

CONSTRUCTION AND EVALUATION OF A HOLISTIC MODEL FOR THE
PROFESSIONAL DEVELOPMENT OF PHYSICS TEACHERS VIA
DISTANCE EDUCATION

by

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I declare that

CONSTRUCTION AND EVALUATION OF A HOLISTIC MODEL FOR THE
PROFESSIONAL DEVELOPMENT OF PHYSICS TEACHERS VIA
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is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

(MRS J KRIEK)

DATE

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Summary

Student performance in Mathematics and Science education is a source of concern for education authorities in South Africa. This was supported by the latest TIMSS results which were released in December 2004. As in the previous studies, TIMSS and TIMSS-R, South African learners were again outperformed by the learners of all other participating countries (Reddy, 2004). To ensure learner achievement in mathematics and science, we need committed, qualified and experienced teachers in these subjects.

In this study a holistic professional development (HPD) model was constructed, tested and evaluated using practicing Grade 10 – 12 teachers. The model developed teachers' content knowledge, teaching approaches and professional attitudes simultaneously. After analysis of the model we found that improving teachers' content knowledge builds their confidence in teaching their subject. This in turn motivates teachers to perform better in their jobs: they come to class better prepared, eager to do a job they know they are good at, no more coming late, no more plodding through uninspiring one-way lessons. They are turned into better professionals with a positive work ethic. Their improved classroom practices lead to higher enrolments of science learners and improved learner achievement, the crown of successful science teaching.

The HPD model was developed in three phases. In the first phase baseline information was obtained to determine problems that exist with the teachers' content knowledge, teaching approaches and professional attitudes. After data analysis it was found that all three of these dimensions needed development.

In the second phase the initial development of the HPD model took place. An intervention programme was structured and the effect of the programme on the teachers' content knowledge, teaching approaches and professional attitudes were analysed. Successful elements of the initial model were extracted and developed further, in addition new elements were added.

In the third phase the HPD model was developed further. Analysis of the data showed the following effect on the teachers: they were extricated from a vicious cycle where poor content knowledge leads to lack of confidence which caused unwillingness to spend time on task (poor professional attitudes, ineffective teaching approaches). Instead they became part of a virtuous circle where improved content knowledge leads to increased confidence, enjoyment and a willingness to spend more time on task (better professional attitudes and effective teaching approaches).

The HPD model was evaluated using international benchmarks, such as the Standards for Professional Development of the National Research Council of New York, USA. Recommendations and possibilities for future research are discussed.

Key terms

Professional development; content knowledge; pedagogical content knowledge, teaching approaches, professional attitudes; Professional development model; science teachers; physics education; distance education.

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Chapter 1 Background and Outline

1.1 Introduction

During her opening of the AMESA conference, Naledi Pandor (2004), the South African Minister of Education highlighted the three thrusts of the National Strategy for Mathematics, Science and Technology, namely:

...to raise participation and performance by historically disadvantaged learners in Senior Certificate Mathematics and Physical Science; to improve on the number and quality of teachers of mathematics, science and technology; and to provide high quality mathematics, science and technology education from grade 1 to grade 12.

Furthermore she acknowledged that

... we need to improve teacher development programs in order to be more successful in the teaching of maths and science.

This study was undertaken to contribute towards the improvement of science teacher development programmes by constructing and evaluating a Holistic Professional Development (HPD) model for physics teachers, via distance education.

1.2 Need for Mathematics and Science Education

A general awareness of the importance of mathematics and science education prevails worldwide. In his capacity as chairman of the USA National Commission on Mathematics and Science Teaching for the 21st Century, John Glenn (2000, p. 4) stated in the foreword to the Commission's report

...the future and well-being of our nation and people depends not just on how well we educate our children generally, but on how well we educate them in mathematics and science specifically.

The following four important reasons for young Americans to achieve competency in mathematics and science are highlighted in this report (Glenn 2000, p.7):

- The rapid pace of change in both the increasingly interdependent global economy and in the American workplace demands widespread mathematics- and science related knowledge and abilities.
- Citizens need both mathematics and science for their everyday decision-making.
- Mathematics and science are linked to the country's security interests.
- Deeper, intrinsic value of mathematical and scientific knowledge shapes and defines our common life, history and culture. Mathematics and science are primary sources of lifelong learning and the progress of our civilization.

Similarly, in a report published by the Scottish Council for Research in Education, concern is expressed about the appropriateness and effectiveness of science education in their country for meeting the needs of future Scottish citizens (Harlen 1999, p. 1). It is emphasised that science education in school has to fulfil two roles, namely

to prepare future scientists and technologists and to provide all citizens with sufficient knowledge and understanding to enable them to make sensible decisions about science-related issues that affect all our lives.

In the past the first role had a strong influence on school science but now it is generally agreed that, in future, far more attention should be given to the second role.

Also in Africa the need for effective mathematics and science teaching is recognised. In his address at the National Teaching Awards Ceremony, South African President, Thabo Mbeki emphasised that learners have to improve their performance in these two critical subjects. He regards the role to be played by teachers as crucial.

Our country and continent are faced with many challenges of poverty, underdevelopment and catching up with the developed world especially on the important issue of modern technology, which is the driving force of today's economies.

We know that to bridge the technological divide between our country and the rest of the world, we need teachers who are, themselves, technologically advanced and are continuously engaged in a process of improving their capacity so as to be in a better position to impart the relevant skills to learners (Mbeki, 2002).

The previous paragraphs highlight the importance of educating children in mathematics and science. This is necessary not only to make everyday decisions but to meet the demands of the global economy.

1.3 Problems in Mathematics and Science Education

Although problems are experienced with mathematics and science education in developed and developing countries, those experienced in developing countries are more severe. To develop a perspective on the nature and severity of these problems in South Africa, the South African situation should be viewed against the problems experienced in both developed and developing countries.

1.3.1 Problems experienced internationally

1.3.1.1 In Developed Countries

The Third International Mathematics and Science Study (TIMSS) provide an international benchmark against which the achievement of learners in mathematics and science can be tested. The study is undertaken every four years and the results, indicating the performance of countries, are widely published. An international average is also given.

A number of developing countries did not do well in the study and their governments expressed their concerns. I decided to select the USA and Scotland as two underperforming developed countries for analysis of problems they are experiencing. The mean score of both the USA and Scotland was just above the international mean (TIMSS, 2003). In addition, the restructuring of South Africa's education system has been strongly influenced by the educational philosophies of these two countries.

The following problems are experienced in both the USA and Scotland:

- **Qualification of teachers**

In the USA, Glenn (2000, p. 5) reports as follows:

The teaching pool in mathematics and science is inadequate to meet our current needs; many classes in these subjects are taught by unqualified and underqualified teachers. Our inability to attract and keep good teachers grows.

In Scotland, Harlen (1999, p. 75) reports that from a random sample of 512 primary teachers, only 20 teachers or 4% had a degree containing a science subject and for 18 of these teachers, the subject was a biological science. Only two teachers in the sample had a degree which included a pass in a physical science subject. Eighty-eight teachers had at least one higher grade pass in a science subject and a further 90 teachers claimed at least one science subject pass at ordinary ("O") grade or its later replacement, standard ("S") grade. Three hundred and fourteen teachers (61%) indicated that they had no science qualifications.

