participants' general information such as age and teaching experience. They also included five-point

Likert scale and dichotomous (Yes or No) questions that focused on teachers' opinions and perceptions about seminar and its sessions, and the usefulness of other programme components during the seminar. The open-ended questions focused more on the issues that needed clarification about teachers' expectations, perceptions and opinions of the seminar. Also, questions on suggestions for improving the seminar were asked.

Classroom observation

Classroom observation was conducted to explore the teaching of probability lessons in a real classroom setting and the extent to which teachers used the exemplary materials. All the mathematics teachers participating in the school-based seminar from the two schools were involved. During the observation, the researcher took notes that were summarised as the lesson report immediately after the lessons. Again, shortly after the lesson, the researcher completed the classroom observation form.

The classroom observation checklist **(see Appendix C)** used in this study was adapted from the observation form used by Thijs (1999) from her Botswana study of the effectiveness of the programme supporting teachers with the implementation of a learner-centred education. However, several modifications were made so as to suit the requirements of this study. The observation form focused on teacher's performance in the teaching activity-based lessons by looking at his/her ability to achieve the following:

- introduce the lesson;
- define important probability concepts;
- introduce classroom activities;
- answer students' questions;
- organise and supervise students' activities;
- Involvement of students in performing activities.

Observation of collaborative activities

Apart from classroom observation, collaboration activities taking place in the mathematics departments were also observed. In order to facilitate data collection on these activities, facilitators were asked to note the types of activities that were taking place, the teachers involved and the frequency of activities. Information collected was used to complement the information collected by the researcher when he visited the schools.

Interviews

Interviews were conducted to gather information from mathematics teachers and facilitators. At the end of the seminar, an interview was conducted with eight mathematics teachers who were selected by using purposive sampling from each school. Purposive sampling refers to the intentional seeking or selecting of individuals or situations likely to yield a greater understanding of the phenomenon of interest (Creswell, 2002; Krathwohl, 1998). The criterion for choosing the individuals or situations is whether they are "information rich" (Patton, 1990). The eight teachers were selected based on the interest they showed in participating in the programme. They were expected to give in-depth information about the seminar to supplement the information gathered through questionnaires. The interview scheme used is shown in **Appendix D**.

The interview was conducted after teachers had filled in the questionnaires. To start with, questionnaires were distributed first to the teachers on the last day of the seminar. After collecting them, the researcher had to conduct interviews with facilitators and teachers. However, before doing this, he went through all the questionnaires so as to get a general picture of the teachers' responses. The exercise helped him note areas that would need special emphasis and clarification during the interviews.

After teachers taught the probability lessons, an interview was also conducted with them to supplement information collected through classroom observation and the observation of peer collaboration activities. The interview schemes for teachers consisted of questions that addressed the following:

- perceptions of the lessons they taught;
- perceptions of the usefulness of exemplary material in facilitating the teaching of probability in a real classroom situation;
- perceptions of the collaborative activities in enhancing their knowledge in probability;
- additional comments about the impact of the COSMAT programme in enhancing pedagogical content knowledge and skills in teaching probability.

Also, throughout the interviews, the facilitators were expected to give in-depth information to supplement information gathered from teachers regarding the organisation, impact and value of the seminar. The interview scheme used with the facilitators is shown in **Appendix E**.

Guided group discussion

Through guided group discussions, students' opinions about the activity-based probability lessons, as well as the teaching approach used for teaching the lessons,

were sought. This is because the ultimate goal of any professional development in education is to improve student learning (cf. Guskey, 2000). The guided group discussion focused on the following issues:

- students' opinions about the lessons in general;
- students' most and least interesting lessons;
- students' opinions on the usefulness of probability.

The discussions were audiotaped. The questions for students guided group discussions are shown in **Appendix F**.

5.1.4 Data analysis procedures

In the study, two types of data analysis procedures were used. First, the means, the standard deviations and percentage, were computed on quantitative aspects of the data. The means and standard deviations were used to determine the positiveness of teachers' opinions and perceptions about the school-based seminar, while the percentage was used to determine teachers' readiness to use what they have learned in the seminar.

Second, teachers' responses about open-ended questions from the questionnaires, interviews and guided group discussions were analysed qualitatively using data coding procedures. According to Miles and Huberman (1994), codes are labels for assigning meanings to the descriptive inferential information compiled during the study. Based on the conceptual framework, the labels were formed in relation to the patterns that emerged from the information collected during data analysis.

Data collected through classroom observation and collaborative activities observation also produced qualitative data. For the classroom observation, comments were made and recorded on how teachers performed in presenting the subject matter, while their teaching skills as perceived by the researcher during the teaching of activity-based probability lessons were also recorded. The data focused on teachers' proficiency in presenting and defining different probability concepts; their ability to clarify classroom activities; and their ability to involve students in doing the classroom activities. The findings were labelled 'sufficient,' 'satisfactory' or 'more support needed.' The teacher who managed to do the mentioned activities with little difficulties was considered as having sufficient knowledge for that level. The teacher who could present and define probability concepts with a low level of difficulty and a considerable amount of student participation, was considered satisfactory. The teacher who had difficulties in defining probability concepts and had insignificant student participation was considered to be in need of more support.

Data was also collected through observation of the collaborative activities conducted in schools. In this regard, data was categorised depending on the nature of activities carried out by the teachers, as recorded by the facilitators and the researcher. The data focused on the frequency of the activities performed by teachers involved and the constraints teachers faced in conducting the activities.

5.2 IMPLEMENTATION OF THE SCHOOL-BASED SEMINAR

The school-based seminar was conducted at the three secondary schools according to plan (see section 4.4). At one of the schools, the seminar was run at the end of the normal class hours to allow teachers to teach their regular lessons. Because of having double sessions, the two other schools ran the seminar in the middle of the day, around lunchtime, to allow teachers from the two sessions to participate. Most of the seminar sessions were covered as expected. The introduction of the important aspects of the seminar, which included a definition of activity-based teaching and introduction to exemplary materials and peer collaboration guidelines, occupied the first day. On the second day, facilitators conducted a demonstration lesson. Through prior arrangement with the researcher, two facilitators from each school prepared and co-planned the demonstration lesson on Lesson 1 (*Probability of an event)*. During this session, which ran for 60 minutes, facilitators acted as teachers while the teachers acted as students. The demonstration lesson was followed by a discussion about the lesson. Thereafter, the planning of the group work activity was done.

On the third day of the seminar, participants had a plenary session to discuss the remaining lessons in groups. During the discussion, teachers identified and noted areas that they needed more clarification. Also, they noted the areas that they felt were not well presented or well written. Thereafter, one of the group members presented the group concerns in the plenary session, where all the groups met. Through the exercise, clarifications were made about the area were teachers raised their concerns.

After the demonstration lessons and plenary session, the co-planning of the lessons for micro-teaching followed. Teachers did this exercise in groups of two and it was planned that the exercise could take 40 minutes. However, this plan was not realistic because teachers were unable to finish co-planing two 20-minutes lessons. Therefore, the exercise was turned into a home assignment, where teachers were given time to prepare the lessons and present them the next day.

The last two days of the seminar were used for micro-teaching. Some teachers could not finish their lessons on time because of overestimating the portion to be taught or taking more time in clarifying some concepts. During the micro-teaching sessions, teachers conducted classroom observation by using observation forms. However, the observation forms could not be filled properly because of the large number of items to be observed. Therefore, teachers resorted to noting down issues that they thought important to discuss after the lessons.

5.3 PARTICIPANTS' REACTIONS TO THE SEMINAR

This section presents the results of the formative evaluation study regarding teachers' reactions to the programme. In this case, the findings were categorised into the following areas: teachers' general impressions about the programme and teachers' perceived benefits of the school-based seminar in enhancing their PCK&S. Also in the section, the presentation is made about teachers perceived benefits of the seminar in enhancing peer collaboration.

5.3.1 General impressions about the school-based seminar

To get general impressions of the seminar, teachers were asked to indicate whether it was useful and had met their expectations. These issues were asked to determine if the seminar had managed to address teachers' learning needs as identified during the needs assessment. It was important to address these needs in order to make teacher learning from the seminar more likely. Table 5.4 shows teachers responses regarding these issues.

Table 5.4: Teachers responses about their general impressions on the seminar

	Mean*	**SD**	**N**
Seminar being useful	4.8	.4	26
Appropriateness of the seminar approach	4.6	.5	26
Seminar meeting the expectations	4.5	.6	26

Note: * 5 = Highly positive, 1= Highly negative.

From Table 5.4 it can be noted that teachers' impressions about the seminar were generally positive. They considered the seminar to be useful. They also said that the seminar approach was appropriate, and that it met their expectations. This might be due to the experiences some of them had with other seminars that they attended before. One teacher said that the seminar was different from others he attended before. Citing an example, he said:

"If I compare this seminar and the other one I attended early March 2000, this one is different in the sense that it aroused the attention and interest of every teacher who attended it. It also encouraged us not to be static in what we are used to; we must exchange ideas among ourselves."

Point of view about seminar logistics and arrangement

Generally, teachers viewed the seminar logistics and arrangements positively as shown in Table 5.5.

Table 5.5: Teachers' opinions on seminar logistics and arrangement

Aspect	**Mean***	**SD**	**N**
Communication between the participants and the co-ordinator	4.8	.4	26
Communication between the participants and facilitators	4.6	.7	26
Information about the seminar	4.4	.5	26
Selection of the facilitators	4.2	.8	26
Seminar organisation	4.2	.7	26
Materials used	4.2	.8	26
Seminar atmosphere	4.0	1.0	26

Note: * 5 = Highly positive, 1 = Highly negative.

Table 5.5 shows participants rated communication between the participants and the co-ordinator and between the participants and the facilitators highly positive. The reason for this could be the frequent contact among these parties about the seminars before and during the seminars. Others items were also rated highly positive, except for the seminar atmosphere which was rated moderately positive. This is because some teachers had the opinion that this seminar would have had greater impact on them if it were run outside of the school environment, where unnecessary disturbances could be avoided.

Opinions about the seminar sessions

Teachers generally showed positive responses about the seminar sessions as shown in Table 5.6.

Table 5.6: Participants' perceptions about the seminar sessions

Session	Mean*	SD	N
The presentation of the exemplary material	4.6	.5	26
The demonstration lesson on the probability of an event	4.6	.5	26
Presentation and the discussion of the activity-based lessons in relation to learner-centred approach	4.5	.5	26
Co-planning of the lessons	4.5	.7	26
Presentation and discussions on the peer coaching guidelines	4.5	.5	26
Lessons discussions: combination of probabilities, mutually exclusive events and independent events	4.4	.5	26
Micro teaching lessons coupled with observations	4.4	.6	26

Note: * 5 = Highly positive, 1 = Highly negative.

Table 5.6 shows how teachers valued the different seminar sessions. They considered the presentation of the exemplary material and the demonstration lessons as the most useful. Teachers also regarded the presentation and the discussion of the activity based lessons in relation to learner-centred teaching; co-planning of the lessons; and presentation and discussions of the peer collaboration guidelines positively. Discussions of the remaining lessons and micro-teaching sessions were also valued positively.

Opinions about the exemplary materials

In the interviews, all eight teachers considered the exemplary teaching materials as useful to them during the seminar. They gave several reasons:

- they made clear each subtopic in probability.
- they were easy to follow.
- Teachers gained new knowledge in the topic and how better to teach it, as a result of the materials.
- they simplified the lesson preparation.

Facilitators' opinions about the usefulness of exemplary materials during the seminar were also sought. All four facilitators argued that materials were helpful because one needed a very short time to prepare during presentations and that there was no need to prepare separate lesson plans and lesson notes. In connection with this, they said, if possible, they would be pleased to have copies of similar kinds of materials for other topics in their schools, as well.

Future use of the exemplary materials

After using the materials in the seminars, all eight teachers claimed that they would use them in their classrooms. Seven teachers said that they would use the materials because they were practical and activities were clearly defined in a way

that would enhance understanding of the topic among students. Five teachers said that they would use the materials for teaching because of its relevance, and that the content covers the probability content as required in the current basic mathematics syllabus. Along with the reasons given by the aforementioned teachers, two intended to use the materials not only because they could arouse the interest of the students to like the topic, but also because they could promote full participation in the teaching and learning process. As one teacher said:

> "*I will use the materials because they will help my students to develop self-confidence and inquiring minds. For me, the material will make the teaching of probability easy.*"

Other opinions regarding the materials included:

- The lessons in the material are presented systematically; thus, they simplify the teaching of the topic (6x).
- It involves students in doing classroom activities, which may encourage them to like the topic (4x).
- The lessons on probability provide a good base for teaching the topic (3x).

In general, participants were positive about the seminar and its components. They considered it useful as it had increased their confidence and competence in teaching probability. However, they proposed more time for the seminar, especially for the co-planning of the lessons and micro-teaching sessions to give teachers more time to plan and practice the activity-based teaching. Teachers and facilitators indicated that the exemplary materials were very useful during the seminar.

5.3.2 Teachers' perceptions of the seminar in enhancing their PCK&S

Since the aim of the programme was to enhance teachers' pedagogical content knowledge and skills (PCK&S), teachers were asked to indicate the extent to which they had benefited from the school-based seminar in this respect. Table 5.7 shows teachers' reactions about the benefits.

Table 5.7: Teachers' perceptions of the seminar in enhancing their PCK&S

Statement	Mean*	SD	N
The seminar has increased confidence in teaching probability	4.5	.6	26
The seminar has given sufficient methodological skills on how to teach probability better	4.5	.7	26
The seminar has broadened knowledge on probability	4.3	.5	26

Note: * 5 = Highly positive, 1 = Highly negative.

In expressing their opinions about the benefits of the seminar in their subject matter knowledge and perceptions of probability, the participants argued that the seminar

had increased their confidence in teaching the topic as shown in Table 5.7. Also, the participants had the opinion that the seminar had broadened their knowledge in the topic.

In general, all the teachers admitted that they had benefited in different ways from the seminar in both subject matter and teaching skills. Along with being exposed to activity-based teaching, one teacher also learned about probability for the first time at the seminar. He admitted that in his school days, he had never been taught this topic.

5.3.3 Teachers' perceptions of the seminar in enhancing peer collaboration

Through the questionnaire, teachers were asked to show the extent to which they agreed or disagreed with the statements related to peer collaboration. The information collected would help to design future collaborative activities that would benefit teachers. Their ratings about the phenomenon are shown in Table 5.8.

Table 5.8: Teachers' perceptions of the seminar contribution on peer collaboration

Statement	Mean*	SD	N
The seminar has furnished me with adequate information on how to conduct peer collaboration	4.5	.6	26
The seminar has provided me with clear picture on how to conduct collaborative activities	4.5	.6	26
The seminar has changed my opinion about peer collaboration	4.0	1.0	26

Note: * 5 = Highly positive, 1 = Highly negative.

Table 5.8 shows that teachers were positive about the seminar's contribution as it furnished them with adequate information and a clear picture on how to conduct peer collaboration. They also indicated that the seminar had changed their opinions of peer collaboration. When asked whether they would organise peer collaboration activities in their respective schools, the majority of teachers showed that they would organise while only 15% said that they were not sure of doing so. Those who said that they would organise put forward a number of reasons:

- Collaborative activities help make teachers experts in their subjects through learning from each other better ways of teaching in the classroom (6x).
- Collaborative activities can make each teacher competent (5x).
- Collaborative activities help to increase knowledge, confidence and sufficient methodological skills in teaching (5x).
- Collaborative activities may help teachers discover hidden talents (4x).
- Collaborative activities can make teachers up-to-date (3x).
- Collaborative activities can make the teaching of mathematics easier (2x).

Those who argued that they were not sure whether they would organise the activities said that because they were just ordinary teachers they could not make decisions for what happens in their schools without consent of the school administration. However, they said that they would participate fully if these activities were to be introduced and conducted in their schools.

Teachers' opinions on the role of facilitators during the seminar

Through interviews, all eight teachers supported the idea of peer teaching through facilitators during the seminar. Seven teachers emphasised that the exercise was very important as it helped teachers improve their teaching performance through sharing experiences and expertise with their immediate colleagues. In addition, they said it helps teachers know their strengths and weaknesses. To put more emphasis on the exercise, one teacher argued that if this practice is to be consolidated in schools, it would help newly employed teachers cope with teaching responsibilities, as most schools in Tanzania lack induction programmes.

All eight teachers had the opinion that the facilitators were very useful. Apart from organising the seminar, they argued that the demonstration lessons they conducted acted as an eye opener for other teachers and that the comments they gave during the seminar were useful. However, they argued that the facilitators themselves needed an orientation programme that would help them gain more insights about activity-based teaching approaches.

Facilitators opinions

Some of the questions that appeared in the teachers' interviews also appeared in the facilitators' interviews. The questions were asked about the general opinion about the seminar; benefits from the seminar; and further support teachers needed in order to teach probability more effectively. Other questions included suggestions on further improvement of the material; support for the peer collaboration idea; strengths and weaknesses of the seminar; and general comments about the seminar. Also the kinds of responses given were more or less similar. Thus, it is not worthwhile to repeat them here. Moreover, commenting on the teachers' reactions about the seminar, four facilitators said that, given their previous experiences with false promises about these kinds of seminars, teachers did not believe that this one would have been conducted. After being conducted, they added, teachers were very happy. One facilitator said that apart from being happy about the seminar, teachers wished it lasted longer than a week so they could learn more.

Regarding organising peer collaboration in their respective departments, all six facilitators argued that they would do so. They gave several reasons for having such an opinion. One facilitator said:

> "*… Because we would like peer collaboration to benefit not only the teachers but also their students. Practice makes perfect.*"

Another facilitator said that:

> "*Yes, I expect to organise peer collaboration in my department because this is the only way teachers can support each other to improve their teaching.*"

Four facilitators said that they would organise peer collaboration activities in their departments because, through collaboration, teachers can learn different teaching approaches and minimise their problems in terms of content knowledge.

Despite appreciating the importance of peer collaboration and their role, all six facilitators admitted that support was needed to make the exercise useful. They mentioned a number of areas where they thought they would need support: administrative support in terms of time, teaching materials and motivational support such as incentives. They also said that as facilitators, they needed support in terms of skills about how to organise and conduct peer collaboration activities and how to better support their colleagues.

In short, teachers appreciated the contribution of the seminar in enhancing peer collaboration. They were most positive about the contribution of the seminar in providing them with adequate information and a clear picture of how to conduct peer collaboration activities. As a result they demonstrated their intention of organising collaborative activities because they felt that such activities could help them enhance their knowledge and confidence in teaching. In connection with peer collaboration, they supported the idea of peer teaching, as they said it was the way to support teachers' improvement.

5.4 THE USE OF PROGRAMME IDEAS IN PRACTICE

This section presents the evaluation study results of the use of programme ideas in practice. The study focused on individual use as well as collaborative use. The next section presents the individual use of the programme ideas.

5.4.1 Individual use of the programme ideas

The individual use of the programme ideas involved the teaching of activity-based lessons in the classroom in order to determine whether or not the programme fits its purpose as well as the use of exemplary materials. The teaching was done after the school-based seminar. The teachers taught co-planned lessons (see section 5.4.2). The researcher observed the lessons focusing on the teachers' subject matter knowledge and teaching methods.