- **Performance of learners**

When Glenn (2000, p.4) referred to the TIMSS test he reported:

Children in the United States were among the leaders in the fourth-grade assessment, but by high school graduation they were almost last.

His reference to "almost last" must have been in terms of the international mean of the TIMSS test. Harlen (1999, p. 1-3) also expressed her concern on the performance of Scottish learners in the TIMSS test.

- **Teaching**

A video tape study of grade 8 mathematics classes in the USA, shows that the basic teaching style has remained almost unchanged for the last two generations. According to Glenn (2000, p. 20) the approach used for the lessons was predictable. It consists of:

- (1) a review of previous material and homework
- (2) a problem illustrated by the teacher
- (3) drill on low-level procedures that imitate those demonstrated by the teacher
- (4) supervised seat work by students, often in isolation
- (5) checking of seatwork problems, and
- (6) assignment of homework.

Harlen (1999, p. 76) reported on the strategies Scottish teachers implement to cope if they have low confidence in their ability to teach science. They were:

- (1) avoidance – teaching as little of the subject as possible
- (2) keeping to topics where their confidence was greater
- (3) stressing process outcomes rather than conceptual development outcomes
- (4) relying on a book, or prescriptive work cards which give pupils step-by-step instructions
- (5) emphasizing expository teaching and underplaying questioning and discussion
- (6) avoiding all but the simplest practical work and any equipment that could go wrong.

- **Teacher's lack of knowledge**

Harlen (1999, p 72) reported that it was found, not only in the UK but also in the USA, Australia, South Africa and Italy that the explanation by primary school teachers of physics concepts was at best incomplete. In many cases the misconceptions held by secondary school students correspond with the gaps in the knowledge of their primary school teachers.

1.3.1.2 In Developing Countries

In the previous section it was shown that problems in developed countries mainly pertained to teaching deficiencies which resulted in inadequate performance by learners. Similar problems are experienced in developing countries, but the situation is aggravated by a number of additional shortcomings. Lewin (2000) identified the following:

- **Big classes**

Learner/teacher ratios in secondary schools in developing countries are generally unfavourable, resulting in class sizes of 30 to 80 learners. As can be expected, such situations pose serious problems, especially in the teaching of science (Lewin 2000, p. 29).

- **Length of teacher career**

According to Howie (2001, p. 104) it is found that

both nationally and internationally, the more experienced teachers tended to have classes with higher achievement scores for science.

However in developing countries the teaching careers of science teachers are usually brief.

But according to Lewin,

Attrition amongst science teachers is typically higher than for other subject specialists. Alternative opportunities are often more readily available for those with science and technology skills. In those countries worst affected by HIV/AIDS attrition is also rising amongst those who are zero-positive. Attrition rates amongst trained teachers can be anything from minimal to 10% annually or more (Lewin 2000, p. 30).

- **Language**

It is often erroneously believed that science is relatively independent of language. However, assimilating and processing abstract concepts requires fluency in the language in which those concepts are taught.

Science is often taught through a medium of instruction which is not a mother tongue. Where it is taught in national languages, there is often a transition point to an international language. Many problems of science learning may be associated with lack of language fluency (Lewin 2000, p. 35).

- **Effectiveness of schools**

Lewin (2000, p. 36) reported that effective science education is most likely to be found in effective schools. In a study on effective schools in South Africa, Malcolm et al. (2000, p. 102) found that in such schools, teachers and learners were expected to be in class, teaching and learning respectively and administrators were expected to be administering in the school. The schools also had to have systems in place for checking that teachers were in class on time.

However, Lockhead and Verspoor (1991, p. 43) describe the situation prevailing in most schools in developing countries as follows:

..the basic elements of an orderly school environment are frequently missing: students and teachers are regularly absent, the stock of teaching materials is limited and the physical surroundings are detrimental to learning. The conditions in many schools are so chaotic that it seems miraculous that learning occurs at all, and much of what does occur appears to be haphazard rather than the result of a deliberate focus on the content and process of instruction.

- **Financial constraints**

The availability of funds for science teaching determines the availability and quality of learning materials, physical infrastructure and equipment and consumable materials (Lewin 2000, p.8). According to the UNESCO Statistical Database (1998) the richest countries allocate more than \$5000 per secondary student per year; the poorest less than \$50.

- **Fewer learners choose science as subjects**

Data indicate that only a small number of learners participating in upper secondary school, specialise in science. Participation rates are typically between 50% and 30% of those at lower secondary level (Lewin 2000, p. 6). Since the participation rates are so low specifically at upper secondary level, a very small number of learners are to choose careers in science related fields.

- **Teaching practices**

Lockheed and Verspoor (1991, p. 67) report that in the developing countries they studied the teaching practices are not conducive to student learning. They found

(a) instruction for the whole class that emphasises lectures by the teacher, has students copy from the blackboard, and offers them few opportunities to ask questions or participate in learning, (b) student memorisation of texts with few opportunities to work actively with the material, and (c) little ongoing monitoring and assessment of student learning through homework, classroom quizzes, or tests.

- **Teacher trainees**

Teachers choosing to teach science often have a low pass mark in secondary science (Lewin 2000, p. 28). This indicates that science teachers are not the ones who are the highest achievers in science.

1.3.2 Problems experienced in South Africa

South Africa is a complex country with a variety of needs due to the country's background. Steyn (1999, p. 207) reports that

during the 1970's and 1980's the schools became a site of struggle in the resistance to the apartheid system. The consequent disintegration of learning environments and the concomitant death of a culture of learning in many Black schools lead to the neglect of quality in education. For this reason there has also been a total breakdown of professional development in many schools in the country.

Due to these circumstances, former President Nelson Mandela called for an investigation into the current state of mathematics and science education in South Africa referred to as the Presidents Education Initiative Research Project (PEI) (Taylor & Vinjevoold, 1999). Three critical areas needing urgent attention were identified, namely the upgrading and reskilling of practicing teachers in science, mathematics and technology; the improvement of the quality of education in schools and the strategies for teaching of large classes.

Additionally, the Centre for Educational Policy Development identified the following as factors influencing the poor performance of previously disadvantaged students:

teacher shortages, inadequate teacher quality, sex bias, lack of space, lack of equipment, lack of print material including textbooks, inappropriate teaching methods, lack of support for science teachers, weak school leadership for science and disrupted schooling. Other factors included low per capita expenditure, high student teacher ratios and poor maintenance and planning (Naidoo 2003, p 205).

The South African Department of Education acknowledges the fact that poor facilities do not promote effective learning and teaching of science.

The majority of schools that offer mathematics and science have a serious problem with regard to facilities such as laboratories and equipment to promote effective learning and teaching. The teaching of science remains at a theoretical level without any experiments to enhance understanding and application of knowledge.

(Department of Education 2001a, p. 13)

Furthermore, the authors of the Report of the PEI cast serious doubt on the general efficiency of public schools.

Compared to other African countries, and many developing countries on other continents, South Africa has high participation rates at all levels of the school system. However, the efficiency of public schooling must be one of the lowest in the world (Taylor & Vinjevold 1999, p. 35).

1.3.2.1 *Problems with teachers*

Teachers are the heart of education and to ensure learner achievement in mathematics and science, committed, qualified and experienced teachers are needed.

The improvement of learner achievement is largely dependent on a competent teaching corps of mathematics and science educators (Department of Education 2001a, p.19).

However, a number of authors found South African mathematics and science teachers lacking in various respects:

- **Attitudes of teachers**

Regarding the attitude of teachers, Taylor and Vinjevold (1999, p. 137) reported that:

some groups of teachers have a disposition to their job which rest on an internalised professional conscience, on a notion of personal responsibility for pupil welfare and outcomes, whilst others have a disposition of a more civil servant cast, a disposition toward teaching that lays far greater stress on the responsibility of the state for pupil welfare and outcomes, and hence does not rest on any notion of internalised personal responsibility.

- **Teacher knowledge**

Taylor and Vinjevold (1999, p. 159) indicated that teachers have a lack of understanding of fundamental concepts which consequently places a strain on their teaching.

Furthermore, Macdonald found in research undertaken during the mid to late eighties in a former South African home-land on the performance of primary school teachers, that teacher's own lack of conceptual knowledge and reading skills were the foundation on which the practices of drilling and memorisation of learners rested.

Teachers remained within their own very confined comfort zones, and resorted to pedagogies which enabled them strictly to control pupils' access to knowledge. Unsure of their own knowledge base, and either unable or unwilling to expand it, their teaching – by instinct or design – ensured that there was no danger of pupils venturing further and threatening the shaky foundations of their teachers (cited in Taylor & Vinjevold 1999, p. 134 -135).

- **Classroom practices**

In the strategy document for mathematics, science and technology of the Gauteng Department of Education (2002, p. 4) it is stated that the teacher's...

..experience is limited to working to a given syllabus with its prescribed textbooks, following the syllabus closely and emphasising content knowledge. Teaching at all levels is inordinately influenced by the external Grade 12 examination, an examination that emphasises content knowledge and recall of facts. Innovation and change has not been a main feature of the professional work of the majority of our teachers.....Science teachers in particular teach theory from a textbook and provide learners with little or no practical experience.

- **Student learning**

Macdonald (cited in Taylor and Vinjevold 1999, p. 134 -135) reported that black children spent most of their time in class listening to their teachers. The dominant pattern of classroom interaction was oral input by teachers with pupils occasionally chanting in response. Teachers did ask questions but these were aimed at recalling facts or determining the learners' level of attention. Classroom tasks in general were oriented towards the acquisition of information rather than higher order cognitive skills.

- **Unqualified teachers**

A National Teacher Education Audit was done in South Africa during 1995. It provided a comprehensive overview and analysis of the state of teacher education in the country. Arnott and Kubeka (1997, p. 1) were tasked to report, amongst others, on the qualifications and experience profile of mathematics and physical science teachers. They found that the majority of mathematics and science educators were not adequately qualified to teach their subjects. Although 85% of mathematics educators were professionally qualified as educators, only 50% had specialised in mathematics in their training. Similarly, while 84% of science educators were professionally qualified, only 42% were qualified in science. An estimated 8 000 mathematics and 8 200 science educators needed to be targeted for in-service training to address their lack of subject knowledge.

Similarly, after the TIMSS-R results had been released, Howie (2001, p. v) was tasked to investigate the state of mathematics and science education. Her report contained key findings regarding pupil's achievements, the schools they attended, their mathematics and science classrooms and teachers and some information about the pupils' background. The following was reported on the qualifications of the teachers:

...nearly a quarter of the teachers (24%) had only completed secondary school. In total 75% of teachers reported having completed a bachelors or college of education diploma, and of these only 2% had a bachelors degree and 1,2% of the teachers had masters or doctoral degrees. While 92% reported having a training certificate, of those who completed pre-service teacher training 39% reported having started this in their secondary schooling. On average, teachers reported having had 2,8 years of teacher education (Howie 2001, p. 106).

- **Undersupply of qualified Mathematics and Science Educators**

Morrow (2004) reports that the country currently has a teacher force of 450 000 of which 350 000 are employed by government and the remaining 100 000 by private schools and school governing bodies. To maintain this level of staffing, 17 000 newly qualified teachers have to be produced annually to replace the normal yearly staff losses. Viewed against the current capacity of the public higher education system, which produces only 5 000 qualified teachers annually, a grim picture emerges. The prospects become even darker when the possible future effects of HIV/Aids on the teacher population are taken into consideration.

Within this already undersupplied teacher work force, the corps of mathematics and science teachers is subject to additional eroding forces. In South Africa, as elsewhere in the world, mathematics and science graduates are in high demand, both in education and in other professions. Often teachers with science qualifications and skills are hired away to better paid occupations in the private sector. Therefore, to attract and retain a sufficient number of science and mathematics graduates into the teaching profession has been a serious problem for many years in South Africa (Department of Education 2001a, p. 19).

Furthermore, the undersupply of potential science teacher candidates is the result of a vicious cycle. Underperforming science learners results in fewer learners who choose the teaching of science as a profession. This in turn, results in underqualified science teachers which again causes learners to underperform.

The resultant effect of few learners graduating in mathematics and science and choosing teaching in these subjects as a career is a vicious cycle of undersupply of educators in these fields of study. As a result, most secondary schools do not offer mathematics and science. In most cases those that offer these subjects have educators who are underqualified and unqualified (Department of Education 2001a, p. 13).

1.3.2.2 Performance of Learners in Mathematics and Science

South African learners participated in three Third International Mathematics and Science Study (TIMSS) tests. Of all the participating countries South African Grade 8 learners came last in Mathematics and Science (Reddy 2004). In the 1999 TIMSS test, the average score for South African learners in the Science Achievement, was 243. The international average was 488.

The performance of learners in Physical Science is a cause of great concern (see Table 1.1). Statistics from the Department of Education (1997 and 2004b) show that the number of Higher Grade and Standard grade candidates enrolled and the number passes in Grade 12 Physical Science (HG and SG). The pass rate in % is given in brackets in the Pass column.

Table 1.1: Number of Physical Science (HG & SG) and their pass rate(%)

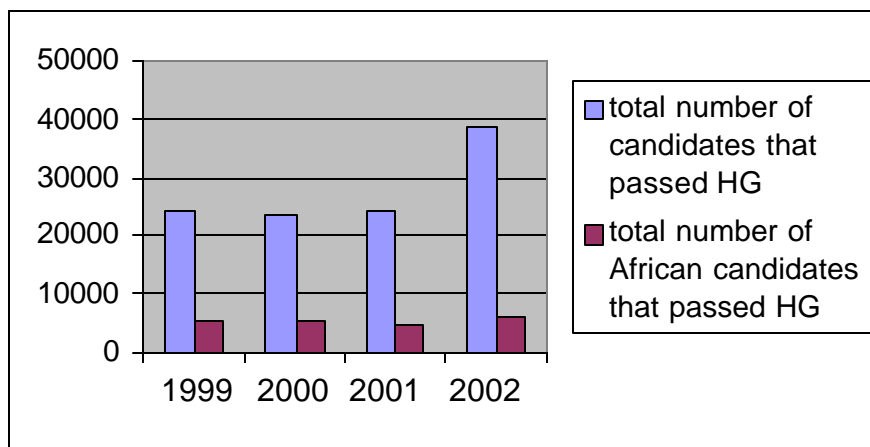
	1999		2000		2001		2002		2003	
	Cand	Pass	Cand	Pass	Cand	Pass	Cand	Pass	Cand	Pass
HG	66486	24191 (36,4%)	55 701	23344 (41,9%)	48996	24280 (49,6%)	50 992	24 888 (48,8%)	52 080	26 067 (50,1%)
SG	94463	44015 (46,6%)	107486	54884 (51,5%)	104851	45314 (43,2%)	102863	56 741 (55,2%)	99 711	61 756 (62,0%)

Table 1.2, presented figures of African students' passes in HG Physical Science from 1999 to 2002 in government and independent schools (Kahn 2004 p. 4). He extracted the figures from the database of all students that wrote the examinations at one sitting in six or more subjects.