The use of exemplary materials

Through classroom observation, it was noted that all eleven teachers used the exemplary teaching materials as suggested in executing their lessons. When interviewed, all eleven teachers perceived the exemplary materials useful in the execution of the probability lessons. They contended that these materials provided them with considerable support on subject matter content for the topic (8x). Also, they argued that the materials had provided them with clear guidelines on how to conduct activities that would facilitate students' understanding of the topic (7x). Other teachers went further by saying that the materials were very helpful in the planning of classroom activities that would ensure student participation and make the lesson easy to follow (6x).

However, teachers added some content from other sources, especially from the regular textbook – Basic Mathematics for Secondary Schools, Book Four, issued by Tanzania Institute of Education (TIE), in order to supplement the materials. Teachers argued that they added this textbook because the materials could not provide enough coverage about the mentioned areas. In most cases, the addition was made for students' homework assignments and teachers' notes.

Execution of the lessons

Besides the use of exemplary materials during the execution of the probability lessons, the observation was made on teachers' performance in terms of subject matter knowledge and teaching skills. Table 5.9 shows teachers' performance in terms of subject matter during the execution of the lessons.

Table 5.9: Observed teachers' performance in subject matter knowledge

Teacher	Taught lesson	Subject matter	Remarks*
H	Lesson 1	▪ Answers students questions correctly ▪ Relates activities to real life experiences.	Sufficient
J	Lesson 1	▪ Managed to clarify few concepts clearly ▪ Managed to answer some of the questions correctly	Satisfactory
K	Lesson 2	▪ Mixing up concepts ▪ Faced difficulties in answering students' questions	Support needed
L	Lesson 2	▪ Gives irrelevant information about the concepts ▪ Makes inappropriate information about the lesson	Support needed
M	Lesson 3	▪ Clarifies few concepts clearly and relates one activity to another	Satisfactory
N	Lesson 3	▪ Gives appropriate information about the lesson ▪ Correctly clarifies the results of the activities done	Sufficient
P	Lesson 4	▪ Minimal relationship between lesson and real life experiences ▪ Faces problems in clarifying concepts and new terms clearly	Support needed
Q	Lesson 4	▪ Gives clear clarification of concepts ▪ Relates activities with learners daily life	Sufficient
R	Lesson 1	▪ Faces problems in answering questions ▪ Gives inappropriate explanation about certain concepts	Support needed
S	Lesson 2	▪ Clarifies few concepts and terms clearly ▪ Answers some of the students questions correctly	Satisfactory
T	Lesson 4	▪ Answers some of the students questions correctly ▪ Clarifies few concepts and terms clearly	Satisfactory
V	Lesson 3	▪ Answers students questions clearly ▪ Defines most of the concepts clearly	Sufficient

Note: * General impression about teacher's subject matter knowledge as observed by the researcher.

Table 5.9 shows that teachers differed in terms of their proficiency in subject matter knowledge. The four teachers marked 'sufficient' were able to explain the concepts clearly and tried as much as possible to present the lessons logically. The four teachers marked 'satisfactory' could clarify few concepts clearly and the four

teachers marked 'support needed' had problems in clarifying and defining the concepts. Teachers' performance in teaching skills is shown in Table 5.10.

Table 5.10: Observed teachers' performance in teaching skills

Teacher	Presented lesson	Teaching skills	Remarks*
H	Lesson 1	▪ Maximum students participation ▪ Organised classroom activities	Sufficient
J	Lesson 1	▪ Low student participation ▪ Poor organisation classroom activities	Support needed
K	Lesson 2	▪ Low student participation ▪ Chalk-and-talk	Support needed
L	Lesson 2	▪ Moderate students participation	Satisfactory
M	Lesson 3	▪ Low student participation ▪ Chalk-and-talk method	Support needed
N	Lesson 3	▪ Maximum student participation ▪ Organised group activities ▪ Improvised teaching aids	Sufficient
P	Lesson 4	▪ Poor organisation of group activities ▪ Low students participation	Support needed
Q	Lesson 4	▪ Poor organisation of classroom activities ▪ Low student participation	Support needed
R	Lesson 1	▪ Chalk-and-talk method ▪ Low student participation	Support needed
S	Lesson 2	▪ Moderate student participation	Satisfactory
T	Lesson 4	▪ Low student participation ▪ Chalk-and-talk method	Support on student participation
V	Lesson 3	▪ Lesson well organised ▪ High student participation	Sufficient

Note: * General impression about teacher's teaching skills as observed by the researcher.

From Table 5.10 it can be seen that teachers also differed in terms of their teaching skills**.** In this aspect, three teachers were marked sufficient, which means that they involved students to a great extent and they were able to improvise teaching aids according to the requirements of the lessons' activities. They also tried to supervise closely group activities performed by students. Two teachers were regarded as satisfactory, which implies that they involved few students in doing activities. Seven teachers were labelled support needed, indicating that their teaching method was predominantly chalk and talk, with low student participation. This signifies that the programme needed to be revised in order to give more support to teachers in handling probability in terms of subject matter knowledge and teaching skills.

In short, the observation revealed that, despite teachers' positive reactions to the programme (see section 5.3), there were a number of teachers who seemed to need more support in both subject matter knowledge and teaching skills. Since teachers valued and used the exemplary materials in executing their lessons, it was considered important to improve them so as to be able to address the noted deficiencies among teachers.

5.4.2 Collaborative use

The collaborative use of programme ideas involved the implementation of collaborative activities that were introduced during the seminar. These activities included co-planning of the lessons, classroom observation, team teaching and study groups.

Implementation of peer collaboration

As a way of getting an opportunity to teach the topic after the seminar, mathematics teachers at the two schools formed pairs for the purpose of co-planning the lessons. The facilitators organised and co-ordinated the exercise so as to ensure that each pair had a lesson to teach for a Form 4 class.

Teachers conducted peer observation during the teaching of the lessons. The observation was conducted between the pairs who co-planned the lessons by exchanging roles, that teacher-observer relationship. Before going to the class, the teachers would agree on the focus of the observation. For that matter, although teachers used the observation forms, they did not follow them strictly. The teachers argued that the forms had many items, thus making them miss the important aspects of the lessons. They argued that apart from observing the colleague for the purpose of noting down issues for discussion in order to improve his/her performance, they also considered observation as a learning process, whereby the observer also gains.

The observation focused on issues related to subject matter knowledge and teaching skills. Three pairs focused on seeing how colleagues clarified probability concepts during teaching. Three pairs (n=3) focused on how colleagues organised classroom activities, student participation and the use of teaching aids.

Peer collaboration not only involves activities inside the classrooms, but also activities outside classrooms focusing on issues that would help improve teaching. Examples of such activities are study groups. After the seminar, teachers were encouraged to organise and conduct study groups at least once per month. This was not well accomplished because of other commitments teachers had in their

schools. However, teachers managed to conduct several meetings within four months after the seminar to discuss issues related to the teaching and learning of probability, and other issues that were related to the teaching and learning of mathematics in general, as shown in Table 5.11.

Table 5.11: Study groups and their focus

Schools	Teachers involved	Focus of discussion
School 1	H, J,K, L (1x)	▪ Reviewing the activity based lessons ▪ Clarification of probability concepts ▪ Past examination papers
	M,N,P,Q (2x)	▪ Planning for group activities ▪ Past examination questions ▪ Clarification of some mathematical concepts ▪ How to facilitate student participation in teaching/learning of maths
School 2	R, S,T, V (4x)	▪ Past examination papers ▪ Student involvement in teaching process ▪ Difficult topics in mathematics

Teachers' perceptions of peer collaboration

The information gathered through the interviews revealed that all eleven mathematics teachers perceived the co-planning of lessons positively. They considered it a useful activity as it helped them discover some of the weaknesses they had in the process of lesson preparations. They also considered it useful in promoting the sharing of ideas and experiences among teachers. They saw the activity as helpful in simplifying the lesson planning activity. Despite its usefulness, teachers noted some problems in performing co-planning of the lessons. The problems include the following:

- Getting convenient time to co-plan the lessons (6x).
- Lack of adequate teaching aids to facilitate students' performance of the activities during the lessons (4x).
- Agreement on the amount of time to be allocated for each component of the lesson (3x).

Regarding team teaching, all eleven teachers considered it beneficial. The major benefit noted was that it helped reduce teaching load on the part of teachers (6x). They also remarked that the exercise resulted in developing a collegial relationship among teachers (5x). One teacher went further, saying that the exercise might also help students gain confidence in their learning as a result of gaining knowledge from different teachers. The major problem noted by teachers regarding team teaching was time that would allow teachers to participate fully in the exercise due to timetable clashes and teaching sessions, if it was to be done regularly.

Regarding peer observation, all the teachers perceived it positively. They argued that the process is very useful for teachers. In expressing his opinion about peer observation, one teacher had this to say:

"*I think the observer gains like a student.*"

Regarding the problems that they encountered in conducting peer observation, teachers claimed that the school timetable made the realisation of the exercise on a regular basis difficult because teachers who had already developed good rapport among themselves could be allocated to different teaching sessions; one session can be in the morning and the other in the afternoon, thus making it difficult to plan for the exercise.

When asked about the usefulness of the study groups, ten out of eleven teachers said that they had benefited from them in terms of subject matter knowledge. They asserted that from the groups they could get clarification of some difficult concepts and subtopics as well as find solutions to difficult and challenging problems.
Regarding teaching skills, all eleven teachers claimed that they have benefited considerably from the study groups. They cited some of the benefits as:

- How to involve students in the teaching and learning process.
- Preparation of teaching aids.
- Designing classroom activities.
- How to use experiments/activities in the teaching of probability.

Teachers also indicated that they encountered a number of problems in conducting study groups. They said that it took a considerable amount of time before the group reached consensus on some of the issues they were discussing (6x). Another problem was convenient time for the group meetings (5x). This problem relates to schools that have two sessions a day. Teachers of the same groups might be located in different sessions. Also, the inadequacy of the materials facilitating teachers' discussion was singled out as one of the problems that hindered the progress of the study groups' activities (4x). Teachers gave suggestions on how to improve study groups given the circumstances in their schools:

- Fixing dates and schedules for group meetings (6x).
- Conducting frequently (5x).
- Supplying more teaching materials that could facilitate the activity (5x).

Teachers perceptions of the role of facilitators in peer collaboration

All eleven teachers argued that the facilitators played a vital role in the organisation and coordination of the collaborative activities. They cited several activities that were performed by facilitators in order to make the collaborative activities functional:

- Ensuring that all the necessary materials required for different collaborative activities were there.
- Assisting teachers in case of problems related to subject matter content.
- Liasing school time-table with collaborative activities.

Despite facilitators' useful role in supporting their colleagues, teachers cited deficiencies that needed to be taken care of in order to make them more useful. Teachers indicated that the facilitators had problems in the following areas: skills in organising peer collaboration activities and knowledge of the range of collaborative activities that can be organised in schools. Therefore, there was a need to help them acquire these skills so they could support their colleagues better.

When interviewed, all four facilitators shared similar opinions with teachers about the importance of collaborative activities. They said that these activities were useful in enhancing teacher subject matter knowledge and teaching skills. They perceived positively their role as facilitators in supporting their colleagues. However, they had the opinion that knowledge about how to organise and conduct collaborative activities was important for them in order to offer better support to their colleagues.

In summary, teachers perceived the collaborative activities and the role of facilitators as beneficial in enhancing their PCK&S. However, there were notable problems that inhibited teachers from benefiting maximally from the activities. Most of the problems were time-related, but others were more skills-related. Time-related problems could be solved depending on the situation, but skills problems required special attention. The most significant problem was facilitators' lack of skills in organising and conducting collaborative activities in their respective schools. This situation indicates the need for a support programme that would address their deficiencies in order to help their colleagues better and to make them realise more benefits from peer collaboration.

5.5 STUDENTS' EXPERIENCES

Students' experiences with probability lessons were determined through guided group discussions. The aim was to gather students' perceptions about the topic and the way it was taught. In general, all 27 students indicated having an interest in the probability lessons, as revealed through the comments they gave. The majority said that the lessons were very interesting and understandable as they were conducted practically. They reported that they had gained knowledge about different issues from the lessons, including the following:

- How probability could be used in everyday life in dealing with uncertainties.
- How to select people/things randomly.
- The reason why an event either does or does not occur in a certain experiment.
- How to express various uncertainties mathematically instead of guessing.
- Being aware that to get something that one is expecting is not always 100% sure, because there is a possibility of getting it or not.

Likewise, when asked about the usefulness of probability, all the students perceived it as a very useful topic to them. According to their opinions probability:

- relates to everyday life by predicting the occurrence of future events;
- helps to solve problems related to uncertainties in life;
- enables one to know his/her chances of winning or losing in games like the lottery, etc.;
- helps in decision making;
- helps to predict the outcomes of one's choice before making it;
- challenges the mind;
- provides an easily interpreted, quantitative chance for events to occur.

When asked their opinions regarding the team teaching approach used in the teaching of probability lessons, the students asserted that they have benefited from the experiences and expertise of different teachers. However, they contended that though the idea is good, some teachers were not well understood because their teaching approach was not very clear.

Students' perceptions suggest that they had benefited from probability lessons by gaining knowledge that was related to everyday life such as determining events that are uncertain in life, prediction of future events and decision making. Their opinions also suggest that activity-based teaching approach was useful for enhanced understanding and making lessons interesting for students. They also considered team teaching useful, though teachers' differences in handling the lessons could result in poor understanding among students.

5.6 CONCLUSIONS AND RECOMMENDATIONS

The study presented in this chapter aimed at exploring teachers' reactions about the COSMAT programme and their use of programme ideas in practice. The study also aimed at exploring students' experiences with the probability lessons. In accomplishing this mission, the study was guided by the following research questions:

- *What are the teachers' general impressions of the school-based seminar and its components?*
- *What are the teachers' perceptions of the school-based seminar in enhancing their PCK&S in the teaching of probability?*
- *What are the teachers' perceptions of the school-based seminar in promoting peer collaboration among teachers?*
- *How do teachers perceive and use the exemplary materials?*
- *How do teachers' collaborate in their school context?*
- *What are teachers' perceptions about peer collaboration?*
- *What are the students' experiences with and opinions about probability lessons?*

From teachers' perceptions, it can be concluded that the programme was successful in enhancing their PCK&S. The teachers showed that the school-based seminar enhanced their subject matter knowledge in probability, teaching skills and increased their confidence in teaching the topic. They also showed that the programme helped them gain a clear picture of how to conduct peer collaboration. In this respect, they valued the contribution of the facilitators in supporting them.

The observed use of programme ideas in practice individually revealed that the programme made a small contribution in enhancing teachers' PCK&S. Teachers used the exemplary materials for teaching the probability lessons. However, they had to consult other resources because the materials could not sufficiently cover the topic. There were a considerable number of teachers who showed the need of more support in both subject matter and teaching skills. In terms of collaborative activities, teachers managed to conduct the co-planning of the lessons, study-groups, team teaching and peer observation. Time constraint was mentioned as one of the major reasons why teachers did not organise collaborative activities on regular basis. Facilitators' lack of basic skills for organising collaborative activities was seen as another reason for the teachers' failure to organise collaborative activities on a regular basis.

For their part, students liked the probability lessons because of their practicality, showing that they appreciated activity-based teaching approach as well as the exemplary materials used for teaching the topic. They also liked team teaching approach, though the differences in teaching approaches among teachers appeared to make some of the students dislike the approach. The next section presents suggestions for the improvement of the programme.

5.6.1 Suggestions for improvement

Teachers' reactions about the programme were generally positive but the use of programme ideas in practice showed that teachers still had problems in both subject matter knowledge and teaching skills. This situation signified that the programme did not satisfactorily address teachers' needs, hence suggesting improvements in the programme. In practice, the exemplary materials were used intensively by teachers. Thus, the materials were considered a good way of helping teachers alleviate their problems related to PCK&S. Nevertheless, teachers were using other resources to supplement the contents of the materials. For that matter, the materials needed to be improved so as to be able to address better teachers' deficiencies. The major areas of improvement should include the following:

- elaborate classroom activities focusing on real life practical examples;
- experiments that can guide student to derive and verify certain principles;
- an increase in the number of suggested homework and test ideas that would help teachers assess their students' achievement;
- teachers' notes that would help teachers get more in-depth knowledge on the subject matter about the topic.

Regarding facilitators, there was a need to strengthen their leadership role by supporting them through an orientation programme. This programme would help them develop skills in order to support their colleagues better during the teaching of probability lessons as well as being able to organise peer collaboration activities in their respective schools. In relation to the collaborative activities, it was suggested that the classroom observation forms for teachers should be skipped so as to enable teachers to choose their own focus of observation in case of conducting peer observation.

Apart from focusing on the exemplary materials and facilitators, which required major revisions to improve them, minor revisions would be done for a school-based seminar programme, whose programme would not be different from the one used in the previous study (see section 4.4).

5.7 REVISION OF THE PROGRAMME

The revisions of the COSMAT programme focused on the suggestions for improvements based on the findings of the formative evaluation study of the programme. The next section presents the redesigning of the programme which was labelled COSMAT-2 programme.

5.7.1 Redesigning the programme

The development of the revised programme involved different people including the researcher, who performed a number of activities. Figure 5.2 shows an overview of the development of the programme. The researcher was involved in the development of the orientation programme for the facilitators. Secondly, in collaboration with a few members of development team, he was also involved in the revision of the exemplary materials.

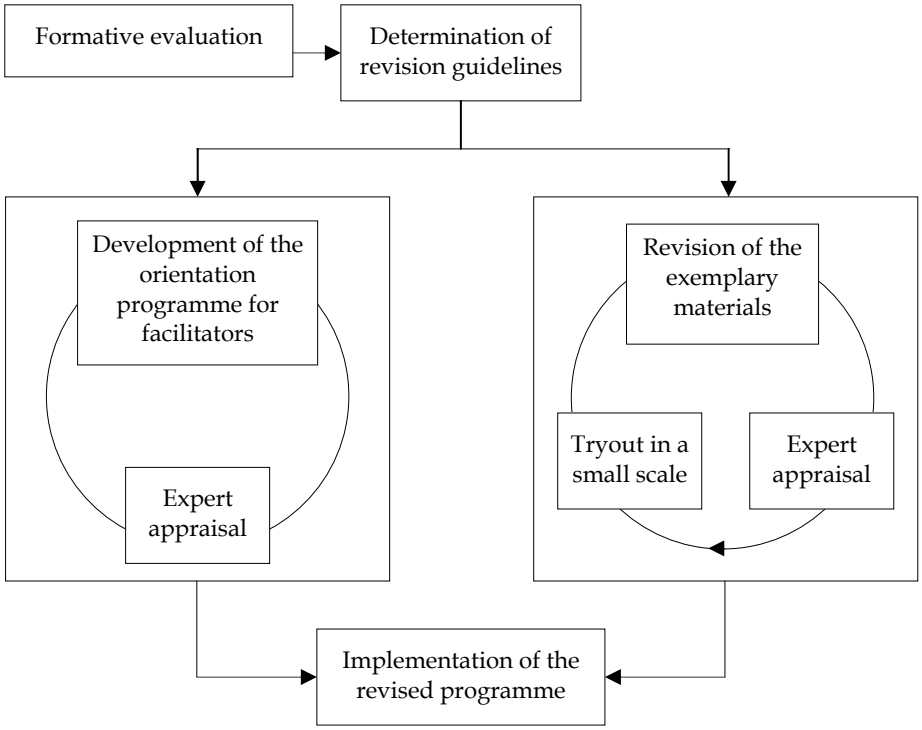

Figure 5.2: An overview of the development of revised programme

5.7.2 The revision of the exemplary materials

The exemplary materials were revised by a few selected members of the development team (DT) in a small workshop organised by the researcher. These few members were involved because the work at this time was not as intensive as it was during the first workshop of the materials development, whereby the participants had to start writing the materials from scratch. The DT did not make changes on the original structure of the lessons, but rather included the issues raised from the evaluation study as indicated in section 5.6.3.

The revised probability lessons were scrutinised by the researcher to see if they contained all the necessary features according to the format presented in section 4.3.1. Thereafter, they were sent to two experts for comments and suggestions on

their validity and practicality. One expert was from the Department of Mathematics at UDSM, with experience in teaching mathematics and mathematics education, and the other one was from the Netherlands, with expertise in mathematics and mathematics education. The experts were expected to focus their comments on the following issues:

- clarity of the objectives and whether they are achievable;
- validity of the subject matter content;
- practicality and validity of the formulated activities;
- validity of the test questions and suggested homework ideas;
- general format of the materials;
- whether the lessons gave enough guidelines for the teacher to conduct activity-based lessons.

The experts noted some errors related to subject matter, classroom activities and homework ideas that could further develop misconceptions people held about probability. They also suggested the addition of more classroom activities. The researcher corrected the errors as well as incorporated suggestions and improvements put forward by the experts.

Thereafter, two teachers tried out the lessons at one of the O-level secondary schools in real classroom practice. This school was not among those selected for evaluation of the impact of the revised programme. The teachers involved, who had vast experience in the teaching of O-level mathematics, volunteered to try-out the materials, which involved only one lesson. The two teachers co-planned the lesson that was taught by one of them. During the teaching, the other teacher was supporting his colleague in supervising students' activities. The aim was to gain insight as to whether teachers could handle the lessons in a real classroom situation. The researcher observed the lesson focusing on how teachers conducted activity-based lessons as well as how competent they were in subject matter knowledge. Generally, the try-out showed that the teachers could handle the activity-based lessons provided adequate time for planning and teaching aids were available. One aspect that needed to be emphasised was more student participation. After the try-out, the responsible teachers were interviewed to get their opinions about the lessons. The teachers said that the lessons were generally quite practical and relevant. They contended that the lessons could save time for lesson preparation. They also appreciated the activity-based teaching approach used in the materials, though they felt that given the large size of the classes in most schools in Tanzania, teachers should be careful in planning the delivery of the lessons for successful student participation.

5.7.3 Orientation programme for facilitators

Aim of the programme

At the beginning, it was assumed that facilitators could conduct and organise collaborative activities without any difficulties by virtue of being experienced teachers with considerable expertise in subject matter knowledge and teaching skills, but in practice the situation was different. The essence orientation programme, which was prepared, was expected to help facilitators to:

- organise and facilitate different collaborative activities in their respective mathematics departments;
- conduct activity-based lessons in the classroom in order to help their colleagues more successfully;
- supervise collaborative activities that would help mathematics teachers enhance their PCK&S.

The orientation programme, which was planned for half a day, consisted of two sessions. The first session was conducted to inform the facilitators about the meaning and rationale of peer collaboration and the role of facilitators in peer collaboration. Also in this session, facilitators would get the opportunity to discuss different collaborative activities going on in their respective mathematics departments. The second session included the discussion about the exemplary materials, specifically on the probability lessons and the activity-based lessons. In this session, facilitators would sit in two groups. One group would go through the first two lessons and the other one would go through the last two lessons. Thereafter, they would meet to discuss what could be gathered by each group from the lessons.

The facilitators would also participate in the school-based seminar for the purpose of conducting the demonstration lessons. They would also participate in the discussions of other lessons and other activities in the sessions in order to gain more insight about the lessons as well as collaborative activities to be conducted during the seminar. Their participation in the seminar would help them know what areas of further support teachers needed.

The first outline of the orientation programme was sent to two experts: one from the Free University of Amsterdam and the other from the University of Dar es Salaam so as to comment on the relevance of the programme sessions. Generally, the experts did not suggest any major changes in the programme. However, they asserted that the concept of activity-based teaching should be further clarified during the programme so as to enable facilitators to help teachers change from chalk-and-talk to more student participation. The suggestions given by the experts were taken into consideration for the purpose of improving the programme.

Participants

The facilitators' orientation programme involved eight teachers from four selected secondary schools. These teachers participated in an orientation programme conducted at Dar es Salaam teachers' resource centre (TRC). Since there were only eight facilitators, it was considered more feasible to run the programme at one centre rather than at each individual school. Of the eight participants five were male and three were female. Table 5.12 shows the summary of the orientation programme participants' profile.

Table 5.12: Participants' profile

Characteristic	Mean	SD	N
Age (years)	33.5	5.1	8
Teaching experience (years)	8.1	5.3	8

Implementation of the orientation programme

The programme with its two sessions was run for about a half-day (5 hours). In the first session, the participants were introduced to peer collaboration. Through the use of peer collaboration guidelines, they were informed about the meaning of peer collaboration, rationale for peer collaboration and the role of facilitators in peer collaboration.

In the second session, the participants were introduced to activity-based probability lessons. The participants were informed about the reasons for adopting the activity-based approach in the teaching of probability. In connection to the introduction to the materials, the researcher also highlighted some of the common misconceptions that people have with probability. Highlighting these misconceptions was considered important so facilitators would be aware of them for the purpose of helping their colleagues overcome them. After the introduction to the materials, the participants divided into two groups, each having a member from each school. One group discussed the first two lessons and the other group discussed the last two lessons. Thereafter, the two groups sat together to discuss what prevailed in the two group discussions. There was no big discussion about the first two lessons. It appeared that each participant was comfortable with his or her content. A lengthy discussion was held on the last two lessons, Lesson 3 and Lesson 4. In Lesson 3, some participants asked for elaborate distinction between two concepts: mutually exclusive events and non-mutually exclusive events. The clarification was given by other participants as well as the researcher. With Lesson 4, some participants needed help with the concepts of independent and dependent events. Also, they wanted to help with how to determine the probability of events that involved

picking objects with replacement and those that involved picking objects without replacements. Clarifications about these concepts were given by other facilitators and the research assistant who happened to be a college mathematics tutor.

In concluding the sessions, the facilitators were asked to prepare demonstration lessons that would be presented in the school-based seminar.

Participants' reactions to the orientation programme

Through interviews, all eight participants of the facilitators' orientation programme expressed positive reactions. In terms of subject matter knowledge, they said that the programme helped them solve a number of small problems and misconceptions they had about probability. Three participants admitted that they still had some problems involving mutually and non-mutually exclusive events. Two participants said that probability problems involving picking objects with or without replacement were a little bit confusing to them. They acknowledged that after the programme, they could deal with those problems without many difficulties.

With regards to activity-based teaching, they all admitted that the idea is very good, as it would help to foster student participation in the classroom and arouse their interest in the lessons. Their major concern about the approach was the large size of classes in most secondary schools in Tanzania. They said that overcrowding of classrooms might hinder the effective use of the approach.

All eight participants acknowledged that the orientation programme helped equip them with skills for conducting collaborative activities in their respective schools. In elaborating this point, two facilitators argued that before the orientation programme, they could not vividly see its importance. They claimed that after the programme, they realised it was important, and they could see the distinct role they could play in supporting their colleagues in both subject matter knowledge and activity-based teaching. In emphasising this point, four facilitators maintained that promoting successful collaborative activities among teachers required special skills that not everybody possessed. They compared these skills to basic teaching skills such as promoting student participation or questioning skills, which are normally acquired through learning programmes and not through trial-and-error or intuition.

In short, the participants asserted that the orientation programme was useful to them. They said that the programme has helped them resolve a number of problems they had in understanding some probability concepts. They also said that it has helped them gain special skills in conducting collaborative activities. Despite

admitting the importance of activity-based teaching in ensuring student participation in the classroom, all the facilitators pointed out that efforts should be made to limit class size so as to guarantee benefits from the approach.

To sum up, the major revisions of the programme focused on the improvement of the exemplary materials and the introduction of the orientation programme for the facilitators. The deficiencies that were observed in exemplary materials in terms of teachers' notes, classroom activities and homework assignments signified that they were not adequate enough to support teachers in terms of subject matter knowledge and teaching skills. Regarding facilitators, teachers' comments and observation revealed that they needed an orientation programme aimed at equipping them with the skills that would help them to support better their colleagues, specifically in organising and co-ordinating peer collaboration activities. The impact of these improvement efforts is discussed in the next chapter.

CHAPTER 6
Exploration of the impact of the revised programme

This chapter presents the design and results of an evaluation study on the impact of the revised COSMAT-2 programme. The aim of the programme was to support mathematics teachers with the implementation of activity based lessons, as well as to conduct peer collaboration activities aimed at enhancing their PCK&S. Section 6.1 presents the design of the study. Section 6.2 presents participants' reactions to the seminar. Section 6.3 explains the use of putting programme ideas into practice. Section 6.4 presents students' experiences with the programme. Section 6.5 presents the conclusions of the study.

6.1 DESIGN OF THE STUDY

6.1.1 Aim and research questions

This chapter presents the results of the evaluation study of the COSMAT-2 programme. The programme emphasised more support for mathematics teachers in implementing activity-based lessons and conducting collaborative activities aimed at enhancing their PCK&S. In order to consolidate this support and all its previous components, the programme included an orientation programme for facilitators. The aim of this orientation programme was to introduce facilitators to the revised exemplary materials, as well as peer collaboration guidelines (see Chapter 5). Similarly, a school-based seminar was organised for teachers. Basically, the seminar programme was the same as the one used in the previous study except that it dealt with the revised exemplary materials.

This study used the same impact indicators as the ones used in the previous study, that is, teachers' reactions to the programme, teachers' use of programme ideas in practice and students' experiences with the probability lessons. However, an addition a student test was administered to assess student learning results. In regard to teachers' reactions, the programme not only focused on their general

impressions and perceptions, but also their expectations of the program. The study was guided by the following research questions:

What are the teachers' general impressions and expectations of the programme?
What are the teachers' perceptions of the programme in enhancing their PCK&S and in promoting peer collaboration?

As in the previous study, participants' practice of programme ideas was categorised into two parts: individual and collaborative use. The focus of these two parts is described in Chapter 5, and the study was guided by the following questions:

How do teachers use and perceive the exemplary materials?
How do teachers execute the probability lessons and perceive the contribution of the programme in their classroom teaching?
How do teachers collaborate and perceive the benefits of this collaboration?

Likewise, Form 4 students, whose teachers participated in the school-based seminar, were also involved. Besides focusing on their experiences with the probability lessons, as done in the previous study (Chapter 5), this study also focused on their learning outcomes. Thus, the study was guided by the following research questions:

What are the students' experiences with and learning outcomes from the probability lessons?

The next section presents the sample and participants of the study.

6.1.2 Sample and participants

In the revised programme it was thought not feasible to use the same schools that participated in the first phase of the study. This was because teachers might not have a keen interest in the programme as a result of repeating the same content several times. For that matter, it was thought important to involve new schools in this phase of the study to explore the impact of the programme within a different context.

The seminar participants were drawn from four secondary schools in the Dar es Salaam region. The schools from this region were purposely selected because they were close to where the researcher lived, making it convenient for him to make frequent visits and close follow-ups, which was necessary to the study. All four schools were co-educational: two were public and the other two private, and a total of 22 O-level mathematics teachers were involved. The aim of having a small sample was to gain in-depth information about the programme's impact. Table 6.1 gives a summary of the participants' profile. There was a considerable range in participants' age and teaching experiences. Out of 22 participants, 15 were male and seven were female.

Table 6.1: Summary of seminar participants' profile

Characteristic	Mean	SD	Min	Max	N
Age (years)	35.3	6.9	27	50	22
Teaching experience (years)	9.6	6.4	1	28	22

The criteria used to select these four schools were what Patton (1990) refers to as information rich. Since the study's intention was to gain more insight into the implementation of school-based seminars, exemplary materials, peer collaboration and facilitators enhancing mathematics teachers PCK&S, the information rich schools were considered to be those with the following attributes:

- leadership that supports teacher professional development efforts;
- teachers willing to participate in the study;
- a form of teacher professional development efforts present that involved some type of peer collaboration;
- mathematics departments that have a considerable number of teachers;
- easy access to schools for the researchers.

With reference to the criteria, one school was not included due to a lack of adequate co-operation from teachers. Therefore, after the seminar, three schools with 15 teachers were pursued further. Out of 15 teachers, six, whose characteristics are shown in Table 6.2, were selected for a more in-depth study on their ability to put programme ideas into practice. These teachers, who were involved in classroom observations and interviews, were selected because at the time of the study they were all teaching Form IV, which included the topic of probability.

Table 6.2: Teachers involved in an in-depth study of the programme's impact

School	Teacher	Teaching experience (years)	Other teaching subjects
School A	Teacher A1	12	Chemistry
	Teacher A2	14	Chemistry
School B	Teacher B1	8	Chemistry
	Teacher B2	28	Physics
School C	Teacher C1	5	Physics
	Teacher C2	8	Physics

Table 6.2 shows that teachers had varying teaching experiences; some had also taught other subjects apart from mathematics.

6.1.3 Data collection instruments and procedures

In this study, several data collection instruments and procedures were used. These included teacher journals, questionnaires, paper-and-pencil probability test,

interviews, observation checklists and guiding questions for group discussions (see Figure 6.1).

Teacher journals

Teacher journals were used to collect teachers' learning experiences from the programme. These journals, which are shown in **Appendix F**, contained questions that were followed by a blank space in which teachers wrote their opinions about the issue raised. Teacher journals are private records of how they feel and make sense of their learning, providing a direct and immediate recount of their experiences undistorted by teacher or researcher interventions (cf. Brookfields, 1990). The journals were used to help teachers reflect on what they had learned and how benefits had been gained from different learning events. At the beginning of the seminar, teachers were asked to record their expectations of the programme in the journals. At the end of the seminar, teachers were again provided with journals and questionnaires. With the journals, they were required to show in percentage the extent to which their expectations were met.

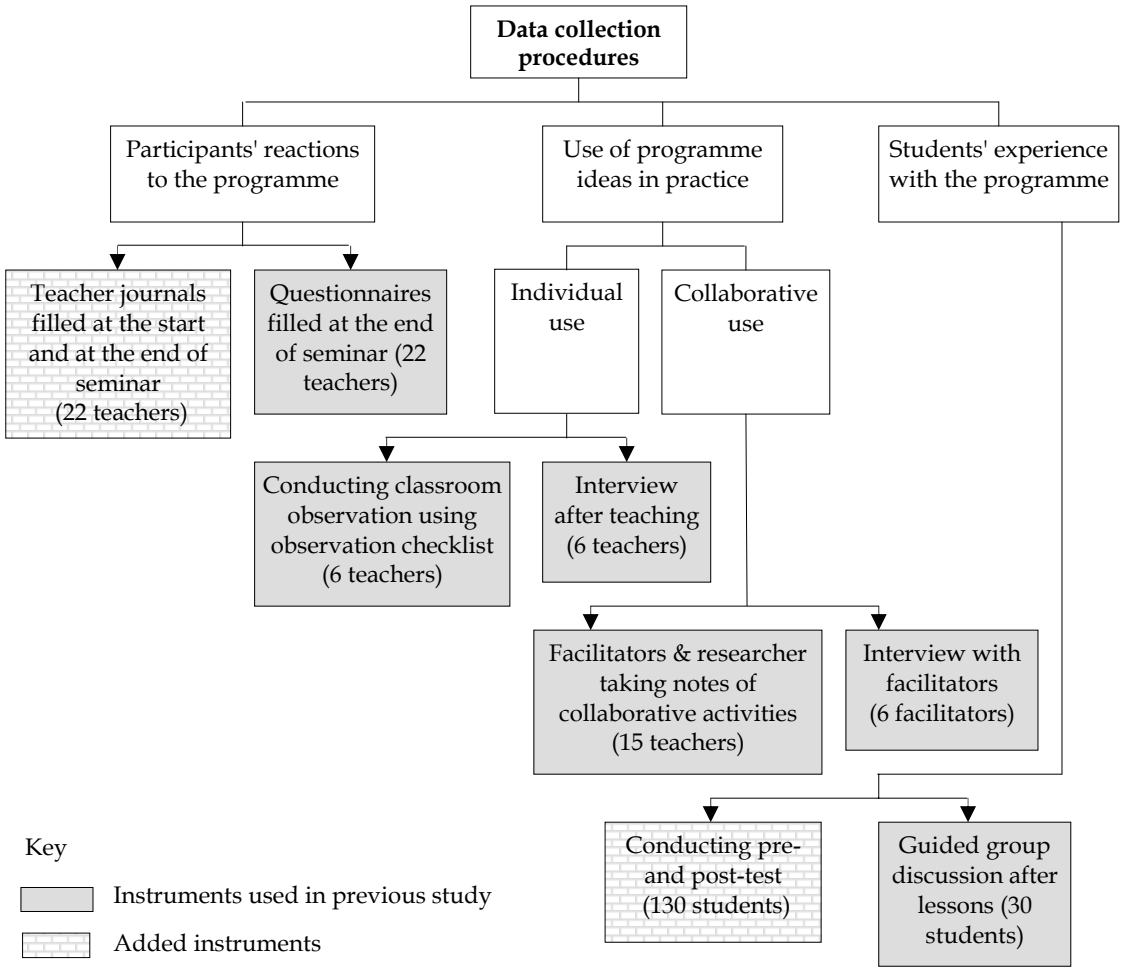

Figure 6.1: Schematic data collection instruments and procedures

Questionnaire

Questionnaire was also used for data collection in this study, which were filled in by the participants at end the seminar. The questionnaire was similar to the one used in the previous study (Chapter 5) except the yes/no questions were omitted (see Appendix H). It contained questions that focused on the following:

- general information such as age, teaching experience and whether they taught subjects outside of mathematics;
- teachers' opinions and perceptions of the usefulness of different sessions of the seminar, as well as the contributions of other components of the programme (that is, the exemplary material, collaborative activities and the facilitators) in enhancing teachers' PCK&S.

Interviews

In this study, there were two sets of interview schemes: one for teachers and the other for facilitators. The teachers' interview scheme consisted of questions aimed at collecting in-depth information about the programme's contribution in enhancing their PCK&S in teaching of probability. It also contained questions about their opinions about peer collaboration and facilitator's contributions in fostering peer collaboration activities in their departments. The facilitators' interview scheme focused on teachers' reactions to the orientation programme, their application of the programme ideas, and their opinions of the programme in general.