Table 1.2: African students: candidates and passes 1999 to 2002

	1999		2000		2001		2002	
	Cand	Pass	Cand	Pass	Cand	Pass	Cand	Pass
Phys. Sci (HG)	35005	5061 (14,5%)	33645	5136 (15,2%)	25838	4898 (19%)	27138	6075 (22%)

In Graph 1.1 the total number of Physical Science HG candidates that passed during the period 1999 – 2002 is given in relation to the total number of African Physical Science HG candidates that passed in the same years.



Graph 1.1: Total Number of Physical Science HG candidates that passed versus total number of Physical science HG African candidates passed

Graph 1.1 shows clearly that only a small number of African students pass HG Physical Science in comparison with the total number of candidates passing. Therefore a great need exists to improve the performance of African students to meet the needs for the future (see 1.2).

1.3.3 Problems experienced at the University of South Africa

This study was done at Unisa, a distance education university. The university is situated in Pretoria, the capital of South Africa. The mode of instruction is by distance education and includes the use of study guides, tutorial letters, assignments and face-to-face workshops. The students enrolled for the programme do not have e-mail access and all communication is done either via telephone or written correspondence. Our students are all teachers who are teaching Grade 10 – 12 Physical Science in both urban and rural areas in South Africa.

Because the students are far from the lecturers, they often experience isolation. They have to study independently. Should problems arise which they are unable to solve, their work is interrupted until they get some help. This is often time consuming and results in frustration. Students must show self discipline to stick to their study programme. In many cases family commitments and work pressure cause work delays which can easily lead to discouragement.

Other factors such as lack of self confidence, long distances that need to be travelled to attend workshops as well as limited time to do the assignments, could hamper their studies. In addition, students have to understand the language of the study material, which is English. In many cases English is a student's second or third language.

Problems experienced regarding Mathematics and Science education have been spelt out in the previous sections (see 1.3.1 and 1.3.2). Some of the above mentioned problems could be addressed through the professional development of mathematics and science teachers.

1.4 The need for Professional Development

In the USA, Glenn (2000, p. 5) outlined the need for sustained high-quality professional development for teachers as follows:

..we are of one mind in our belief that the way to interest children in mathematics and science is through teachers who are not only enthusiastic about their subject, but who are also steeped in their disciplines and who have the professional training – as teachers - to teach those subjects well. Nor is this teacher training simply a matter of preparation; it depends just as much – or even more - on sustained high-quality professional development.

Glenn (2000, p. 8) maintains further:

Better mathematics and science teaching is therefore grounded, first of all in improving the quality of teacher preparation and in making continuing professional education available for all teachers.

.....teaching innovation and higher student performance are well documented in other countries, where students' improvements are anchored to an insistence on strong professional development for teachers.

The report names an extensive set of characteristics of “high quality teaching.” When they are focused through the lens of exemplary teacher preparation and an integrated system of professional development, an enormous potential for empowering teachers and improving instruction is apparent.

In her testimony to the US House of Representatives Committee on Science Kahle (1999, p. 1) indicated that teacher professional development was both the starting point and the central focus of the initiative to reform mathematics and science education. She remarked further that schools:

..... are only as good as their teachers, regardless of how high their standards, how up-to-date their technology, or how innovative their programs. But if teachers are not given adequate opportunities to learn through sustained professional development they have little chance of meeting the ever increasing demands of our technological society. For this reason, professional development for teachers is a critical component of improving schools and our nation's teachers.

In the National Strategy for Mathematics, Science and Technology Education of South Africa (Department of Education 2001a, p. 19), the following needs are stated:

Programmes that can equip educators with competences to teach at all levels of the schooling system...Higher education institutions will have to play a far more active role in improving the knowledge and skills of educators currently in the system, as well as those of future trainees. They should develop rigorous new programmes for educator preparation, strengthening both subject matter expertise and pedagogical mastery. The quality and relevance of the training programmes should be reviewed to ensure that when trainees complete they are competent in both subject content knowledge and teaching skills and strategies (pedagogic content knowledge)... The training programme should reflect a strong "discipline" component balanced with a good understanding of what they are teaching as well as how to teach.

An upgrading programme that focuses on both subject content knowledge and teaching skills will be introduced as a matter of urgency.

Prof Kader Asmal (former Minister of Education) acknowledged the importance of implementing a programme for professional growth as well. In his speech at the Teacher Education colloquium, he said:

Whilst good and relevant basic teacher education is a prerequisite it is also only the beginning. Teachers also require a program of professional growth to meet the ever-changing demands of a transforming society. Teachers are after all key agents for the transformation of our society. We must prepare teachers to keep pace with technology, curriculum, teaching methods and social realities, and to predict the future needs of their students and the education system. A program of continuing professional development must be an integral part of a teacher's career. This is true for all other professions, and should be no different for the teaching profession (Asmal, 2003).

If quality education is envisaged for all learners in South Africa, ongoing professional development is essential.

1.5 Objective of Study

The objective of this study is to construct and evaluate a holistic professional development model for Physics teachers in a distance education context. Three dimensions will be developed simultaneously, namely the teachers' content knowledge, their teaching approaches as well as their professional attitudes. Henceforth the constructed model will be referred to as the HPD (Holistic Professional Development) model.

An iterative process was used to develop the model involving a continuous cycle of feedback and reflection. In the final stage of the study the HPD model was evaluated using international benchmarks.

1.6 Research Methods

Different qualitative research methods were applied during the different stages of the study. The first phase of the study involved constructing a baseline of teachers' content knowledge, teaching approaches and professional attitudes. A case study approach (Neuman 1997, p. 344-380) was used for this phase. A variety of forms of data were collected including classroom observation notes, assignments, questionnaires, pre- and post tests. This data was triangulated in order to create an in-depth profile of three physics teachers.

The aim of the second phase was to create an initial version of the HPD model. Additional forms of data were collected such as interviews, workshop evaluations and journal entries. The design framework developed by Loucks-Horsley et al. (1998, p. 16 – 24) was used as a guide for the research process. This design framework specifies broad categories of aspects that need to be considered when designing professional development for mathematics and science teachers. Grounded theory was used to arrive at the specific elements within each category which was appropriate for this research context.

Grounded theory is described as a

qualitative research method that uses a systematic set of procedures to develop an inductively derived theory about a phenomenon (Strauss & Corbin 1990, p. 24).

During the third phase the revising and further development of the HPD model was done using in addition to all the previous data sources, teacher and peer observation forms.

The development of the HPD model was an iterative process, comprising continuous change, using the design framework and grounded theory to constantly revising the HPD model.