Classroom observations

The classroom observations were conducted by the researcher and research assistant by using classroom observation checklists. The structure of the checklist was similar to those used in the previous study, but some revisions were made as a result of gaining insights from the checklist used by Ottevanger (2001). The revisions made distinctions between basic teaching skills, activity-based teaching and subject matter knowledge, each of which was aligned to the three stages of the lesson: introduction, body and conclusion.

Test

Since the aim is to improve classroom teaching, students' learning was explored. In order to collect information from students, one of the instruments used was a test. The test, which is shown in **Appendix I,** consisted of 25 multiple-choice questions worth four points each. The test was developed by the researcher and covered all lessons in the exemplary material. The test was moderated by two experts: one from the University of Dar es Salaam and the other from the University of Twente so as to check its validity. The experts were guided by a table of specifications,

which helped them relate to the objectives and content of the lessons. The Cronbach's alpha was computed to determine the reliability of the test. The higher the score, the more reliable the generated scale was. Nunnaly (1978) has indicated 0.7 to be an acceptable reliability coefficient. The overall raw alpha was found to be 0.79, which was good enough for this research purpose considering .70 is the cut-off value for being acceptable. The test was administered via pre- and post-test designs. The pre-test was administered before the teaching of probability. After the teaching, the same test was administered to the same group of students to see whether the probability lessons taught through an activity-based approach had an impact on their learning.

Guided group discussion

Also with the students, a guided group discussion was conducted after the probability lessons were taught. The set of questions used here was similar to the one used in the previous study (Chapter 5). The questions focused on gathering information about students' perceptions and experiences of the revised probability lessons. The questions specifically focused on the usefulness of probability, group work and a team teaching approach.

Collaborative activities

In order to facilitate data collection of peer collaboration activities that were to take place in the mathematics department, facilitators were asked to take notes on these activities. This would help them accumulate information about activities that would take place informally, without prior notice to the researcher. The researcher and the research assistant also participated in taking notes on activities that were taking place in schools. All those involved were informed of the type of information they were to collect during these activities. Information collected was compiled ready report writing.

6.1.4 Data analysis procedures

Like in the previous study (Chapter 5), two data analysis procedures were used in this study. For the quantitative aspects of the data, standard deviations and percentages, t-values and Cronbach's alpha-coefficient were computed. The means and standard deviations were used to determine the magnitude of the positiveness or negativeness of the teachers' opinions and perceptions of the programme as in the previous study. They were also used to determine the difference in performance among students in both the pre-test and post-test. The percentages were used to determine the teachers' thoughts about the extent to which their expectations had been met by the programme. The Cronbach's alpha coefficient

was used to verify the reliability of the test, while t-values were used to determine whether there was significant difference in performance among students before and after the probability lessons.

Data from the questionnaires open-ended questions, interviews, teachers' journals and guided group discussions were analysed qualitatively as done in the previous study. Some of the original quotes from the participants were also used as evidence to support the patterns.

The classroom observation data in this study was analysed differently from those in the previous study. In the previous one, more global statements were used to get a general impression on how the programme contributed in enhancing teachers' PCK&S. In this study, a more detailed analysis was done that also involved numerical values to determine the impact of the programme on teachers. In order to analyse the classroom observation data, each statement marked 'yes' was assigned a score of '1' and a statement marked 'no' was assigned a score of '0'. The scores of individual statements were counted for each checklist for all the lessons observed per teacher and then expressed in a percentage. Since the checklist was divided into three sections: introduction, body and conclusion, and each of these sections was further divided into three subsections: basic teaching skills, activity-based teaching and subject matter knowledge, each subsection was analysed separately.

Besides quantitative data, qualitative data was also used for classroom observation. Notes taken by the researcher and the research assistant as lessons flow were written into reports to form input for the scoring of the lessons. The data collected through notes made by the researcher, research assistant and the facilitators during the observation of the peer collaboration activities resulted in detailed information about the conduction of the peer collaboration activities. The information from classroom observation and peer collaboration activities observation was used to explore the extent to which the participants used programme ideas in practice.

6.2 PARTICIPANTS' REACTIONS TO THE SEMINAR

This section presents participant's reactions to the seminar. As in the previous study (see Chapter 5), reactions were based on participants' general impressions of the seminar, which included their expectations of the seminar and opinions of different seminar sessions and the exemplary materials used during the seminar. Teachers' reactions also focused on the perceived benefits of the seminar in enhancing teachers PCK&S and in promoting the implementation of peer collaboration.

Participants' expectations

All participants were positive about the seminar as they were looking forward to gain a considerable level of confidence and competence in both subject matter knowledge and teaching probability skills. They were also looking forward to getting the opportunity to share expertise and experiences with their colleagues. In summary, teachers' (n=22) expectations focused on gaining knowledge on the following issues:

- The seminar would highlight methods and skills of teaching probability without many problems (9x).
- The seminar would eliminate some of the problems they had in teaching probability (7x).
- The seminar would help them learn how to deal with misconceptions people have in probability (7x).
- The seminar would cover probability in detail for the purpose of teaching O-level secondary schools (7x).
- The seminar would improve knowledge and expertise in the teaching of probability (6x).
- The seminar would give them the opportunity to discuss their problems in teaching probability (6x).
- The seminar would help solve probability problems that involve selecting items with or without a replacement (6x).
- The seminar would give them opportunity to share experience and expertise by teaching with experienced teachers (4x).

In short, participants' expectations from the seminar can be categorised into two parts. There were those who expected to gain more insight into subject matter knowledge, enabling them to teach O-level probability with few problems. This group includes those participants who expected to gain more knowledge on the specific areas of the topic. The second group involved the participants who expected to gain more insight into teaching skills that would help them teach probability without many problems.

The journals participants (n=22) filled in at the end of the seminar revealed that the seminar had attempted to meet their expectations. They maintained that the seminar had addressed the issues that they needed information from most. A good number of teachers (n=13) said that their expectations were met by 90%, several teachers (n=7) claimed that their expectations were met by 80% and few teachers (n=2) said that their expectations were met by 75%.

Perceived contribution of the seminar on enhancing teachers' PCK&S

Participants gave their opinions about the usefulness of the seminar in enhancing their PCK&S through the questionnaire. Table J1 (Appendix J) summarises participants' opinions. From the table it can be seen that, just like in the previous study, participants were generally positive about the seminar's usefulness. They were also positive about the seminar's contribution in raising their confidence in teaching probability. One teacher said:

Before this seminar, I hated probability, but now I can teach it confidently

Another teacher was quoted as saying:

I used to skip teaching this topic because of difficulties I was facing but not now.

In support of these opinions, they said that the seminar had accomplished the following:

- enabled them to handle a topic which appeared to be difficult before the seminar (10x);
- reduced their fear of teaching the topic (9x);
- helped to minimise problems they experienced in teaching probability (7x);
- enabled them to discover mistakes normally committed in teaching probability (6x);
- introduced them to a new teaching approach that facilitates student participation (6x);
- helped to increase their confidence in teaching probability (4x).

In short, the participants perceived the seminar as useful in enhancing both subject matter knowledge in probability and teaching skills.

Perceived contribution of the seminar on promoting peer collaboration

Besides raising their confidence in teaching probability, participants were also positive about the seminar raising their confidence in conducting peer collaboration activities as shown in Table J2 (Appendix J). Several teachers (n=7) argued that the seminar had reduced their fear of discussing teaching problems related to probability with their colleagues, whereas six teachers argued that the seminar had provided them with the courage to stand in front of their colleagues and teach. When asked about their opinions of introducing peer collaboration in schools, they said it was important for the following reasons:

- it builds unity among teachers (8x);
- it saves time in solving teaching problems (6x);
- it can lead to enhanced performance by the teachers(5x);
- it facilitates sharing of expertise and experiences (4x).

Despite being positive about its usefulness, three teachers showed doubt about introducing the idea of peer collaboration in schools as they said that some teachers might be uncomfortable sharing knowledge with their colleagues.

Teachers' opinions about seminar sessions

Participants' opinions of seminar sessions were also sought. Generally, participants were positive about the seminar sessions, as shown in Table J2 (Appendix J). As in the previous study, the demonstration lesson session was the most appreciated one by participants. They also rated the other sessions highly in terms of usefulness, that is, the presentation of the exemplary materials, group work sessions, the co-planning of the lessons and micro-teaching sessions. Participants gave a number of reasons for this:

- they learned from colleagues how activity-based teaching can be conducted (11x);
- they learned how to promote students' participation in the classroom (8x);
- they received clarification about probability concepts that were confusing before the seminar (7x).

Teachers' opinions about exemplary materials

The participants considered the exemplary materials useful during the seminar in supporting them with content, as well as activity-based teaching skills as shown in Table J3 (Appendix J). They pointed out that the materials helped them in the following areas:

- the understanding of probability concepts (8x);
- teaching methods that encourages student participation(8x);
- the use of teaching aids that facilitate understanding of the topic (6x).

To sum up, teachers' reactions about the usefulness of the seminar in enhancing their PCK&S were generally positive. They were confident about participating in collaborative activities, despite doubts that some teachers might not feel comfortable sharing their knowledge through peer collaboration.

6.3 INDIVIDUAL USE OF PROGRAMME IDEAS

Having positive reactions about the programme is an important indicator of its impact. However, in this study, teachers' use of programme ideas in practice was considered the most important indicator of its impact on teachers. This section presents individual use of programme ideas in practice. As in the previous study, the focus was on the extent to which teachers used the exemplary materials in

executing these lessons and how they executed the probability lessons in a real classroom situation.

6.3.1 Observed use in practice

Use of the exemplary materials

The classroom observations involved six mathematics teachers from the three schools who participated in the school-based seminar (see Table 6.2). At the time of this study, these teachers were teaching Form 4 classes at their respective schools where the topic of probability was allocated. A total of 20 lessons were observed, whereby two teachers (Teacher A_1 and Teacher C_2) were observed for three lessons, three teachers (Teachers A_2, Teacher B_1 and Teacher B_2) were observed for four lessons each and one teacher (Teacher C_1) was observed for two lessons. During the observations, it was noted that all teachers used the exemplary materials intensively. They used them in all stages of the lessons, that is, from the introduction to the conclusion, despite additions from other resources from some teachers. Table 6.3 shows the areas and the extent to which the exemplary materials were used.

Table 6.3: Teachers' use of exemplary materials

	School A		**School B**		**School C**	
Area of use	*Teacher A1*	*Teacher A2*	*Teacher B1*	*Teacher B2*	*Teacher C1*	*Teacher C2*
Classroom activities	✓	✓	✓	✓	✓	✓
Teacher notes	✓	✓	✓	✓	✓*	✓*
Homework/test ideas	✓*	✓*	✓	✓	✓*	✓*

Note: ✓ = Used as they were proposed, ✓* = Supplemented with other resources such as textbooks and reference books.

The materials were prepared with the intention of covering the content of the probability topic as outlined in the syllabus. Teachers were not expected to use extra materials during the teaching of the topic. Despite this, teachers used additional resources as shown in Table 6.3., which also occurred during the previous study. Nevertheless, in interviews with teachers, it was revealed that the use of additional resources was not because the exemplary materials were insufficient. Teachers who used additional resources (Teacher A_1, Teacher A_2, Teacher C_1, and Teacher C_2) claimed that the exemplary materials made them enthusiastic thus inspired to look for and use other resources to enrich their lessons. Another reason for using additional sources was given by Teacher C_1 and Teacher C_2. This reason was related to the final examination coverage. According to their explanation, previous experiences showed that NECTA sometimes did bring questions in the examinations whose topics/subtopics were already omitted from

the syllabus. For that matter, besides using the exemplary materials for getting lessons' summaries for the probability content covered in the syllabus, teachers also used other sources to get more content, specifically, for covering one subtopic also called *permutations and combinations.* This subtopic was not included in the materials because it was not indicated in the current basic mathematics syllabus. Teachers said that they believed that a question from this subtopic might be in the final examination, so they decided to teach it to their students.

Teachers from School A and School B used other sources, particularly past final examination questions for assessing their students' abilities following an activity-based approach in teaching the topic. They argued that this could motivate students further if they could answer questions from national examinations.

Despite the additions from basic textbooks, other reference books and past examination papers, the exemplary materials were used intensively by all six teachers from the three schools for teaching probability lessons. Teachers claimed that they liked the materials because not only could they get sufficient content coverage for the topic from them, they helped simplify their lessons preparations, as well.

What did the lessons look like?

The individual use of programme ideas in practice also involved observing the execution of the probability lessons in a real classroom situation. The observation focused on teachers' basic teaching skills, an activity-based teaching approach and subject matter knowledge (see Table 6.4).

*Table 6.4: Summary scores for the observed lessons per teacher**

	Teacher A1	**Teacher A2**	**Teacher B1**	**Teacher B2**	**Teacher C1**	**Teacher C2**	**Average**
BTS	77	59	49	57	53	67	60
ABT	74	62	53	54	64	68	63
SMK	74	68	60	64	68	72	68
Average	75	64	54	58	62	69	64

Legend: * Scores are expressed as percentage of the maximum possible score.
Note: BTS = Basic teaching skills; ABT = Activity-based teaching; SMK = Subject matter knowledge.

Table 6.3 indicates the average scores for all observed lessons for each individual teacher, and the overall average scores in basic teaching skills, activity-based teaching and subject matter knowledge. From the table it can be seen that in general the programme's impact would be regarded as satisfactory because the

scores are well above 50% of the maximum. The average scores for each of the three aspects of the lessons - basic teaching skills, activity-based teaching and subject matter - indicate that teachers performed slightly better in the subject matter knowledge than other areas. In terms of teaching skills, teachers did slightly better in activity-based teaching than in basic teaching skills. This might be attributed to the teachers' tendency to skip some basic teaching skills such as explaining the purpose of the lessons, ensuring full participation of all students, encouraging students to ask questions, and paying more attention to areas that reflect activity-based teaching. In terms of relative performance, Teacher A_1 performed better than the rest of the teachers in all the aspects, while Teacher B_1 performed the least well, especially in basic teaching skills.

Despite the fact that teachers had planned specifically how much time would be spent in each stage of the lesson, they had difficulties following these time frames. There were a number of reasons for this. First, class periods starting late affected the whole plan. Therefore teachers were forced to skip some of the basic teaching skills. Second, the activity-based teaching, which was new for both teachers and students, created difficulties for teachers' estimating appropriate time for each stage of the lessons. In most cases, earlier stages took more time than the following ones.
The next sections present teachers' performances in the three sections of the lessons: introduction, body and conclusion as outlined in the exemplary materials and the observation checklist.

Introduction of the lesson
In the introduction stage of the lesson, teachers appeared to be adequately prepared except for one teacher (Teacher B_1) whose lessons were affected by a delayed start to the periods. In most cases, teachers introduced lessons by asking students oral questions that were related to the previous lessons or about students' experiences with probability (Teacher A_1, Teacher B_2, Teacher C_1). Teachers' efforts to involve students through these oral questions were not rewarding for some teachers because students were unwilling to answer questions (Teacher B_2) because of language problems. If the same questions were repeated in Kiswahili, students were ready to answer them. On other occasions the lessons were started by doing activities related to the day's lessons (Teacher A_1, Teacher C_1 and Teacher C_2). Some activities took a longer time than anticipated hence affecting the time for the lesson's other stages. An example of an introduction that started with an activity is one whereby a teacher asked students to fill in the table on the blackboard with statements that focused on predicting future events. The events included the possibility of rain during certain months of the year or predicting the winner of a

football match between two rival classes in the school or two popular teams in the country. Students were asked to give reasons for the answers they gave. Also, it was observed that teachers used the introduction stage of some lessons to correct homework assignments from previous lessons. There were occasions where teachers gave an incorrect statement or an incomplete statement to students (two teachers, Teacher B_1 and Teacher B_2). Table 6.5 indicates the summary scores for all lessons per teacher for the introduction section of the lesson.

*Table 6.5: Summary scores for the observed lessons per teacher: Introduction of the lesson**

	Teacher A1	**Teacher A2**	**Teacher B1**	**Teacher B2**	**Teacher C1**	**Teacher C2**	**Average**
BTS	80	60	40	70	60	60	62
ABT	70	60	50	63	60	63	61
SMK	67	67	50	50	67	67	61
Average	72	62	47	61	62	63	61

Legend: * Scores are expressed as a percentage of the maximum possible score.
Note: BTS = Basic teaching skills; ABT = Activity-based teaching; SMK = Subject matter knowledge.

Body of the lesson

This stage is one that involved many classroom activities. Most of the activities were done in groups of five to eight students. In other cases, teachers asked two students to come in front of the class and do an activity on behalf of the other students. One example of this activity involved tossing a coin 20 times (two lessons by Teacher B_1 and Teacher B_2). Of the two students involved, one tossed a coin while the other recorded the outcomes on the chalkboard. The aim of the approach was to save time and also overcome difficulties of forming concrete groups within congested classrooms. The approach to this activity ignored the majority of students in the class, allowing them to do things unrelated to the lesson. Some teachers organised groups by asking students who sat close to each other to form into groups. During the activities, Teacher A_1, Teacher A_2 and Teacher C_2 asked students to elect two people to play leadership roles - a group leader who supervised group activities and a secretary who recorded the outcomes of the groups' activities. Teachers allowed 10-15 minutes for groups to report their outcomes either verbally or written on the chalkboard. However, little time was allotted for students to reflect on the differences and similarities that occurred in the outcomes of the activities. This happened to all the teachers except Teacher A_1. After the presentation of the outcomes, students were asked questions that were related to the experiments/activities completed. The questions were answered orally or written in the exercise books. For those questions that were answered in the exercise books, teachers went around to mark them while helping students with individual

problems (Teacher A_1, Teacher A_2, Teacher C_1 and Teacher C_2). Table 6.6 indicates summary scores for all lessons per teacher in the body section of the lesson.

*Table 6.6: Summary scores for the observed lessons per teacher: Body of the lesson**

	Teacher A1	**Teacher A2**	**Teacher B1**	**Teacher B2**	**Teacher C1**	**Teacher C2**	**Average**
BTS	75	60	50	50	60	75	62
ABT	77	76	58	50	57	66	64
SMK	80	63	63	75	70	75	71
Average	77	66	57	58	62	72	66

Legend: * Scores are expressed as percentage of the maximum possible score.
Note: BTS = Basic teaching skills; ABT = Activity-based teaching; SMK = Subject matter knowledge.

Conclusion of the lesson

This stage of the lessons involved a variety of activities depending on what was going in the body stage of the lesson. In most cases it involved asking students oral questions about what they learned in the lessons. However, the answers were often given hurriedly because of time constraints. It also involved giving students home assignments, or correcting classroom exercises. The correction of classroom exercises was sometimes postponed or teachers asked students to collect their exercise books so that they could do the marking at home. It also involved giving a summary of the lesson and informing students what they would learn in the next period.

With three teachers (Teacher A_2, Teacher B_1, and Teacher B_2), most of their lessons ended with a summary without reaching a concrete conclusion about what students learned in the lessons. Either it was done in a rush because the body of the lesson occupied most of the time or lessons started late. Three teachers (Teacher A_1, Teacher C_1 and Teacher C_2) indicated some efforts in this section. Table 6.7 indicates summary scores for all lessons per teacher in the conclusion stage of the lesson.

*Table 6.7: Summary scores for the observed lessons per teacher: Conclusion of the lesson**

	Teacher A_1	**Teacher A_2**	**Teacher B_1**	**Teacher B_2**	**Teacher C_1**	**Teacher C_2**	**Average**
BTS	75	58	58	50	67	67	60
ABT	75	50	50	50	75	75	62
SMK	70	62	58	58	67	75	62
Average	73	57	55	53	64	72	61

Legend: * scores are expressed as percentage of the maximum possible score.
Note: BTS = Basic teaching skills; ABT = Activity-based teaching; SMK = Subject matter knowledge.

In conclusion, classroom observation had revealed that teachers were enthusiastic about the exemplary materials and they used them intensively, along with some additions, in executing the probability lessons. The additions were made not because the materials were deficient, but rather to enrich the lessons and cover a subtopic not included in the syllabus, which teachers felt may arise in the national exam. Teachers did slightly better in activity-based teaching than in basic teaching skills. Time constraints forced them to skip some activities involving basic teaching skills such as encouraging students to ask questions or explaining the lesson's purpose.

6.3.2 Teachers' perceptions after the lessons

Perceptions of the usefulness of the exemplary materials

Through the interview, it was gathered that teachers perceived the exemplary materials as important for supporting them in teaching probability. They considered them as having considerable impact on the teaching and learning of the topic. Table 6.8 shows teachers' perceived usefulness of the exemplary materials.

Table 6.8: Teachers' perceptions of the usefulness of the exemplary materials

School	Teacher	Usefulness
School A	Teacher A_1	▪ Provided elaborate subject matter ▪ Provided suitable classroom activities ▪ Aroused students' interest in lessons ▪ Facilitated step-by-step teaching ▪ Promoted student participation
	Teachers A_2	▪ Provided elaborate subject matter ▪ Provided suitable classroom activities ▪ Facilitated step-by-step teaching ▪ Encouraged the use of teaching aids
School B	Teacher B_1	▪ Provided elaborate notes ▪ Aroused students interest in the lessons ▪ Facilitated step-by-step teaching
	Teacher B_2	▪ Provided elaborate subject matter ▪ Simplified lessons preparations ▪ Facilitated step-by-step teaching
School C	Teacher C_1	▪ Provided elaborate notes ▪ Promoted student participation ▪ Facilitated step-by-step teaching
	Teacher C_2	▪ Provided elaborate subject matter ▪ Simplified lessons preparations ▪ Facilitated step-by-step teaching ▪ Encouraged the use of teaching aids

Apart from providing subject matter knowledge, all six teachers argued that the material supported them on how to conduct step-by-step teaching. Furthermore, they contended that the material helped them promote student participation during the execution of lessons through the different activities. According to Teacher A_1, Teacher B_1 and Teacher C_2, this helped to arouse students' interest in the lessons.

When asked about the problems they encountered with the materials, all six teachers contended that the major problem was the lack of appropriate teaching aids for certain activities. They claimed that although some of the teaching aids could be improvised such as spinners, it was difficult for others, such as dice.

Although teachers appreciated that the activities aroused students' interests in the lessons, they claimed that they made teaching of the topic take longer than if it was taught without them.

In short, teachers valued the exemplary materials because they could benefit from them with subject matter knowledge and step-by-step teaching of probability through activity-based teaching, hence promoting students participation. Despite the usefulness of the approach, especially in advocating activity-based teaching, time constraints and the lack of appropriate teaching aids were pinpointed as the major obstacles.

Teachers' perceptions of the contribution of the programme on teaching

When interviewed, all six teachers from the three schools expressed positive feelings about the impact of the programme as a whole in their classroom teaching, though there were notable constraints as shown in Table 6.9.

Table 6.9: Perceived impact and constraints of the programme on classroom teaching

School	Teacher	Perceived impact	Constraints
School A	Teacher A_1	▪ enhanced subject matter knowledge ▪ increased confidence in teaching ▪ changed teaching style ▪ facilitated students' participation	▪ big class size
	Teacher A_2	▪ enhanced subject matter knowledge ▪ changed teaching style ▪ encouraged the use of teaching aids	▪ lack of enough teaching aids ▪ big class size ▪ language problem among students
School B	Teacher B_1	▪ enhanced subject matter knowledge ▪ changed teaching style	▪ big class size
	Teacher B_2	▪ enhanced subject matter knowledge ▪ increased confidence in teaching	▪ language problem among students ▪ big class size
School C	Teacher C_1	▪ enhanced subject knowledge ▪ changed teaching style ▪ encouraged the use of teaching aids	▪ lack of teaching aids ▪ big class size
	Teacher C_2	▪ enhanced subject matter ▪ encouraged the use of teaching aids ▪ facilitated students, participation	▪ big class size

From Table 6.9, it can be deduced that teachers from the three schools were positive about the impact of the programme in their classroom teaching in terms of subject matter knowledge and teaching skills. They claimed that the programme helped enhance their subject matter knowledge as well as change their teaching styles from chalk-and-talk method to activity-based teaching, which emphasised student participation. It was also noted that the programme encouraged the use of teaching aids, which helped arouse students' interest in the topic. Nevertheless, the large number of students in the classroom was presented by all the teachers as one of the constraints in the effective use of activity-based teaching approach. The lack of sufficient and appropriate teaching aids was also noted by several teachers as a constraint in the use of activity-based teaching approach.

Despite the fact that all the teachers appreciated the contribution of the programme in enhancing their pedagogical content knowledge and skills, classroom observation revealed that there were differences among teachers in terms of how they executed the lessons. All teachers perceived the impact but also the constraints. Classroom observation gave a differentiated picture about teacher performance. Some teachers showed good performance in basic teaching skills, activity-based teaching and subject matter knowledge, whereas others appeared to have difficulties in these areas.

6.4 COLLABORATIVE USE OF PROGRAMME IDEAS IN PRACTICE

6.4.1 Peer collaboration activities

The aim of the programme was to encourage teachers to co-plan the lessons, team teach, and organise study groups. Table 6.10 shows that teachers conducted more variety of collaborative activities including discussion of the past exam questions and solving students' questions.

Table 6.10: Collaborative activities performed at schools

	School		
Activity	*School A*	*School B*	*School C*
▪ Co-planning of lessons	✓	✓	✓
▪ Team teaching	✓	✓	✓
▪ Study Groups	✓	✓	✓
▪ Discussion of the past exams questions	✓		✓
▪ Solving students' questions	✓		✓

Table 6.10 shows that all three schools performed the suggested activities; School A and School C performed other activities as well. Co-planning of the lessons and team teaching were conducted by those teaching Form 4 classes, whereas the study groups were conducted by all the mathematics teachers in the department as shown in Table 6.10.

Table 6.11: Frequency of collaborative activities performed at the three schools

	Schools		
Activity	*School A*	*School B*	*School C*
Co-planning of the lessons	Teacher A_1 & Teacher A_2 (4x)	Teacher B_1 & Teacher B_2 (2x)	Teacher C_1 & Teacher C_2 (4x)
Team teaching	Teacher A_1 & Teacher A_2 (2x)	Teacher B_1 & Teacher B_2 (2x)	Teacher C_1 & Teacher C_2 (4x)
Study groups	Five teachers in the department (3x)	Four teachers in the department (1x)	Six teachers in the department (2x)
Discussion of past exam questions	Teacher A_1 & Teacher A_2 (1x)		Teacher C_1 & Teacher C_2 (1x)
Solving students' questions	Teacher A_1 & Teacher A_2 (3x)		Teacher C_1 & Teacher C_2 (2x)

Table 6.11 shows that School A and School C conducted more collaborative activities than School B. This can be attributed to the teachers' commitment to their work, as these two schools were private. Thus efforts to perform better would guarantee more students for the school.

6.4.2 Teachers' perceptions of peer collaboration

The study also sought to explore the impact of the collaborative activities as perceived by teachers. Table 6.12 gives the summary of the areas in which teachers thought the collaborative activities had impact on them.

Table 6.12: Perceived impacts of suggested peer collaboration activities

Activity	School A	School B	School C
Co-planning of lessons	▪ Enhanced competence using activity-based teaching	▪ Enhanced compe-tence using activity-based teaching	▪ Discovering weaknesses in lesson planning
Study groups (Including discus-sion on past exam papers and solving students problems/ questions)	▪ Consolidated subject matter knowledge ▪ Filling knowledge gaps	▪ Consolidated subject matter knowledge	▪ Clearing doubts about some areas in the topic ▪ Consolidated subject matter knowledge
Team teaching	▪ Promoting collegiality ▪ Enhanced competence using activity-based teaching		▪ Promoting collegiality ▪ Enhanced competence using activity-based teaching

Through interviews, all six teachers from the three schools acknowledged that they benefited from collaborative activities both in subject matter knowledge and activity-based teaching as shown in Table 6.11.

Teachers from all three schools claimed that collaborative activities consolidated their subject matter knowledge. While teachers from School A argued that the collaborative activities helped them fill knowledge gaps that they had in the topic, their colleagues from School C argued that the activities helped them discover the weaknesses in the planning of lessons and cleared some doubts they had pertaining to some areas in the topic. Regarding activities-based teaching, teachers from School A and School B contended that collaborative activities, especially team teaching and co-planning of lessons helped enhance their competence in using the approach.

6.4.3 The role of facilitators

After the orientation programme, facilitators were expected to play a leadership role in their respective departments in order to help their colleagues enhance their pedagogical content knowledge and skills (PCK&S) in the teaching of probability (see Chapter 5). The facilitators tried to organise or take part in organising some collaborative activities in their respective schools four months after the orientation programme as shown in Table 6.13.

Table 6.13: Collaborative activities organised by facilitators

School	Role played by facilitators
School A	▪ Discussed seminar activities with all the teachers at the school ▪ Organised three study group sessions ▪ Led informal discussion about the exemplary materials
School B	▪ Organised informal meetings to discussed activity-based teaching ▪ Organised study group meeting
School C	▪ Discussed seminar activities with all the teachers at the school ▪ Organised study group meetings

The facilitators' contributions differed to some extent among the three schools as shown in Table 6.13. In School A and School C, facilitators had the opportunity to share what they had acquired from the seminar with the entire teaching staff through staff meetings, whereby they received positive reactions from the other teachers, especially in the idea of activity-based teaching. This teaching approach is in line with current efforts in the country towards teaching that encourages a student-centred approach. Facilitators in all three schools also valued study groups, which they used as avenues for encouraging their colleagues to adopt the collaborative activities performed during the seminar (co-planning of the lessons and team teaching).

Facilitators from all the schools, besides appreciating the significance of peer collaboration and the role they played, claimed that lack of time and workload had been a major problem for realising more effective collaboration among teachers. Besides being facilitators, they had teaching obligations to accomplish. There was no provision to reduce their workload.

6.4.4 Perceived impact of facilitators

Teachers' opinions about the contribution of facilitators did not differ much among the three schools. As in the previous study (Chapter 5), teachers were all positive about the contribution of facilitators. They contended that the facilitators played a vital role in supporting their colleagues. Teacher A_2, for example, said that whenever he was stuck either in solving a probability question or in understanding a certain concept, the first person he consulted was the facilitator. He added that facilitators had been very supportive during the teaching of lessons in the classroom situation. Teacher A_1, TeacherA_2, Teacher B_2, and Teacher C_2 argued that in terms of subject matter, the facilitators had been very supportive as they could spend some of their time helping clarify a certain content or taking the initiative to find solutions from other sources. In teaching activity-based lessons, Teachers A_1,

Teacher A_2 and Teacher C_2 argued that the facilitators were ready to advise on how to plan lessons so that they could meet the demands of the classrooms and the availability of the teaching aids. In the previous study, the major concern about facilitators was their skills in conducting collaborative activities. However, as Teachers A_1 and Teacher B_1 pinpointed it, the major concern was the availability of the facilitators. They argued that it was sometimes difficult to get hold of the facilitators as they were busy teaching like other teachers, since their workload had not been reduced so they could spend more time helping their colleagues. Moreover, for all the teachers, the presence of the facilitators had helped to promote collegial relationship among mathematics teachers in their respective departments by organising collaborative activities so as to enhance teachers PCK&S.

6.4.5 Constraints in conducting peer collaboration activities

When interviewed, all six teachers and the facilitators identified several constraints they faced in conducting collaborative activities in their respective schools. These constraints are summarised in Table 6.14.

Table 6.14: Problems encountered in conducting collaborative activities

School A	School B	School C
▪ Lack of time ▪ Clashing timetable ▪ Teachers leaving the school ▪ Occupied by private tuition	▪ Lack of time ▪ Double sessions ▪ Clashing timetables	▪ Lack of time ▪ Double sessions ▪ Preparation and marking of mock exams ▪ Occupied by private tuition

Table 6.14 shows that lack of time was indicated as one of the major problems all three schools faced in conducting collaborative activities. They associated the lack of time with congested timetables and the marking of large numbers of student exercise books. Teachers from School B and School C noted that the existence of double sessions in schools was another problem whereby mathematics teachers are split into two groups in such a way that it made it difficult for them to get the opportunity to conduct peer collaboration activities. Teachers from School A and School B considered clashing timetables as another constraint in conducting collaborative activities. This was specifically associated with team teaching. Team partners were sometimes allocated to teach at the same time in different classes. Teachers School A and School B claimed that their meagre salaries forced them to use any extra time they were getting to conduct private tuition or do other small projects so as to make ends meet.

In summary, teachers from the three schools conducted a number of collaborative activities that included co-planning of the lessons, team teaching, study groups and joint preparation of students' tests. Though teachers appreciated the importance of peer collaboration, time was a major constraint for them to benefit from the scenario. The time constraint was associated with clashing timetables, double sessions and teachers being involved in private tuition.

6.5 STUDENTS' EXPERIENCES AND LEARNING OUTCOMES

The study also explored students' experiences and learning outcomes with the activity-based probability lessons. These experiences, which were collected through guided group discussions and by a paper-and-pencil probability test, were classified into two parts: students' perceptions and students' learning from the programme. As pointed out in section 6.1.2, students as ultimate beneficiaries of change or innovation, the information gathered from them was considered useful for gaining insight into the potential impact of the programme on teachers.

6.5.1 Students' perceptions

This subsection presents students' perceptions on probability lessons and the teaching approach used for teaching the topic. Since students' perceptions did not differ much among the three schools, they have been pooled together for the purpose of getting a general picture of the impact of the programme on students' perspective.

Students' general opinions about probability lessons

In general, all the students (n=30) from the three schools who were involved in the guided group discussion were positive about the probability lessons. They said that the topic in general was interesting because it was taught through activities and experiments instead of just listening to the teachers and writing notes.

When asked to comment on the activities they found interesting in the lessons, they said that all the activities were interesting because they involved things that they encountered in their daily life experiences. Moreover, they pinpointed some activities that they found more interesting than others as shown in Table 6.15.

Table 6.15: Students' opinions about very interesting and least interesting classroom activities

Very interesting activity(ties)	**Reasons**
Tossing coins and throwing dice	▪ Very familiar ▪ Easy to understand the outcomes ▪ Easy to get a clear picture about probability
Least interesting activity(ties)	
▪ Drawing a tree diagram	▪ Difficult to comprehend the outcomes
▪ Selecting balls without replacement	▪ Confusing to determine the probabilities of the remaining balls
▪ Drawing cards from the deck	▪ Not familiar with cards ▪ Conceived as gambling so it is a sin
▪ Tossing coins	▪ Also done by robbers

From Table 6.15 it can be seen that some students considered activities that involved the tossing of the coins very interesting because it was familiar and easy to comprehend the outcomes; others considered tossing coins least interesting because they deemed it similar to an activity performed by a gang of robbers. The differences in perceptions were mainly associated with exposure, level of comprehension and beliefs.

In summary, students perceived the probability lessons positively, as they considered the topic very interesting. Nonetheless, they showed some differences in terms of the activities that they considered interesting and those they considered least interesting.

Students' perceptions of the benefits of group work

Activity-based teaching advocates the need for students to work in groups. When inquired how they felt about group work during probability lessons, all the students appeared to like the idea. They mentioned a number of reasons why they supported the idea. They said that working in groups:

- promotes students' participation, hence helping facilitate easy understanding of probability.

  Working in groups is good because every student participates and helps each other in case one does not understand the lesson well. Through group work, every student becomes perfect in the lesson.

- can give students a lot of information without using much energy and time compared to working individually. To elaborate on this, one student said:

  I like working in groups because I can get a lot of information without using much energy, different from just working alone.

Another student supports this idea by using a Swahili saying:

I like so much working in groups, as you know 'unity is power'.

- simplifies teacher's work because students teach each other. In elaborating this point one student argued:

  I did like to work in groups because if one student understands a question he/she elaborates it other students. Students are very good in teaching their colleagues.

Other reasons given by students as to why they liked working in groups are:

- working in groups saves time;
- the activities/experiments become easy and quickly done;
- makes the lessons interesting and helps to build a strong relationship among students and with their teachers.

In short, students were positive about the idea of working in groups, as they argued that it facilitates understanding of the topic through sharing of ideas, as well as simplifying teachers' work and saves time.

Students' perceptions of the usefulness of probability

An inquiry was made as to whether after being taught the probability lessons, students found probability useful in their daily lives. The majority of the students argued that they found probability useful, because it helps:

- caution people not to be completely sure of an event they are expecting to occur, as there are chances that it may occur or it may not.
- encourage one to face a challenging situation because of being aware that in whatever one endeavours to achieve, there are two possibilities: success or failure.
- in predicting future events. Elaborating on this point, one student argued that:
- *Probability is very useful in daily life because it is applied in predicting different events such as weather forecasting, results of different games, and so on.*
- in decision making, that is, by providing an idea of the degree of success or failure in a certain event, thus making it easy to decide what to do in order to avoid risks.

In general, the students perceived probability as useful in everyday life as it helps in decision making and in making reasonable judgements before indulging in a certain action.

Students' perceptions of team teaching

Since the teaching of probability involved team teaching, students were asked to give their opinions about the presence of two teachers in their classroom during the teaching of probability lessons. Students had mixed opinions about this issue. However, the majority of them supported the idea and few of them did not like it.

Those who liked the idea asserted that when two teachers were in the classroom, they helped one another make the lessons more understandable to students. Because the practice was not common in schools, one student claimed that

> *At the beginning, when I saw two teachers in the classroom, I was surprised, but when the teachers started teaching and support each other, I liked so much.*

Those who supported the practice also contended that team teaching was good because it helped promote attention and seriousness on the part of students. They further argued that each teacher had his/her style of teaching that helped make it easier to understand the probability lessons.