1.7 Outline of Chapters

In Chapter 2 a variety of professional development approaches were reviewed to determine the limitations of current approaches to professional development for mathematics and science teachers. This review revealed a general consensus among researchers regarding the type of professional development that should be encouraged (Kahle 1999, p. 4). Recommended features of professional development programmes which proved to have significant positive effects on the teachers' knowledge and consequent changes in their classroom practice Desimone et al. (2002, p. 83) were discussed.

In the first part of Chapter 3 the professional development design framework for mathematics and science education reform as described by Loucks-Horsley, Hewson, Love and Stiles (1998, pp. 16 – 24) were discussed as well as the motivation for using this framework in the study. In the latter part, my views on the features of a framework for the South African situation were given.

The study comprised three phases. During the first phase (see Chapter 4) data was collected from a variety of sources and triangulated. This was used to generate case studies in order to obtain what the current state of Grade 10

-12 teachers' content knowledge, teaching approaches and professional attitudes were. The data clearly showed that the teachers need development in all three dimensions.

During the second phase (see Chapter 5) the initial development of the HPD model started. An intervention programme was structured aimed at the simultaneous development of teachers' content knowledge, teaching approaches and professional attitudes. The effect of the intervention programme was analysed and in the reflection stage, using the grounded theory, new elements were generated and used to further develop the HPD model.

During the third phase (see Chapter 6), effective elements of the initial model, the less effective elements which had been adjusted and new elements had to be tested to develop the revised HPD model. In the reflection stage recommendations were considered and tested before the HPD model was finalised and discussed (see Chapter 7). Also in Chapter 7, the final HPD model was evaluated using international benchmarks.

In the final Chapter (see Chapter 8) constraints encountered during the development of the HPD model as well as recommendations were addressed. A summary of the model is given as well as possibilities for future research.

Chapter 2 Literature Review

2.1 Overview of the Chapter

In Chapter 1 the need for mathematics and science education was discussed and an outline was given of a number of problems that need to be addressed. Committed, qualified and experienced teachers are needed to ensure learner achievement in mathematics and science. If quality education is envisaged for all learners in South Africa, ongoing professional development is essential for all teachers and not only to a select group.

This chapter begins with a definition of terms relevant to the model developed in this study, namely, holistic, professional development and model. Selected professional development approaches for mathematics and science teachers are then discussed to give an overview of the global situation. A distinction is made between professional development projects (2.3.1), programmes (2.3.2) and models (2.3.3). All three are discussed in section (2.4).

Limitations of current professional development approaches are described (see 2.5.1) and recommendations on professional development are made (see 2.5.2). Recommended features of professional development programmes, such as content, learning, coherence, types of activities, participation and duration of activities are discussed in section (2.6). This Chapter is summarised in section (2.7).

2.2 Definition of Terms

The purpose of the study is to construct and evaluate a Holistic Professional Development (HPD) model. It is appropriate at this stage to define each of these terms:

- **Holistic**

A sound professional attitude, a comprehensive content knowledge and ability to transfer knowledge by means of applicable teaching approaches are essential attributes which needs to be instilled in every teacher to effect successful teaching. The model is aimed at the simultaneous development and improvement of these three professional dimensions namely teachers' content knowledge, teaching approaches and professional attitudes. The focus of the approach continuously encompasses all three dimensions, hence it is holistic.

- **Professional development**

Professional development in education is known by many names such as professional growth, on-the-job training, continuing education, in-service training, human resource development and staff development (Webb, Montello & Norton 1994, p. 234).

Staff development for teachers is defined as “those processes that improve the job-related knowledge, skills or attitudes of school employees” (Sparks & Loucks-Horsely 1990, p. 234). According to these authors,

the most important purpose of staff development is to enhance student learning, and the individuals most responsible for this are teachers (Sparks & Loucks-Horsely 1990, p. 235).

Furthermore, Guthrie and Reed, stated that the terms professional development and in-service training are frequently used interchangeably. However, a logical distinction between these concepts can be made.

Professional development relates to life-long development programmes which focus on a wide range of knowledge, skills and attitudes in order to educate students more effectively (O'Neill, 1994:285; Dunlap, 1995:149). It is a formal systematic programme, designed to promote personal and professional growth. On the other hand in-service training refers to the acquisition of specific knowledge or a particular skill. As such it

can be regarded as a component of professional development in the broader context.
(cited in Steyn 1999, p. 207).

- **Model**

For the purpose of this study, the term model implies a “staff development model” and the following definition is used in accordance with Joyce and Weil’s (1972):

a staff development model is a pattern or plan that can be used to guide the design of a staff development program (cited in Sparks & Loucks-Horsely 1990, p. 235)

2.3 Overview of Selected Professional Development Approaches

To provide a background for this study, I examined professional development approaches that have been tried and implemented in various countries and found to be sustainable. In the following sections, a selection of different professional development projects (2.3.1), programmes (2.3.2) and models (2.3.3) are discussed that illustrate a variety of approaches. The order in which these approaches are presented is of no significance.

2.3.1 Professional Development Projects

2.3.1.1 Project for Enhancing Effective Learning (PEEL)

PEEL was launched during 1985 in a working-class high school in Melbourne, Australia (Northfield, Gunstone & Ericson 1996, p. 193). The reason for launching the project was academics and teachers shared concerns about the prevalence of passive, dependent, unreflective learning in their classrooms. Hence, PEEL focused on how students were learning. New teaching approaches were evaluated on the extent to which they stimulated cognitive behaviour amongst students (Mitchell 2000).

In addition PEEL is an example of a teacher education approach based on research from a constructivist perspective, providing conditions for teachers to undertake action research in their classrooms (Northfield et al. 1996, p. 206).

As the project is still running 20 years later, it can be regarded as sustainable. This could be because the teachers took the initiative themselves and that the project is based on practitioners being reflective. They no longer require an outside agent to keep the project running.

PEEL has its own web page (PEEL, 2004) and publication entitled PEEL SEEDS. They offer two day in-service activities twice a year as well as two day in-service workshops aimed at professional development coordinators and consultants. A conference for teachers, teacher educators and other representatives is held annually. Presenters from all over the world are invited to the conference.

2.3.1.2 Science Teacher Education Project (STEP)

Yager and Penick (1990, p. 667) looked into fundamental improvements in Science Teacher Education outside the USA. STEP, an example of model teacher education practices in the international arena, was undertaken in Britain. It was regarded as potentially the most effective approach available for the improvement of science teacher education.

The project's key feature was the establishment of a "community of tutors" sharing the common interest of improving their methods (Yager & Penick 1990, p. 667). More than 200 tutors all over Britain participated in STEP. The following were the characteristics of the activities constituting the programme:

- Integration of content of science and pedagogy.
- Small group discussion and team planning.
- Short activities, not more than 1 – 1,5 hours.
- Enhancement of qualities and skills of teachers.

- Usage of resource materials such as films, videos, audiotapes and slides.

A conscious effort has been made in STEP activities to show how theoretical matters bear on actual classroom practice. As I could not find any evidence of it still being in progress, STEP cannot be regarded as sustainable.