The few students (n=5) who did not like the idea of having two teachers in the classroom said that the situation not only gave teachers very little freedom and autonomy, but also interrupt students' attention. One student argued that:

> *It was not fair to have two teachers in the classroom because it interfered students' attention, they were feeling shy in answering questions as well as asking questions about the areas they did not understand. The idea makes some teachers not to teach properly because of the presence of his colleague in the classroom.*

Students' perceived learning from probability lessons

Students remarked that they learned a number of things from probability lessons. They said that through the knowledge of combined events, one can figure out how to put on small number of clothes he/she has in such a way that he/she would be seen as having a lot of clothes. They said that they also learned that probability can be used to make important decisions that would otherwise result in complaints from the parties involved. They cited the example of a referee coin toss before the start of a match (football, basketball, etc.) to decide which team would start on which side of the pitch. They argued that before the lessons, they thought that it was just a normal procedure before the game starts. They said that after the lessons they came to realise that the major reason was to avoid favouritism or bias in the selection of the side each team would start to play.

Apart from the given areas, they said that through knowledge of probability, they have also learned how to predict certain important events given the conditions surrounding those events, such as weather forecast.

In general, students showed positive perceptions about probability lessons. They considered probability very useful and applicable to different activities in every day life such as decision making bearing in mind the chances of success and failure. They also pinpointed that probability could be used in making selection of objects or people without bias. Furthermore, the majority of students appreciated the teaching approach that was used in teaching the topic, activity-based approach; however, they

differed in which activities they found most interesting and least interesting. The differences were either due to exposure, experiences or religious beliefs.

6.5.2 Student learning

As explained in section 6.1.5 students did the same test before and after the teaching of the probability lessons. Table 6.16 shows the overall performance for all the three schools pooled together.

Table 6.16: Pre-test and post-test results for all the three schools

Test	Mean	SD	N	t
Pre-test	32.6	12.9	130	29.6*
Post-test	63.8	17.4	130	

Note: *is statistically significant (p<0.05).

Table 6.16 shows that for all the three schools there was a significant difference between pre-test and post-test indicating that learning took place as a result of teachers using exemplary materials. Table 6.17 shows the performance of individual schools.

Table 6.17: Pre-test and post-test scores for individual schools

	School A				School B				School C			
Test	*Mean*	*SD*	*n*	*t**	*Mean*	*SD*	*N*	*t**	*Mean*	*SD*	*n*	*t**
Pre	40.3	14.7	50	17.84	28.6	8.7	45	18.49	26.9	8.5	35	14.94
Post	71.9	20.4	50		58.3	13.6	45		59.2	12.3	35	

Note: *is statistically significant (p<0.05).

From Table 6.17 it can be gathered that in overall performance, School A scored higher in both pre-test and post-test than School B and School C. The difference might be due to the teachers' performance in the classroom as indicated in section 6.3.1 where teachers from School A appeared to perform better than teachers in School B and School C.

In short, the teaching of activity-based probability lessons had an impact on students as revealed in their test results.

6.6 CONCLUSIONS

This chapter presented the results of the evaluation of the impact of the COSMAT-2 programme in enhancing mathematics teachers' pedagogical content knowledge and skills. The evaluation focused on teachers' reactions to the programme,

teachers' use of the programme ideas in practice and students' experiences and learning outcomes with the probability lessons.

The findings indicated that teachers were positive about the programme. They considered it useful in terms of:

- enhancing their subject matter knowledge in probability;
- enhancing their teaching skills by using activity-based teaching which, they said, helped promote students' participation;
- promoting collegiality among teachers.

Regarding the individual use of programme ideas in practice, there were differences between perceived and observed use. In terms of perceived use, teachers felt that as a result of the programme, their confidence in teaching probability increased because of enhanced subject matter knowledge. They also were of the opinion that their teaching skills had changed as a result of being introduced to activity-based teaching. In this regard they considered exemplary materials as being very useful in teaching the topic by helping them with subject matter knowledge and teachings skills that promoted students' participation in the classroom. However, some of them were of the opinion that the approach was difficult to implement due to large class size and lack of sufficient and appropriate teaching aids that could be used for conducting classroom activities. They further claimed that teaching with an activity-based approach consumed more time per lesson than teaching without the approach. This remark concurred with the findings from the observations. Though it was noted that teachers made efforts to conduct activity-based teaching, there were differences among them within the same school and between the schools involved. There were teachers who showed some competence in the use of approach, and there were those who showed that the approach was still far-reaching to them. Also some differences were marked on the use of the exemplary materials between the schools, especially in getting teachers' notes and students' exercises. The difference was due to the teachers' experience and desire to motivate their students as well as to examine what they could do after the lessons.

Teachers also perceived the programme as very useful in developing confidence in conducting collaborative activities. The activities they conducted included co-planning of the lessons, team teaching and study groups. They acknowledge that the activities helped them consolidate the subject matter knowledge and teaching skills through support from colleagues and facilitators. Even so, they said that lack of time, clashing timetables, teachers occupied with other private activities to make ends meet due to meagre salaries, and double sessions were major problems that hampered them benefiting from collaborating with their colleagues.

On their part, students were positive about activity-based probability lessons and the approach used for teaching the topic. Generally, students considered probability useful in daily life for decision making and selecting people or objects without bias. About the teaching approach, that is, group work and team teaching, the students said they helped facilitate learning and understanding of the topic. The post-test results were higher than pre-test ones indicating that activity-based probability lessons had an impact on students' learning. The results also showed that there are true differences in performance between the schools.

To sum up, it can be said that the programme had a positive impact on teachers' learning. Through its four major components (school-based seminar, exemplary materials, peer collaboration and facilitators) it contributed towards enhancing mathematics teachers' PCK&S. Nevertheless, the impact of the components differed among the teachers and between the schools. For all the schools, the exemplary materials appeared to be the most appreciated component of the programme by the teachers because they addressed topics many teachers perceived difficult to understand and teach. They were used intensively by teachers despite consulting other additional resources. The impact of the seminar was also appreciated. It was considered an appropriate avenue for helping teachers enhance their knowledge or acquire new skills, though time was seen as the major obstacle. Besides the aforementioned components, teachers also appreciated the impact of peer collaboration activities in enhancing their PCK&S. The role played by the facilitators during the seminar, for example, in conducting demonstration lessons and after the seminar that is supporting teachers in implementing activity-based teaching and organising collaborative activities, was also appreciated by the teachers. However, to be able to perform their activities effectively, facilitators needed to be equipped with skills and knowledge about their roles and the areas for which they would be responsible. In this study, facilitators could not play their roles well, because as teachers they had their own obligations, such as teaching, marking students' work and so on. For facilitators to be effective in supporting their colleagues, ways to reduce some of their workload need to be found.

CHAPTER 7
Discussion

This chapter discusses the results of the COSMAT study, draws some conclusions and makes a number of recommendations. Section 7.1 briefly recapitulates the research problem and approach. Section 7.2 offers a summary of the overall evaluation findings. The following sections discuss three prominent features of the programme in relation to those findings: focus on improving pedagogical content knowledge and skills (7.3); emphasis on peer collaboration (7.4); aiming at a comprehensive approach (7.5). Section 7.6 closes with conclusions and recommendations from the study.

7.1 RECAPITULATION OF THE RESEARCH PROBLEM AND APPROACH

The Tanzanian government has emphasized the need for regular in-service education to improve teacher quality and professionalism. In-service programmes are considered necessary not only to support teachers in acquiring new instructional approaches, but also to improve the basic quality of teachers since many schools are staffed by unqualified and underqualified teachers. Even those with formal qualifications commonly have problems in their teaching due to inadequate preparation during their pre-service education in teacher-training colleges. There are a number of reasons that so little has been done to address this situation. Because of the country's size, it is difficult to organise in-service education programmes that reach all mathematics teachers scattered throughout the country. One-shot in-service programmes may be possible, but it is difficult to organise follow-up sessions. However, professional development literature indicates that one-shot in-service education programmes are not effective, and the importance of follow-up activities at the school level is widely recognised (Fullan, 2001).

The COSMAT study was initiated to explore ways of providing teachers with school level support, within the existing constraints, in order to enhance their pedagogical content knowledge and skills (PCK&S). The study was organised within the framework of the *Teacher Education Assistance in Mathematics and Science*

(TEAMS) project. One of the main activities of that project is to organise in-service education for science and mathematics teachers. The aim of this study was to generate and test design guidelines for a sound teacher professional development scenario that is appropriate for the Tanzanian context. Peer collaboration, as an important component of such a scenario (in addition to other components, such as exemplary materials, school-based seminar and facilitators), was deemed to offer suitable support for providing teachers with on-the-spot and follow-up support at school level.

In order to design and evaluate such a scenario, the study opted for a development research approach. A preliminary orientation study included (a) a literature review to gain insight into promising professional development approaches, emphasizing peer collaboration; and (b) a context analysis to gain insight into the learning needs of mathematics teachers as well as the existing situation of the provision of in-service education in Tanzania. This orientation study offered useful information that helped in the formulation of guidelines for the development of the COSMAT programme. The guidelines were applied in two cycles of design and evaluation activities. In the first cycle, the programme was designed and piloted in three secondary schools. The formative evaluation showed that the programme did not fully achieve its goals, as many teachers appeared to need more support in terms of subject matter knowledge and skills. In response to this, the programme was revised and then evaluated with three other schools. The impact of the programme was measured directly through teachers' reactions and use of programme ideas in practice, and indirectly through students' learning outcomes.

In this chapter, the main findings of the study are summarized and discussed. After a summary of the overall findings (section 7.2), the following three sections discuss the extent to which the programme achieved its multiple aims, that is: enhancing mathematics teachers' PCK&S (section 7.3), promoting peer collaboration (section 7.4), and supporting PCK&S with a comprehensive approach (section 7.5). The design of the COSMAT programme is revisited in section 7.6 by looking at the main challenges and insights in designing a comprehensive, school-based teacher professional development scenario. The main conclusions and recommendations regarding the programme are presented in section 7.7.

7.2 SUMMARY OF OVERALL FINDINGS

This section presents the overall findings regarding the impact of the COSMAT programme with respect to the evaluation levels addressed in this study (as inspired

by Guskey, 2000). The levels include participants' reactions, participants' use of the programme ideas in practice and students' experiences and learning outcomes.
In terms of reactions, findings presented in chapters 5 and 6 indicate that in both cycles of the study, teachers were positive about the programme. Through the seminar with the exemplary materials, their confidence and competence in teaching had been improved. They have benefited in both subject matter and teaching skills. Teachers were also positive about the contribution of the programme in enhancing peer collaboration. Through the seminar they could get a clear picture about how peer collaboration could be conducted, which motivated them to organise collaborative activities.
These findings are based on teachers' self-reports. Taken alone these data do not give direct evidence about the impact of the programme in classroom practice. However, including this information is useful, because if participating teachers do not value the content and approach of the programme, it is highly unlikely that they would expend the effort to implement programme ideas and recommendations.

Results related to classroom enactment revealed that teachers did use programme ideas. In terms of individual use, teachers used exemplary materials intensively in teaching probability lessons. Results indicate that teachers also appreciate the material because the content, which they perceived as difficult to teach, was covered more clearly than in regular textbooks. A few teachers used the textbook as an additional source, because they erroneously thought that the exemplary materials did not cover some topics of the mathematics syllabus.
School visits and interviews with teachers also showed that teachers had adopted the collaborative activities that were promoted through the programme for the purpose of enhancing their PCK&S. Moreover, they were also stimulated to conduct other collaborative activities.

A third data source refers to student performance and experiences with the new approach. Findings from students' test results showed that there was a significant difference between pre-test and post-test scores, demonstrating that students gained knowledge as a result of activity-based probability lessons. This is a promising result, because probability is a topic that teachers indicate to be amongst the most difficult.
Findings also indicate that students valued the topic of probability as being useful in day-to-day activities. They also appreciated activity-based teaching and team-teaching approaches. They considered activity-based teaching (most of the time involving group work) useful, practical and interesting. They also perceived the

team-teaching approach as useful as it helped them gain knowledge from the shared expertise of two teachers.

Combining the results of the three data sources (teachers' perceptions, observations in classroom and schools, and student learning and experience), it can be concluded that the COSMAT-programme has yielded a positive impact on teachers' PCK&S and teacher collaboration. In the next sections this impact findings will be discussed in more detail.

7.3 PEDAGOGICAL CONTENT KNOWLEDGE AND SKILLS

A key concept in this research focuses on teachers' pedagogical content knowledge and skills. This blending of subject matter knowledge and pedagogy forms a unique part of the knowledge base of the teaching profession.
In the COSMAT programme several choices had been made in exemplifying PCK&S. First, probability was chosen as the topic since teachers in Tanzania indicate that it is among the most challenging. Second, from the perspective of pedagogy, an activity-based approach was preferred because student-centred learning is promoted in the Tanzanian mathematics syllabus. Thus, activity-based teaching of probability is a challenge for teachers from both a content as well as an instructional perspective. Results of this study indicate that the teachers could implement active learning strategies in teaching probability, but that this combination put a rather heavy cognitive load on them. As a consequence, their basic teaching strategies did not show the expected level of proficiency. In hindsight, it may have been a good idea to have chosen a less difficult topic as a starting point to learn and practice activity-based lessons. Had that been the case, teachers could have focused their full attention on integrating the innovative approach in their normal routines, without having to spend much extra energy on the subject matter.

Despite the fact that teachers appreciated the importance of activity-based teaching for ensuring student participation, some showed concern about it. For them, using an activity-based approach takes more time than other methods. Their concern was brought about by the class size, lack of appropriate teaching material and pressure to finish the syllabus.
An activity-based approach mandates a high degree of student-teacher interactions. Language plays an important role in this approach. Through observation, it was noted that in some classes there was a problem of interaction between teachers and

students because of language problems. Findings indicate that a number of students could not respond to teachers' questions – not because they did not have an idea of how to answer, but because they did not know how to communicate their ideas to the teacher. If the same question was asked in Kiswahili, students were able to answer it, but also in Kiswahili. Apparently, language has an important impact on students' understanding of mathematics (cf. Howie, 2002).

7.4 PEER COLLABORATION

In the previous section we discussed *what* the teachers learned from the COSMAT programme. Equally important, however, is *how* teachers learn. Peer collaboration is a way of teacher learning that grounds professional development in practice and builds on collegial interaction amongst teachers. A basic assumption in the COSMAT programme is that professional development should not be seen as a one-shot, quick-fix activity, but as a continuum of meaningful experiences that are closely connected to teachers' work settings. Therefore, peer collaboration played a crucial role in the COSMAT programme. The impact of the programme on peer collaboration is discussed from two perspectives: (i) promoting peer collaboration, and (ii) enhancing teachers' PCK&S.

Encouraging peer collaboration

In terms of promoting peer collaboration, findings show that the programme has increased teachers' confidence in conducting peer collaboration activities, and in increasing their readiness to organise and conduct the activities in their respective schools. Their readiness to do so manifested itself in the range of collaborative activities they performed. Teachers not only performed collaborative activities that were encouraged and promoted during the seminar (i.e. co-planning of lessons, team teaching and study groups), they carried out other collaborative activities that included discussions on past examinations questions and solving students' questions. Having a variety of collaborative activities helped to cater to individual teacher preferences and possibilities, as evidenced in the differences among the schools and teachers in terms of collaborative activities they performed. This demonstrates that motives for collaboration and preferences for ways of learning differ among teachers (cf. Thijs, 1999).

A distinctive characteristic of the COSMAT programme is that the collaborative activities were organised and co-ordinated by experienced teachers who took on the role of facilitator. In this study the role of the facilitator is related to a broad

variety of tasks, although all are connected to the improvement of mathematics education in the school. It was initially assumed that teaching experience, authority in the department and participation in the materials development workshop were sufficient requirements for performing the facilitator role successfully. However, findings from the formative evaluations called for a revision of this assumption and prompted subsequent action. The facilitators also needed extra support regarding the skills required to organise and conduct collaborative activities (cf. Sparks, 2002). Therefore, in the second cycle of the COSMAT programme implementation, facilitators were offered an orientation programme. Findings indicate that the facilitators perceived the orientation programme as beneficial in providing them with a clear picture of how collaboration activities could be conducted. Because different participants took part in the first and second cycles of the study, it is not possible to formulate comparative findings about the effect of the orientation programme.

In general, the findings indicate that the facilitators played an important role in the success of peer collaboration in the COSMAT programme. They provided for logistical support, but more important, they were trustworthy and nearby resources for their colleagues. However, even the able performance of the facilitators could not ensure a flawless implementation of peer collaboration activities. As also experienced in a previous study (Thijs, 1999), implementing peer collaboration activities in teachers' daily context is a complex endeavour. Findings show that high teaching loads and tight time tables were major constraints, making it difficult for teachers to benefit fully from collaborative endeavours. As confirmed in earlier studies (Little, 1993; Stuart, 1997; Thijs, 1999), teachers lacked time for collaboration in their daily context. This was not only the case for the teachers, but also for the facilitators. Moreover, there were no formal incentives for carrying out the facilitating tasks.

Peer collaboration and PCK&S

The impact of peer collaboration is revealed as a result of the benefits teachers gained from the variety of collaborative activities they performed. Findings show that teachers appreciated the contributions of peer collaboration activities in consolidating their subject matter knowledge and teaching skills. By conducting co-planning of the lessons with the use of the exemplary materials teachers were provided with the opportunity to gain more insight about how to plan lessons better with activity-based teaching aimed at realising student involvement. Through co-planning of the lessons, teachers became more aware of their weaknesses and potential strengths in lesson planning. Co-planning coupled with

team teaching, with the support of the exemplary materials, helped teachers to gain more insight on how lessons with an activity-based approach can be implemented in real classroom situations. These activities not only brought benefits to the individual teachers involved, but fostered collegial relationships among them. Similar findings were also documented in other studies conducted in Southern Africa. Thijs (1999) in her study in Botswana found that peer collaboration, including informal discussions, team teaching sessions and cluster meetings, provided teachers with an opportunity to exchange ideas and broaden their view of innovation. Harvey's study (1999) in South Africa found that coaching helped teachers to introduce a wider variation of learner-centred strategies.
Being involved in other collaborative activities outside the classroom (study groups) provided teachers with the opportunity to gain in-depth understanding about PCK&S through seeking solutions for their own, and their students', problems. This finding supports the findings from other studies that showed that learning in groups significantly improves learning and that, although structures for group work differ, all are more effective than solitary learning (Korthagen & Kessels, 1999; Springer, Stanne & Donovan, 1999).

It can be concluded that the COSMAT programme was effective in supporting teachers and facilitators to engage in peer collaboration activities and that these activities were productively linked to the improvement of mathematics education by enhancing teachers' PCK&S.

7.5 THE COMPREHENSIVE APPROACH OF THE COSMAT PROGRAMME

The COSMAT programme opted for a comprehensive approach primarily because a variety of professional development activities were considered necessary for effective and sustainable support. This argument rests on the assumption that it is very important to have a combination of activities that cause teachers to collaborate in serious and sustained ways and reflect on their work and its effects on students (Sparks, 2000). There is no single 'best' approach to professional development; rather it is most effective to use multiple approaches.
In this section an account is given of the choices taken by the COSMAT programme. This account concentrates on the important place of the concept of curriculum in the programme and on the interaction between generic and site-specific components. Moreover, the interactions of the different components are presented in a model.
Curriculum perspective

Fishman, Marx, Best and Tal (2003) place the concept of curriculum central to every professional development endeavour, because curriculum represents what, and often also how, teachers are directed or suggested to teach in the classroom. In this study the concept of curriculum plays a pivotal role in several ways.
First, the content of the programme was directed to enhance teachers' subject matter knowledge in the topic of probability. This topic, as revealed in the needs assessment at the beginning of this study, was perceived by teachers to be one of the most difficult in the Tanzanian mathematics syllabus.
Second, it was decided that activity-based learning would be used as an innovative method of mathematics education. As argued earlier, using a difficult topic in combination with an innovative instructional strategy may have been too great a burden on the participating teachers. The ambitious combination of a difficult topic and an innovative teaching strategy may lead to promising results. However, chances for sustainable improvement may grow if teachers have the opportunity to gradually incorporate active learning strategies into their routine repertoire.
Third, curriculum played an important role in the COSMAT programme in the form of materials. These materials served several functions. In the seminar, the curriculum materials aimed at demonstrating what the innovative approach is about and also served as a source for subject matter knowledge. Moreover, the materials were used by the seminar participants to prepare and conduct micro-teaching lessons. The curriculum materials also helped teachers to implement the innovative approach of teaching probability in their classroom. Results of this study confirm findings of other studies that curriculum materials are an important and relatively cheap source for teacher learning (Ball & Cohen, 1996; Ottevanger, 2001; Van den Akker, 1988; Van den Berg, 1996).
In addition, curriculum materials were also applied in this study as a means to focus peer collaboration amongst teachers to the innovation at hand. Experienced teachers within the mathematics department of the school developed these materials, together with the researcher, and used the materials to help their colleagues at the department with implementation.

Site-specific and generic components

The context of teacher learning may be situated in daily practice or may have a more generic nature. Classroom practice is perceived as a vital source for teacher learning. However, the accrual of experience does not automatically translate to teacher learning. Berliner (2003) coins the term 'deliberate practice' to indicate a combination of practice and reflection that enhances teachers' level of competence. In the COSMAT programme this deliberate practice is encouraged by peer collaboration with the support of an experienced teacher as facilitator. So, the source for learning is not in the isolation of the teacher's classroom, but in peer

collaboration through team teaching and on-site help from a more knowledgeable colleague, resulting in 'deliberate practice'.
However, the COSMAT programme is not entirely site-specific; it also has a generic component, included for reasons of effectiveness. The context analysis showed that there are genuine problems in teacher preparation and student performance in mathematics across the curriculum. A more generic approach in the form of central development of the content of the seminar and the curriculum materials by facilitators seemed to be appropriate.
In the follow-up of the seminar, the benefits of a more site-specific approach were instigated. Although participants valued the peer collaboration activities, results also indicate that these activities may not be sustainable. Clashing timetables, heavy teaching loads and no extra time for the facilitators are major obstacles. Minnet (2003) stresses the importance of planning and scheduling of collaborative activities on a regular basis. Those activities should have a formal status endorsed by the school administration.

The comprehensive nature of the programme was reflected in the interaction among the various components in supporting mathematics teachers to enhance their PCK&S rather than each component working as a separate entity. See Figure 7.1 for a visual representation of the components and their interaction.

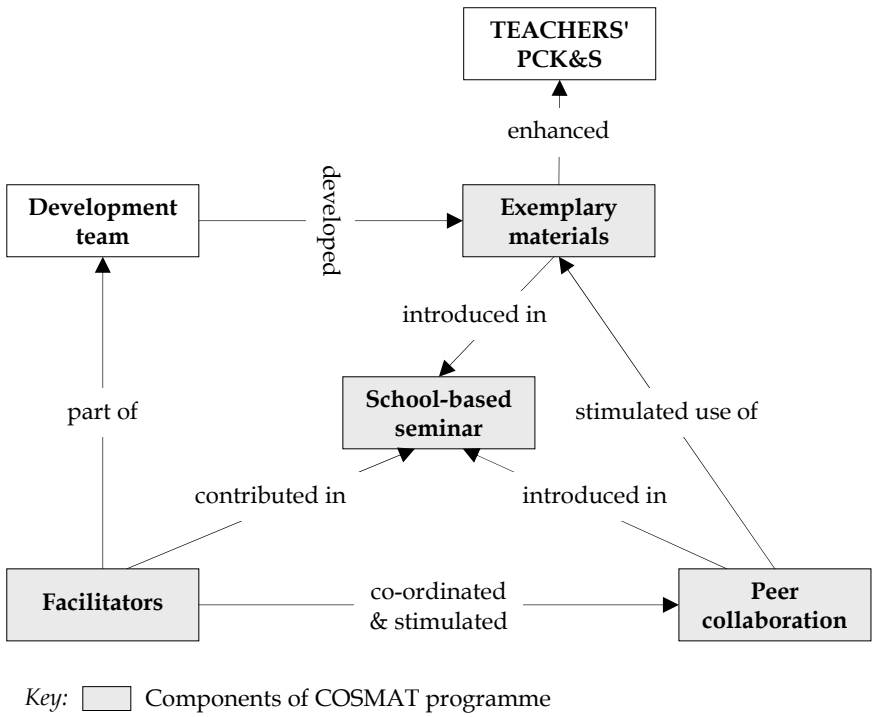

Figure 7.1: Overview of components and interactions in teacher professional development

7.6 CONCLUSIONS AND RECOMMENDATIONS

The general conclusion of the COSMAT study is that a professional development programme with multiple components can lead to the improvement of mathematics education in Tanzania. On a more specific level, a number of lessons learned can be formulated.

Context-responsive design choices

This study has underlined the necessity of responsiveness to particular educational development characteristics at various system levels when trying to apply general principles (cf. de Feiter, Vonk & van den Akker, 1995).

For example, the combination of generic and site-specific development components has proven to be (cost-)effective. In a developing country like Tanzania it is not feasible to realise development approaches that are completely tailor-made to the local needs of all schools and teachers. Comparable problems with mathematics education are apparent throughout the entire country. From a cost-benefit point of view, it makes sense in such a context to develop curriculum materials and in-service programmes at a national level. Of course, such a generic strategy cannot adequately address local, specific support needs of teachers as they work to implement innovations in their classroom practice. For that purpose, a site-specific approach has been chosen: teachers receive support from experienced colleagues who have participated in a short in-service programme for this task and who have also gained relevant pedagogical content knowledge as participants in curriculum materials development.

Positive role of curriculum materials

This study has confirmed findings from previous research about the effectiveness of (exemplary) curriculum materials as a tool for facilitating teacher learning about innovative curriculum proposals (cf. van den Akker, 1988; Ottevanger, 2001). Moreover, the role of curriculum materials as a component within in-service programmes has reconfirmed previous positive findings (van den Berg, 1996; Stronkhorst, 2001).

Also, the curriculum materials proved to be helpful in focusing peer collaboration on the innovation at issue (cf. Thijs, 1999; Thijs & van den Berg, 2002).

A new element of the COSMAT approach was the joint development of curriculum materials as a means to mobilise and feed the pedagogical content expertise of experienced teachers who then served as facilitators in their own schools. This seems a productive strategy, especially for developing countries, with a twofold outcome: learning of facilitators and the materials themselves.

Peer collaboration

The COSMAT programme has resulted in various ways of peer collaboration between teachers. To stimulate such practices, the role of the facilitator appeared to be very productive. This form of teacher leadership helped to focus collaboration on actually improving mathematics instruction. The results indicate that this type of collaboration and the joint piloting of the innovation can be considered as the most important outcomes of the programme. However, arranging sufficient time and other facilities for such collaborative teacher activities appeared to be problematic. That obstacle creates a risk for the sustainability of the innovation in school practice.

Teacher learning in PCK&S

Analysis of the study also leads to the conclusion that the subject matter within PCK&S deserves even more attention than initially expected. Based upon the results of the formative evaluation, the COSMAT programme had to be bolstered in this area. The learning task was very complicated and challenging for the teachers: instruction on a difficult topic (probability) and at the same time implementing a new pedagogical approach. This combination led to cognitive overload for teachers, resulting in less than adequate lesson practices, even on routine elements.

Nevertheless, we may conclude that the COSMAT programme contributed to an improvement of the pedagogical content skills of the participating teachers. The significantly better student results also point in that direction.

Future directions

In terms of both innovation strategies as well as research activities, it seems worthwhile to further explore and evaluate efforts to scale up the professional development approach with multiple components as applied in the COSMAT programme. This study has produced promising building blocks and valuable professional experiences. A major challenge seems to be how to develop an approach that combines the strengths of interventions at both generic and site-specific levels, which is at the same time feasible and cost-effective when implemented at large scale.

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ENGLISH SUMMARY
Enhancing mathematics teachers' pedagogical knowledge and skills in Tanzania

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CONTEXT

Basic Mathematics is a compulsory subject that is taught at O-level secondary schools in Tanzania. The main objectives of teaching this programme at school are as follows:

i) to promote the development and application of mathematical skills in interpreting the world and solving problems in daily life;
ii) to provide pupils with mathematical tools and logical thinking skills, which they can apply in understanding other subjects better;
iii) to develop a foundation of mathematical knowledge, techniques and skills for studying mathematics and related subjects at higher levels of education.

However, students have been performing very poorly in this subject. Many reasons have been given to explain the situation, one of them being the inadequate quality of mathematics teachers. In recent years, due to the expansion of student enrolment and the expansion of secondary schools, there has been a shortage of qualified teachers. Schools have been staffed by unqualified and underqualified teachers. These teachers have problems in pedagogical content knowledge and skills (PCK&S), as do many teachers who have earned a formal qualification. There is a need to support these teachers through professional development so as to enable them to enhance their PCK&S, which may ultimately lead to students' improved performance.

The government, through the Ministry of Education, is facing challenges in organising in-service education programmes. Due to the large size of the country, it is difficult to organise in-service programmes that reach all mathematics teachers who are scattered throughout the country. One-shot in-service programmes may be possible, but it is difficult to organise follow-up sessions. Recent literature on

professional development affirms that short in-service courses are not effective, especially when follow-up support at school level is lacking. Peer collaboration has been seen as a promising strategy in this respect.

PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

The purpose of the study was to explore, design and evaluate a school-based teacher professional development programme with peer collaboration aimed at enhancing mathematics teachers' PCK&S. In order to develop and evaluate such a programme, the study was guided by the following research questions:

- What are the characteristics of school-based professional development that includes peer collaboration?
- How does such a programme enhance mathematics teachers' pedagogical content knowledge and skills?

RESEARCH APPROACH AND DESIGN OF THE STUDY

Since teacher professional development with peer collaboration was a new phenomenon in the Tanzanian context, the COSMAT study opted for a development research approach. This approach allows step-by-step development of the programme and sensitivity to the context. The study was divided into three (somewhat overlapping) stages: the foundation building stage, the development stage and the evaluation stage. The foundation building stage involved preliminary investigations, including a literature review to gain insight into promising professional development approaches with peer collaboration. This stage also involved a context analysis aimed at gaining insight into mathematics teachers' learning needs as well as the situation of the provision of in-service education in Tanzania. The development stage dwelled on the development of the programme whereby formative evaluation played a major role. In the evaluation stage, the study focused on the impact of the programme, as measured through teachers' reactions, teachers' use of programme ideas in practice and students' experiences and learning outcomes.

The designed programme was comprehensive in nature through a combination of multiple components: exemplary materials, a school-based seminar, peer collaboration and facilitators. The exemplary materials, including many procedural specifications, were used to enhance mathematics teachers PCK&S in the teaching

of probability (a topic many teachers perceived as being difficult to understand and teach). The school-based seminar was used to introduce and elaborate the ideas behind the exemplary materials. Peer collaboration, being the core of the programme, was intended to stimulate the use of the exemplary materials. Facilitators played a fundamental role by being able to support teachers by giving on-the-spot support in the use of programme ideas in practice. They also participated in stimulating and organising peer collaboration activities.

RESULTS

In terms of reactions, teachers were positive about the programme. Through the seminar with the exemplary materials, their confidence and competence in teaching in mathematics had been increased. They had benefited in both subject matter and teaching skills. Teachers were also positive about the contribution of the programme in enhancing peer collaboration. Through the seminar they could get a clear picture about how peer collaboration could be conducted, which gave them motivation to organise such collaborative activities.

Teachers' appreciation of the programme was also evidenced through their use of programme ideas in practice, individually or collaboratively. In terms of individual use, teachers made much use of exemplary materials in teaching probability lessons, though they made some additions from other sources. The intensive use of materials underlined the relevance of the content. Moreover, the materials covered the topic more clearly than was done in the regular textbooks.

In terms of collaborative use, teachers adopted the collaborative activities that were promoted through the programme for the purpose of enhancing their PCK&S. They also conducted other collaborative activities that were deemed appropriate to support them.

On the part of students, their test results showed that some learning had taken place as a result of the activity-based teaching. Their perceptions suggest that they had benefited from the probability lessons by gaining knowledge that was related to everyday life, such as determining events that are uncertain in life, prediction of future events and decision making. Their opinions also suggested that the activity-based teaching approach was useful for enhanced understanding and appreciated for making lessons more interesting.

CONCLUSION

The study has revealed that the use of a comprehensive, school-based programme, emphasising peer collaboration, can be a promising scenario for professional development of mathematics teachers in Tanzania. Such a comprehensive approach has the potential of supporting teachers with diverse levels of expertise and experience in teaching. By tailoring the programme to the school level, it can help to offer support that is contextually relevant and meaningfully addressing the needs of the teachers.

APPENDIX A1
Teachers' questionnaire (for learning needs assessment)

Dear Teacher,
You will be requested to participate in the in-service education programme which will be organised in your school. Through this questionnaire we would like to get your opinions and learning needs regarding the teaching of mathematics. The information you provide will be used as the basis for designing and organising the programme. The major aim of designing this programme is to try to make the provision of in-service education and teacher professional development programmes sustainable.

We would like to assure you that all the information you provide will be treated strictly confidential, and will be used for research purposes only.

A: General Information

1. Name of school? _____
2. What is your age? _____ years.
3. What kind of qualification do you have?
   - ☐ Diploma
   - ☐ MEd/MSc(Ed)
   - ☐ B.Ed/BSc(Ed)
   - ☐ Other, namely _____
4. Which forms do you teach?
   - ☐ Form 1
   - ☐ Form 3
   - ☐ Form 2
   - ☐ Form 4
5. What other subjects do you teach apart from mathematics?
   - ☐ Chemistry
   - ☐ Physics
   - ☐ Geography
   - ☐ Other, namely _____
6. How many in-service education programmes have you attended? _____

B: Mathematics Teaching

7. Which topics in basic mathematics syllabus do you think you would appreciate to have further training ? (*Put a **V** in a box against the topic you need further training and an **X** in a box against the topic which you do not need further training*)
   - ☐ Functions
   - ☐ Linear programming
   - ☐ Matrices and transformations
   - ☐ Probability
   - ☐ Sequences and series
   - ☐ Statistics

   Others (specify) _____

C: Peer Collaboration

8. What do you think about collaborating with colleagues?
   - ☐ Not important
   - ☐ Slightly important
   - ☐ Important
   - ☐ Very important

9. How do you feel with the idea of observing a colleague teaching?
   - ☐ Very uncomfortable
   - ☐ Uncomfortable
   - ☐ Comfortable
   - ☐ Very comfortable

10. Have you ever observed a colleague teaching?
    - ☐ Yes
    - ☐ No

11. Do you think you can benefit from observing a colleague teaching?
    - ☐ Very much
    - ☐ Much
    - ☐ Little
    - ☐ Very little
    - ☐ Not at all

    Please explain _____

12. How do you feel with the idea of being observed by a colleague?
    - ☐ Very uncomfortable
    - ☐ Uncomfortable
    - ☐ Comfortable
    - ☐ Very comfortable

13. Do you think you can benefit from being observed by a colleague?
    - ☐ Very much
    - ☐ Much
    - ☐ Little
    - ☐ Very little
    - ☐ Not at all

    Please explain _____

APPENDIX A2
Interview questions for heads of maths department

---

1. How many teachers are in your department? What are their qualifications?

Qualification	**Number of Teachers**
Diploma (Ed.)	
B.Ed./BSc (Ed.)	
M.Ed/MSc	
Other(specify)	

2. Do teachers in your department get opportunities to attend in-service education programmes ?
   If yes, how often?
   If no, why?

3. What kind of teacher development activities do you have in your department? What opinion do you have about their quality?

4. Do teachers perform collaborative activities in your department?
   If yes, what are they? How do they function?
   If no, why ?

5. In your opinion, which mathematics topics in the basic mathematics syllabus teachers find it difficult to teach ? Why ?

6. Which topics do mathematics teachers find it easy to teach?

7. Which teaching methodological skills do teachers mostly use in teaching mathematics in your school? Why ?

8. What is the situation of mathematics teaching materials in your school?

9. What other teacher collaborative activities would you like to share with us so as to improve teachers' performance in the classroom setting ?

APPENDIX A3
Interview questions for heads of schools

---

1. What comments do you have about the current trend of the provision of in-service education for mathematics teachers in Tanzania?

2. Is there any teacher professional development programme in your school?
   If yes, how do you organise it?
   If no, why?

3. What kind of support do you give to your teachers in order to be successful in professional development efforts?

4. Do teachers perform collaborative activities in your school?
   If yes, what are they? How do they function?
   If no, why?

5. What is your opinion about the idea of introducing peer collaboration in your school?

6. What is the situation of mathematics teaching materials in your school?

7. In your opinion, do you think that through collaboration, teachers can help in producing teaching materials?
   If yes, how?
   If no, why?

8. What other collaborative activities would you like to share with us?

APPENDIX A4
Interview for teacher educators

---

1. According to your opinion, what is the quality of mathematics teaching at ordinary level secondary schools in Tanzania?

2. What is your opinion about the quality of mathematics teachers?

3. What comments do you have about the trend of the provision of in-service education for mathematics teachers in Tanzania?

4. What opinion do you have about teacher collaboration in their job of teaching mathematics?

5. Do you think that peer coaching can have any effect on teachers' performance in the classroom setting? Why?

6. If peer collaboration is to be introduced in schools, how should it be designed order to make it more effective?

7. In your opinion, which mathematics topics in the basic mathematics syllabus teachers find it difficult to teach?

8. Which teaching methodological skills do teachers mostly use in teaching mathematics in schools?

APPENDIX B
Teachers' questionnaire

Dear Teacher,

This questionnaire is aimed at collecting your opinion about the seminar. You are hereby requested to provide your genuine responses about each question. The information you provide will be treated strictly confidential, and be used for this research only.