2.3.1.3 *Discovery*

A project entitled Discovery was launched in January 1995 with the support of schools and communities in Ohio, USA to “paint the landscape of science and mathematics education”. Jane Butler Kahle was the co-Principal Investigator of the project. Discovery's mission is to enhance the teaching and learning of science and mathematics through sustained professional development of teachers “within the overall context of systemic change” (Discovery 1996).

With the ultimate goal of improving learning for all students, Discovery strives to meet three objectives:

- initiate validated professional development models designed to build a critical mass of teachers who are knowledgeable in content and skilled in equitable and exemplary instructional practices;
- develop an infrastructure to support those models and teachers; and
- act as a catalyst for lasting systemic reform of the teaching and learning of science and mathematics.

The following lessons have been learnt from this project (Discovery, 1996):

Increased use of problem solving and inquiry approaches enhances student achievement; regional infrastructures are needed to support teachers and schools undergoing reform; systemic reform is dependent upon constant attention to equity issues, particularly opportunity to learn issues; teachers readily access and exchange

information and ideas through electronic media and evaluation of reform needs to be coordinated centrally, using specialised personnel and external consultants.

Responses to these lessons have been made (Discovery, 1996) but it is done in the USA context. This project is still running which indicates its sustainability.

2.3.1.4 Mpumalanga Secondary Science Initiative (MSSI)

In South Africa, MSSI is an intervention created through a partnership between the Mpumalanga Department of Education (MDE), the Japanese International Cooperation Agency (JICA) and the University of Pretoria (UP). Its overall goal is to improve the teaching of mathematics and science at junior secondary level in the province of Mpumalanga (Rogan et al., 2002). The MSSI intervention uses the concept of teacher clustering (or networks) to pursue its professional development activities. Cluster leaders are brought together periodically for professional development activities. They are expected to share their experiences with their cluster members in their school settings (Jita & Ndlalane 2005, p. 296).

This project is still in progress (2005) however research has uncovered several disturbing findings for example that teachers who acted as cluster leaders have shown “misconceptions” in their content knowledge (Jita & Ndlalane 2005, p. 300).

2.3.1.5 The Learning for Sustainability Project

A cluster approach to professional development for teachers in South Africa was proposed for an environmental education pilot project within Gauteng’s and Mpumalanga’s Departments of Education. The Learning for Sustainability Project supports curriculum development and pilots a model for in-service teacher capacity building within the field of environmental learning. A component of the work entailed developing and testing a model for

professional development that is congruent with the Outcomes-Based Education curriculum framework (Du Toit & Sguazzin 2000, p. 7).

Ten Key features of the spiral model for professional development which they used in the project are:

- Contextualisation: Social, educational and environmental contexts in which professional development occur must be taken into account. Teachers use and refer to things that come directly from their own socio-political, biophysical and educational contexts.
- Participation: Relies on active participation by teachers in cluster and individual activities. Examples include discussion of and familiarisation with current policy, discussing and negotiating aspects of professional development, practising skills, carrying out professional development tasks, and contributing opinions, information, suggestions and criticisms.
- Dialogue: Constant dialogue among education practitioners on relevant issues allows the sharing and growth of increasingly sophisticated understandings of concepts. It also provides the opportunity to discuss new knowledge, professional issues and classroom practice.
- Reflexivity: By reflecting critically on previous actions, teachers learn to “do” better. Putting ideas into practice and then deciding on whether their implementation is useful or not can be an important tool for professional development, and ensures a form of built in self-evaluation and evaluation of policy.
- Integration of theory and practice: Allows for the building and refining of competencies in the context in which they will be used. It provides the opportunity to discuss theoretical issues, try their practical implementation in schools and reflect on this implementation and how it can be improved. The integration of theory and practice helps to build an ever-increasing feedback cycle that helps to ensure the appropriateness of practical implementation of policy.
- Flexibility: A model that responds to needs as they arise and allows for ongoing modification and adjustment of professional development processes encourages continuous updating of skills and competences and life long learning. Different contexts result in different needs, and issues may have different relevancies in different context. In addition, there is high diversity within the South African education system, and not all teachers have the same professional development needs. This model takes this into account, unlike the “one size fits all” approach of many of the previous models.
- Democracy: Teachers take responsibility for their own learning processes – they negotiate aspects of the professional development programme and logistical

arrangements, attend cluster meetings and complete their negotiated tasks. This model encourages a high level of negotiated self-determination and transparency.

- A constructivist approach: If learning is the making of meaning and knowledge is meaning that has been socially negotiated, it is important to recognise that there is not one single right way that can be adopted uncritically. The socially constructivist orientation of this model acknowledges the importance of the construction of the most appropriate knowledge and a critical orientation to learning processes in a particular context.
- Development of sophistication of meaning: The extended time frame and frequent dialogue that form part of the spiral orientation to professional development encourage the development of increasingly complex understandings of educational and, in the case of the Learning for Sustainability project, environmental themes. The learning processes that form part of this model facilitate the development of meaning that is appropriate, relevant and contextually situated.
- Continuous learning: Life long learning is a concept embraced by the new education and training policy framework. The long term nature of the spiral model for professional development allows for the mediation of continuous learning, rather than providing isolated workshops of inputs to professional development (Du Toit & Sguazzin 2000, p. 16).

In conclusion Du Toit and Sguazzin (2000, p. 69) suggested that the cluster approach to professional development can be done in a multitude of ways. However, they used clusters according to the spiral model with the above mentioned features. The main problem experienced in the project was to find competent and motivated facilitators.

2.3.2 Professional Development Programmes

2.3.2.1 CEER

CEER as described by Marx, Freeman, Krajcik and Blumenfeld (1998, p. 678) is an

attempt to use the research literature to produce a coherent and sophisticated conception of professional development.

A range of interpersonal and technological tools is used to help teachers to change their instructional practices.

CEER is not aimed at the acquisition of a set of prescribed behaviours, but rather the development of theoretically congruent practices (Marx et al. 1998, p. 672).

In a professional development programme involving 100 science teachers in Michigan, USA, the elements required for successful staff development were identified as the interplay between the following four elements (Marx et al. 1998, p 672)

C: Collaboration with others

Teachers and university researchers work together to inform, criticise and support each other. Collaboration provides opportunities for sharing and criticising ideas, plans and classroom practices.

E: Enactment of new practices in classrooms,

Enactment emphasises that the process of planning for innovating and conducting new practices in the classroom is generative and constructive. Teachers determine what is feasible in their situation and modify their ideas accordingly.

E: Extended effort to initiate change

Change requires more than helping teachers to learn new approaches to their craft. For example if there is a change of curriculum, it influences local, district and national policies and implies changes in the broader social setting in which schools are embedded.

R: Reflection on practice

There is a general agreement amongst authors that experience educates via reflection. Hence, teachers must reflect on teaching to extract the knowledge that leads to improved student learning (Marx et al. 1998, p. 674)

CEER has been tested and further shaped by designing and conducting

a range of interpersonal interventions (e.g. two seven day workshops, monthly face-to-face meetings and on-site consultations) and designed and deployed a suite of computational and communication tools that complements the interpersonal intervention and provides unique supportive functionality (Marx et al. 1998, p. 675).

2.3.2.2 *The Japanese approach to Professional Development*

The central Education Ministry of Japan¹ designed a model plan and determined guidelines for professional development of teachers. This programme consists of the following elements (Collison & Ono 2001, p. 228 - 239):

- *In-school initial training*, comprising at least 60 days a year (two days a week) which allows for the observation of new teachers by mentors and vice versa, for exchange of ideas, for writing of reflection notes and for receiving of individual coaching after observation (p. 228).
- *Out-of-school initial training* which involves 30 days per year (one day per week) that takes place at a prefectural Education Centre and covers the common basics, such as “basic knowledge of the educational service, personnel duties and ethics”. This is done in addition to the 60 days in school training for beginner teachers (p. 228).
- *Ongoing, school-based training* which is conducted in all schools. Teachers have to decide on a theme related to a subject area. They stick to the theme for a period of three years, publishing research reports at the end of each school year. A Research and Training committee is responsible for school based training and coordinates

¹ Japan has been considered due to the fact that this country came out as one of the top five countries in the TIMSS evaluation. South Africa also has links with Japan in the area of science teacher development.

activities. The core of the training is collaborative research on the teaching and learning processes (p. 238).

- *Professional development programmes at a Centre* which comprises five days of essential training for teachers in their 5th, 10th and 20th years of teaching. This element is compulsory for all teachers (p. 239).
- *Other professional development opportunities.* The prefectural government offer teachers the opportunity of becoming a teacher consultant and supports them financially for one year of training (p. 239).

2.3.2.3 Professional Development Schools

During the mid – 1980s, the Holmes Group, lead by the Dean of the Faculty Education of the University of Wisconsin, USA, identified a need for Professional Development Schools for educators. It was realised that many universities' training programmes for pre-service teachers were focusing more on teaching theories than on providing these teachers with the essential skills and practical knowledge necessary for successful day-to-day teaching. Hence, many practising teachers were experiencing problems caused by such “misguided teacher training programmes” (Riel, Gossard and Bass, 2000). Consequently the activities of the Holmes Group sparked the establishment of professional development schools aimed at maintaining the efficacy of teachers who had been subjected to such deficient training or incoherent professional development (Riel, et al., 2000).

Professional Development Schools are intended to provide meaningful on-site professional development through the collaboration of teaching staff and universities.

In the bureaucratic administration of teaching, guidelines for curriculum and instruction are determined more or less by a singular authority and then dictated to the minions of the various faculties. Professional Development Schools seek to provide new structures and approaches for deepening and sharing knowledge for teaching; to

develop shared norms for learner-centred practice; to enable teachers to assume responsibility for professional standard setting; and to induct new entrants into the profession (Riel et al., 2000).

The approach followed by Professional Development Schools is similar to the approach followed at Japanese prefecture teacher centres (see 2.3.2.2).

It enhances the teacher's sense of self as a professional, recognises the value of the teacher's experience and expertise, entrusts teachers with vital decisions and helps establish the context wherein teachers can seek advice collaboratively, take risks freely and work responsibly toward common goals (Riel et al., 2000).

There are many Professional Development Schools on trial in the USA and it is difficult to demonstrate uniform effects. However an

increased sense of professionalism, responsibility, collaboration, among teachers as well as an incorporation of reflective practice, utilisation of research as a basis for self-evaluation of practice and stronger supportive relationships between teachers was found (Riel et al., 2000).

Furthermore, more innovative approaches to curriculum development and instruction and a greater sense of efficacy amongst teachers were observed. However, problems such as inadequate resources and resistance to change were also encountered at these schools (Riel et al., 2000).

The Professional Development Schools forged partnerships between the teachers and the faculties of universities. In 2000, 91 Professional Development Schools were reported in the USA. Research undertaken and insight developed by university faculties are shared with teachers through collaborative discussions. They (the teachers) in turn, engage in research, debates and implementation of innovations. New teachers serving "internships" are brought into the culture by taking part in the discussions and experiments. "By incorporating constructivist teacher learning, the likelihood of developing teachers who will do likewise with students also increases" (Riel et al., 2000).

2.3.3 Professional Development Models

2.3.3.1 *Teacher Development Model of Bell and Gilbert*

The University of Waikato, funded by the New Zealand Ministry of Education, undertook a three-year research project (Learning in Science Project (Teacher Development)) aimed at the development of science teachers in their country. The researchers monitored the “development of science teachers as they learnt new teaching activities that enabled them to take into account students’ thinking” (Bell & Gilbert 1996, p. 10).

Forty-eight teachers participated voluntarily in the project. Four teacher development programmes were run which consisted of two-hour weekly meetings, after school over one to two school terms. Involvement in the programme did not give the participants any credit towards a qualification.

The meetings had two components, namely the sharing of new teaching activities which the teachers had been trying in their classrooms and workshop activities on various aspects of science and science education.

The workshop activities themselves included keeping a journal, modelling the suggested classroom teaching activities, discussion activities to clarify and share thinking on issues in science education and reading on aspects of science education (Bell & Gilbert 1996, p 15)

The teacher development programme and the research were run concurrently over a period of three years. Information generated through the research was applied to improve the process through which the teachers were developed. The final product was a teacher development model comprising the following features:

- Social development, which involves the renegotiation and reconstruction of what it means to be a teacher. It also involves developing ways of working with others to foster the kinds of social interaction necessary for renegotiating and reconstructing what it means to be a teacher of science.
- Personal development, which involves each individual teacher constructing, evaluating and accepting or rejecting for her/himself the new socially constructed knowledge about what it means to be a teacher of science, and managing the feelings associated with changing their activities and beliefs about science education, particularly when these go “against the grain” of socially constructed and accepted knowledge
- Professional development, as an aspect of teacher development, that involves the use of different teaching activities, the development of beliefs and conceptions underlying the activities and the development of subject matter knowledge and skills (Bell & Gilbert 1996, p. 15).

In the final Chapter of their book, Bell and Gilbert admitted that they did not have a recipe that would automatically lead to better learning for teachers. They expressed the hope, however that “teachers in wanting to help their students develop and grow.... are persistent in seeking changes based on their concerns” (Bell & Gilbert 1996, p. 173).

2.3.3.2 Five models of Staff Development

During the 70s and 80s education authorities in the USA regarded staff development as a key component of their school improvement efforts. Consequently, many staff development projects were initiated during those years by school districts in an effort to improve student learning. Comprehensive research on staff development was also conducted during that period. Its focus was mainly on actual teaching practices rather than attitudes. As a consequence, an extensive body of knowledge was generated

by the research and practical experience provided by the projects. Professional development specialists were able to tap into this knowledge and distil from it a variety of staff development approaches for various circumstances (Sparks & Loucks-Horsley 1990, p. 234).

Sparks and Loucks-Horsley (1990) described five models of staff development. As personal requirements for professional development may vary from one teacher to another these five approaches were developed to allow teachers to select their preferred models for learning. These five models are:

- Individually guided staff development
It is a process through which teachers plan for and pursue activities they believe will promote their own learning (p. 235).
- Observation / assessment model
Teachers are provided with objective data and feedback regarding their classroom performance (p. 237).
- Development / improvement process
This process engages teachers in developing curricula, designing programmes or school-improvement processes to solve general or specific problems (p. 239).
- Training model
Teachers acquire knowledge or skills through appropriate individual or group instruction (p. 241).
- Inquiry model
Requires teachers to identify an area of instructional interest, collect data, and make changes in their instruction on the basis of an interpretation of those data (p. 243).