A: General information

1. Name of the school _____
2. Name of the teacher _____
3. Sex: ☐ Male ☐ Female
4. Age: _____ (years).
5. What is your teaching experience? _____ (years)
6. Other teaching subjects apart from mathematics
   ☐ Physics ☐ Geography
   ☐ Chemistry ☐ Other(specify) _____

B: Information about seminar

7. How did you find the seminar?
   Very useful 5 4 3 2 1 Not useful at all
   Explain _____
8. To what extent has the seminar met your expectations?
   Very much 5 4 3 2 1 Very Low
   Explain _____
9. How did you find the resource persons?
   Very useful 5 4 3 2 1 Not useful at all
   Explain _____
10. How did you find lesson presentations?
    Very useful 5 4 3 2 1 Not useful at all
    Explain _____

11. To what extent have the lesson discussions broaden your knowledge in probability?
    Very much 5 4 3 2 1 Very low
    Explain _____

12. How useful was micro-teaching component in this seminar?
    Very useful 5 4 3 2 1 Not useful at all
    Explain _____

13. To what extent has the seminar increased your confidence in teaching probability? Very much 5 4 3 2 1 Very low
    Please elaborate _____

14. Did the seminar change your perception about probability?

Yes	
No	
Not sure	

    If yes, how? If no, why?
    _____

15. How do you find the exemplary materials?
    Very useful5 4 3 2 1 Not useful at all
    _____

16. Do you expect to use the materials for teaching probability in you class?

Yes	
No	
Not sure	

    Please elaborate _____

17. What problems do you expect in teaching probability in your classroom?
    _____

18. Do you support the idea of peer collaboration in schools?

Yes	
No	
Not sure	

    Explain _____

19. How do you rate your confidence in implementing peer collaboration in your department? Very confident 5 4 3 2 1 Not confident at all
    Explain _____

20. What problems do you expect in implementing peer collaboration in your department?
    _____

APPENDIX C
Classroom observation checklist

Introduction to the lesson

	Yes	N/a	No	
A. Basic teaching skills				
1. Teacher to be prepared for the lesson	☐	☐	☐	_____
2. Teacher asks oral questions about the previous lesson and waits students' answer	☐	☐	☐	_____
3. Teacher makes clear statement of the purpose of the lesson	☐	☐	☐	_____
4. Teacher use regular classroom aids	☐	☐	☐	_____
5. Teacher makes references to textbooks (where necessary)	☐	☐	☐	_____
6. Teacher discusses and review previous homework (when necessary)	☐	☐	☐	_____
B. Activity-based teaching				
1. Teacher introduces the lesson by an activity	☐	☐	☐	_____
2. Teacher asks learners about their ideas about the activity	☐	☐	☐	_____
3. Teacher clarifies how the activity will be conducted	☐	☐	☐	_____
4. Teacher explains the relationship of the activity with the previous lesson	☐	☐	☐	_____
5. Teacher establishes relevance of the activity to the learners' daily lives	☐	☐	☐	_____
C. Subject matter knowledge				
1. Teacher gives appropriate information about the lesson	☐	☐	☐	_____
2. Teachers gives accurate information to learners about the activity	☐	☐	☐	_____
3. Teacher relates the information to the previous topics/lessons	☐	☐	☐	_____

Body of the lesson

	Yes	N/a	No	
A. Basic teaching skills				
1. Teacher has all the necessary teaching materials	☐	☐	☐	_____
2. Teacher ensures participation of all the students	☐	☐	☐	_____
3. Teacher encourages students to ask questions	☐	☐	☐	_____
4. Teacher organises students in groups	☐	☐	☐	_____
5. Teacher supervises group presentations	☐	☐	☐	_____
6. Teacher effectively handles timing difficulties	☐	☐	☐	_____
7. Teacher moves round the class	☐	☐	☐	_____
8. Teacher's preparedness contributes to a smooth lesson	☐	☐	☐	_____
9. Teacher maintains positive learning environment during activity	☐	☐	☐	_____
B. Activity-based teaching				
1. Teacher introduces the activity	☐	☐	☐	_____
2. Teachers gives the objective of the activity	☐	☐	☐	_____
3. Teacher divides class in groups for the activity	☐	☐	☐	_____
4. Teacher demonstrates how to do the activity	☐	☐	☐	_____
5. The demonstration is visibly clear to all the learners	☐	☐	☐	_____
6. Teacher supports groups of students by asking questions	☐	☐	☐	_____
7. Teachers supports groups of students by giving advice	☐	☐	☐	_____
8. Teacher gives clear instructions on how to perform the activity	☐	☐	☐	_____
9. Teacher closely supervises the groups by moving around the class	☐	☐	☐	_____
10. Teacher interacts equally with all groups	☐	☐	☐	_____
11. Teacher encourages learners to ask questions	☐	☐	☐	_____
12. Teacher allows sufficient time to answer questions	☐	☐	☐	_____
13. Teacher interacts with students during activities	☐	☐	☐	_____

	Yes	N/a	No	
C. Subject matter knowledge				
1. Teacher relates appropriately one activity to another	☐	☐	☐	_____
2. Teacher answers students' questions correctly	☐	☐	☐	_____
3. Teacher clarifies the new terms and concepts appropriately	☐	☐	☐	_____
4. Teacher relates activity with learners daily life experiences	☐	☐	☐	_____
Conclusion of the lesson				
A. Basic teaching skills				
1. Teacher summarises the lesson	☐	☐	☐	_____
2. Teacher ask groups to present their results	☐	☐	☐	_____
3. Teacher summarises the findings of activity	☐	☐	☐	_____
4. Teacher spends time to discuss the activity thereafter	☐	☐	☐	_____
5. Teacher asks learners questions and waits for responses	☐	☐	☐	_____
6. Teacher encourages learners to ask questions	☐	☐	☐	_____
7. Teacher gives homework assignment	☐	☐	☐	_____
8. Teacher explains the significance of the homework	☐	☐	☐	_____
9. Teacher clarifies how the homework will be done	☐	☐	☐	_____
B. Activity-based teaching				
1. Teacher asks the group to report their results to the class	☐	☐	☐	_____
2. Teacher draws conclusion from the activity(ies)	☐	☐	☐	_____
3. Teacher, together with learners, draw conclusions from the activities	☐	☐	☐	_____
4. Teacher guides the learners to know the differences in their results	☐	☐	☐	_____
C. Subject matter knowledge				
1. Teacher correctly clarifies the results of the activity	☐	☐	☐	_____
2. Teachers relates the activity with the theory behind it	☐	☐	☐	_____
3. Teacher provides theoretical conclusion from activity	☐	☐	☐	_____
4. Teacher appropriately summarises the lesson	☐	☐	☐	_____

	Yes	N/a	No	
General impression				
A. Basic teaching skills				
1. Teacher asks thought provoking questions	☐	☐	☐	_____
2. Teachers listens to students' answers	☐	☐	☐	_____
3. Teachers encourages students to ask questions	☐	☐	☐	_____
4. Teacher well prepared for the lesson	☐	☐	☐	_____
5. Teacher uses period time effectively	☐	☐	☐	_____
6. Teacher uses classroom aids properly	☐	☐	☐	_____
7. Teacher improvises the teaching aids	☐	☐	☐	_____
8. Teachers uses teaching aids to make the lesson more clear	☐	☐	☐	_____
B: Activity-based teaching				
1. Teacher organises students in groups for classroom activities	☐	☐	☐	_____
2. Teachers clarifies the activities	☐	☐	☐	_____
3. Teacher guides students in doing activities	☐	☐	☐	_____
4. Teachers gives students opportunity to reflect on the results	☐	☐	☐	_____
C: Subject matter knowledge				
1. Learners meet overall lesson objectives	☐	☐	☐	_____
2. Teacher appears confident in lesson content	☐	☐	☐	_____
3. Teacher appears confident in lesson content	☐	☐	☐	_____
4. Teacher seem to have firm understanding of subject area	☐	☐	☐	_____

APPENDIX D
Interview scheme for teachers

---

1. How did you find the seminar?

2. Explain whether seminar has contributed in enhancing your skills in teaching activity-based probability lessons.

3. What can you say about the contribution of the seminar on enhancing your subject matter knowledge?

4. Everything has strengths and weaknesses. What are the strong points for this seminar? What are the weak points for this seminar?

5. In what ways do you think you have benefited from the collaborative activities in terms of enhancing your subject matter knowledge in probability?

6. In what ways do you think you have benefited from the collaborative activities in terms of enhancing your skills in teaching activity-based lessons?

7. What problems did you encounter in conducting collaborative activities?

8. What are your specific comments about the support you got from the exemplary teaching material in terms of enhancing your subject matter knowledge?

9. What are your specific comments about the support you got from the exemplary teaching material In terms of enhancing your skills in teaching activity-based lessons?

10. Do you expect to use the exemplary teaching material in future in teaching probability?

11. Describe the role of facilitators in terms of supporting you to enhance your subject matter knowledge.

12. What can you say about the support you received from facilitators in terms of enhancing your skills in conducting activity-based lessons?

APPENDIX E
Interview questions for the facilitators

---

1. What is your general impression about the seminar?
2. In what ways do you think you have benefited from the seminar?
3. What were the teachers' reactions about the seminar?
4. How useful was this seminar to the teachers?
5. What comment do you have about your role as facilitator?
6. How helpful the teaching material was to you in conducting the seminar?
7. Do you have any suggestions on further improvement of the material?
8. Do you support this idea of peer collaboration?
9. What can be done to improve these kinds of seminars in schools?

APPENDIX F
Questions for students guided group discussion

---

1. What is your general opinion about the probability lessons?

2. How did you like that there were two teachers in the classroom?

3. (a) Which lesson activity was very interesting to you? Why?
   (b) Which lesson activity was least interesting to you? Why?

4. Do you find probability useful to you in your daily life? Why?

5. What have you learned from the probability lessons?

6. How did you like working in groups?

APPENDIX G
Teacher journal

(a) At the beginning of the programme

Name:_____
Date_____

1. What are your expectations from this programme?

Learning Journal

At the end of the programme

Name _____
Date _____

2. To what extent to do think that your expectations have been met? (express your answer in percentage)

APPENDIX H
Seminar evaluation teachers' questionnaire

Dear Teacher,

This questionnaire is aimed at collecting your opinion about the seminar. You are hereby requested to provide your genuine responses about each question. The information you provide will be treated strictly confidential, and be used for this research only.

A: General information

1. Name of the school _____
2. Name of the teacher _____
3. Sex: ☐ Male ☐ Female
4. Age: _____ (years).
5. What is your teaching experience? _____ (years)
6. Other teaching subjects apart from mathematics
   ☐ Physics ☐ Geography
   ☐ Chemistry ☐ Other(specify) _____

B: Information about the seminar

8. What is your general opinion about the seminar?
   Very useful 5 4 3 2 1 Not useful at all
   Explain _____
9. How did you find the presentation of exemplary materials?
   Very useful 5 4 3 2 1 Not useful at all
   Explain _____
10. How did you find demonstration lessons?
    Very useful 5 4 3 2 1 Not useful at all
    Explain _____
11. To what extent have the group discussions broadened your subject matter knowledge on probability?
    Very much 5 4 3 2 1 Very low
    Explain _____

12. How useful was the micro-teaching component in enhancing your skills in teaching activity based lessons?
    Very useful 5 4 3 2 1 Not useful at all
    Explain _____
13. How useful was the co-planning of the lessons in enhancing your skills in teaching activity based lessons?
    Very useful 5 4 3 2 1 Not useful at all
    Explain _____
14. How useful were the facilitators in enhancing your subject matter knowledge and skills in conducting activity-based lessons?
    Very useful 5 4 3 2 1 Not useful at all
    Explain _____
15. To what extent has the seminar increased your confidence in teaching probability?
    Very much 5 4 3 2 1 Very little
    Please elaborate _____
16. How do you find the teaching materials in enhancing your subject matter knowledge in probability?
    Very useful5 4 3 2 1 Not useful at all
    Please explain _____
17. How do you find the teaching material in enhancing your skills for teaching activity-based lessons?
    Very useful5 4 3 2 1 Not useful at all
    Please explain _____
18. How do you find the idea of conducting peer collaboration activities in schools?
    Explain _____
19. How much has the seminar helped you to raise your confidence in conducting collaborative activities?
    Very much 5 4 3 2 1 Very little
    Please elaborate _____
20. How do you rate your confidence in implementing peer collaboration in your department?
    Very confident 5 4 3 2 1 Not confident at all
    Explain _____
21. What were the strengths of the seminar?
    _____
22. What were the weaknesses of the seminar?
    _____

APPENDIX I
Probability test for form 4 students

Time: 1:30 Hours
Instruction: *Answer all the questions by circling the letter of the correct alternative for each item*

1. Probability is a branch of mathematics which is concerned with the
   (a) measure of certainties
   (b) measure of uncertainties
   (c) measure of mathematical ability
   (d) measure of mathematical capability

2. Which of the following is the probability experiment?
   (a) Tossing a coin (c) A head
   (b) A red ball (d) A blue colour

3. Which of the following is sample space when the two coins are tossed?
   (a) {H, T, H, T} (c) {HH, HT, TH, TT}
   (b) {H, T} (d) {TT, HH}

4. What is the probability of getting a head when a fair coin is tossed once?
   (a) 1 (c) $\frac{1}{2}$
   (b) $\frac{1}{4}$ (d) 0

5. If a fair die is tossed, what is the probability of getting a prime number?
   (a) $\frac{1}{6}$ (c) $\frac{2}{3}$
   (b) $\frac{1}{3}$ (d) $\frac{1}{2}$

6. Three coins are tossed simultaneously. What is the probability that three heads appear?
   (a) $\frac{1}{3}$ (c) $\frac{3}{8}$
   (b) $\frac{1}{8}$ (d) $\frac{2}{3}$

7. Which of the following experiments does NOT have equally likely outcomes?
   (a) choosing a number at random between 1-7
   (b) Tossing a fair coin
   (c) Choosing a letter from the word CARTOON
   (d) Tossing a fair six-sided coin

8. All of the following are mutually exclusive events when a day of the is chosen at random EXCEPT
   (a) Choosing a Monday or choosing a Tuesday
   (b) Choosing a Saturday or choosing a Saturday
   (c) Choosing a weekend or choosing a weekday
   (d) Choosing a Saturday or choosing a weekend

9. In probability, when two or more events are represented by a single event, they are called
   (a) mutually exclusive events (c) dependent events
   (b) independent events (d) combined events

10. A student is chosen at random from the class of 26 girls and 24 boys. What is the probability that the student chosen at random is not a girl?
    (a) $\frac{13}{25}$ (c) $\frac{12}{25}$
    (b) $\frac{24}{25}$ (d) $\frac{1}{25}$

11. A teachers chooses a student at random from a class of 30 girls. What is the probability that the student chosen is a boy?
    (a) 1 (c) $\frac{1}{30}$
    (b) 0 (d) $\frac{1}{15}$

12. If spinner with 4 equal sectors coloured yellow, blue, green and red is spinned and a coin is tossed. What is the probability of landing on yellow and a tail?
    (a) $\frac{1}{2}$ (c) $\frac{1}{6}$
    (b) $\frac{1}{4}$ (d) $\frac{1}{8}$

13. A die and a coin are tossed simultaneously. Find the probability that an even number greater that 3 and a tail appear.
    (a) $\frac{1}{2}$ (c) $\frac{1}{6}$
    (b) $\frac{2}{3}$ (d) $\frac{1}{3}$

14. Mary has 3 blouses: red, blue and yellow. She has also 2 skirts: white and green. What is the probability that she will put on a blue blouse and a green skirt?
    (a) $\frac{1}{2}$ (c) $\frac{1}{3}$
    (b) $\frac{1}{6}$ (d) $\frac{1}{4}$

15. A single letter is chosen at random from the word **TEACHER**. Find the probability of choosing an **E** or a **T**?
    (a) $\frac{3}{7}$ (c) $\frac{3}{4}$
    (b) $\frac{2}{7}$ (d) $\frac{1}{7}$

16. In probability, we say that two events are independent if
    (a) the occurrence of one event is related to the probability of the occurrence of the other.
    (b) the occurrence of one event is not related to the probability of the occurrence of the other.
    (c) one and only one event among the two events can take place at a time.
    (d) two are represented by a single event.

17. A spinner has 5 equal sectors labelled **A, B, C, D** and **E**. What is the probability of landing on **A** or **D** after spinning a spinner?
    (a) $\frac{1}{5}$ (c) $\frac{4}{5}$
    (b) $\frac{2}{5}$ (d) 1

18. A single six-sided die is rolled. Find the probability of getting a number greater than 3 or an even number.
    (a) $\frac{2}{3}$ (c) 1
    (b) $\frac{5}{6}$ (d) $\frac{1}{2}$

19. All of the following are mutually exclusive events when a single 6-sided die is rolled EXCEPT
    (a) Getting a number less that 4 or getting a number greater than 4.
    (b) Getting a 2 or getting an odd number
    (c) Getting a 2 or getting an even number
    (d) Getting a 4 or getting a prime number

20. A coin is tossed and a single six-sided die is rolled. Find the probability of getting a head on the coin and a 5 in the die.

    (a) $\frac{1}{6}$ (c) $\frac{1}{3}$

    (b) $\frac{1}{2}$ (d) $\frac{1}{12}$

21. A box contains 5 red, 4 green, and 6 black balls. A ball is chosen at random from the box. After replacing it, a second ball is chosen. What is the probability of getting a green and a black ball?

    (a) $\frac{10}{15}$ (c) $\frac{10}{75}$

    (b) $\frac{8}{75}$ (d) $\frac{8}{15}$

22. In a shipment of 20 computers, 4 are defective. Three computers are randomly selected and tested. What is the probability that all three are defective if first and the second ones are not replaced after being tested?

    (a) $\frac{1}{285}$ (c) $\frac{1}{720}$

    (b) $\frac{1}{30}$ (d) $\frac{1}{180}$

23. If a fair coin I tossed once, what is the probability of getting a head and a tail?

    (a) 0 (c) $\frac{1}{2}$

    (b) 1 (d) $\frac{1}{4}$

24. On a math test, 6 out of 25 students got an A. I f two students are chosen at random without replacement, what is the probability that both got an A on the test?

    (a) $\frac{36}{625}$ (c) $\frac{6}{25}$

    (b) $\frac{3}{50}$ (d) $\frac{1}{20}$

25. Mr. John needs two students to help him with a science demonstration for his class of 18 girls and 12 boys. He randomly chooses one student who comes to the front of the room. He then chooses a second student from those still seated. What is the probability that both students chosen are girls?

    (a) $\frac{2}{3}$ (c) $\frac{3}{5}$

    (b) $\frac{51}{145}$ (d) $\frac{36}{145}$

APPENDIX J
Teachers' opinions

Table J1: Summary of the teachers' opinions about seminar sessions

Session	Mean	S.D.	N
Demonstration lessons	4.3	0.6	22
Presentation of the exemplary materials	4.2	0.9	22
Group discussion	4.2	0.6	22
Co-planning of the lessons	4.1	0.7	22
Micro-teaching	4.1	0.9	22

Table J2: Summary of teachers'opinions about usefulness of the exemplary materials

	Mean	S.D.	N
Enhanced subject matter knowledge	4.2	0.6	22
Enhanced knowledge in teaching activity-based lessons	4.1	0.8	22

Table J3: Summary of the teachers' opinions about the usefulness

	Mean	S.D.	N
Usefulness of the seminar in general	4.3	0.8	22
Raise confidence in teaching probability	4.3	0.8	22
Confidence in conducting peer collaboration	4.2	0.7	22