2.4 Comments on these Professional Development Approaches

The design and implementation of meaningful and effective professional development initiatives for mathematics and science education are complex issues. A great deal of consensus about what constitutes effective professional development exists, but unfortunately there is a gap between knowledge and practice. This could be due to the lack of rich descriptions of effective programmes.

Nowhere is there an accumulation of the knowledge of effective professional development strategies and structures for teachers of mathematics and science nor is there any one place where guidance about how these teachers can best be assisted in their professional growth can be found (Loucks-Horsley et al. 1998, p. xii).

Reasons for this could be that the research and theory building in professional development have been driven not by subject matter concerns but rather by general concerns regarding adult growth and development (see section 2.3.3.1 on the Bell and Gilbert model). There is a large body of literature on adult learning and staff development but unfortunately it is not connected to the disciplines of mathematics and science. Another reason could be that, although there is consensus about the general characteristics of effective professional development, there is much less known about how to put those principles into practice.

Characteristics of a model of professional development of mathematics and science educators must be in line with the new directions professional development is taking. This paradigm shift in professional development suggested a

change in emphasis from transmission of knowledge to experiential learning; from reliance on existing research findings to examining one's own teaching practice; from individual-focused to collaborative learning; and from mimicking best practice to problem-focused learning (Loucks-Horsley et al. 1998, p. xv).

In conclusion after considering and describing a number of professional development projects (2.3.1), programmes (2.3.2) and models (2.3.3), not one could be used unaltered. However, much can be learnt from these professional development approaches and features of these professional development projects, programmes and models were taken into consideration when the HPD model was constructed.

2.5 General features of Professional Development

2.5.1 Limitations of Professional Development Approaches

In her testimony to the US House of Representatives Committee on Science and Teacher Professional Development, Jane Butler Kahle (1999, p. 1), criticised traditional in-service mathematics and science programmes as being too superficial and short-term. She stated:

...teacher professional development can be described as, “a mile wide and an inch deep.” That is, professional development has focused on programs that followed a training paradigm: short term, standardised sessions designed to impart discrete skills and/or techniques. This type of professional development can work (1) to deliver certain types of information (e.g. how to evaluate student portfolios) or (2) to develop specific skills (e.g. learning a new telecommunication software package). But short-term, finite programs (described in the vernacular as “make and take” or “spray and pray” workshops) usually do not result in improved content knowledge for teachers, or changed teaching practice, or enhanced student learning.

Collison and Ono (2001) present an overview of professional development in the USA and Japan, examining similarities and differences in the two countries. They have found since the 1970's until recently, no major changes have been reported regarding professional development approaches.

They report that in the USA

..professional development has suffered from a poor reputation for several decades and still lacks a coherent theoretical framework (Fullan, 1995a). In the 1970s and 1980s, it was considered piecemeal and haphazard (Edelfelt & Lawrence, 1975; Lortie,

1975), brief and atheoretical (Joyce et al., 1976) and “take-it-or-leave-it” (National Commission on Teaching and America’s Future, 1996, p.20). The format during the 1970s and 1980s was almost exclusively workshops, conferences, university courses or keynote address by a paid “expert”. Researchers quickly observed that the transfer of knowledge and skills, especially from workshops to classroom practice, was weak or absent, in part because of no follow-up after the workshops (Joyce & Schower, 1980, 1983). As Fullan (1991) explained, “Nothing has promised so much and has been so frustratingly wasteful as the thousands of workshops and conferences that led to no significant change in practice when the teachers returned to their classroom (cited in Collison & Ono 2001, p. 230).

In addition to the shortcomings in the current development programmes, Bell and Gilbert (1996, p. 9) indicated that teachers have concerns of their own regarding their professional development. They often have to do it on their own initiative, in their own time and at their own expense.

Furthermore, developing countries are no exception. In a study done in the BoLeSwa-countries (Botswana, Lesotho and Swaziland) in Southern Africa, De Feiter, Vonk and van den Akker (1995, p. 1-2) reported that a major problem regarding in-service teacher education projects experienced in the early 1990s was how to design interventions for optimal effect and how to establish their effectiveness. It was further maintained that little information was available (and still is) on what effective in-service teacher development interventions in the circumstances of developing countries are, because

literature on models for effective in-service training has only gradually appeared internationally over the last decade and the information for developing countries is still quite scarce.

South Africa follows the same trend experienced nationally and internationally.

2.5.2 Recommendations for Professional Development

As the importance of professional development in education is generally acknowledged, it is to be expected that educationists over a wide front will give serious thought to the shortcomings (see 2.5.1) encountered in current

development activities as well as to ways to improve it. Consequently many authors, who are regarded as experts in their field, responded in recent years with recommendations and suggestions aimed at the enhancement of professional development.

John Glenn (2000, p. 18) proposed that professional development should ideally be a collaborative educational process aimed at the continuous improvement of teachers. Such a process should

- Deepen their knowledge of the subject (content knowledge) they are teaching
- Sharpen their teaching skills in the classroom
- Keep up with developments in their fields and in education in general
- Generate and contribute new knowledge to the profession
- Increase their ability to monitor students' work, so they can provide constructive feedback to students and appropriately redirect their own teaching

In the same vein, Kahle (1999, p. 4) outlined the type of professional development that should be encouraged and supported:

- Be sustained, content-based and use new teaching methods
- Provide for follow up experiences so that teachers have opportunities to test, discuss and analyse new teaching strategies
- Include leadership opportunities and model strategies that teachers will use with their students
- Provide time for teachers to reflect on and practice what has been learned
- Include ongoing assessments that provide information to revise and redesign the professional development experiences
- Provide incentives (graduate credit) and be tied to career goals, including differential staffing and teacher career ladders
- Be accountable, including research to assess changes in teaching practices and in student learning.

The National Institute for Science Education in the USA wrestled with the question of whether the science and mathematics community on the one hand, and the professional development communities on the other, shared a common understanding of what the nature of effective professional learning

experiences was, and on how teacher development should be guided. After an extensive review of standards and related material, it was concluded that professional development experiences for science and mathematics educators can only be effective if based on the following seven principles: (Loucks-Horsley, Stiles & Hewson 1996).

1. They are driven by a clear, well-defined image of effective classroom learning and teaching.
2. They provide teachers with opportunities to develop knowledge and skills and broaden their teaching approaches, so they can create better learning opportunities for students.
3. They use instructional methods to promote learning for adults which mirror the methods to be used with students.
4. They build or strengthen the learning community of science and mathematics teachers.
5. They prepare and support teachers to serve in leadership roles if they are inclined to do so. As teachers master the skills of their profession, they need to be encouraged to step beyond their classrooms and play roles in the development of the whole school and beyond.
6. They consciously provide links to other parts of the educational system
7. They include continuous assessment.

In their comparative study on professional development of teachers in the USA and Japan Collison and Ono suggested that:

professional development (teacher training) must be a continuous job-embedded, career-long process; it should be planned; it should be specifically focused on improving teaching and learning (curriculum, instruction, assessment), as well as improving the individual and the school, it should involve teacher/school inquiry (analysis of data) and reflection; and it should be evaluated, ultimately showing improved student learning and teacher competence (Collison & Ono 2001, p. 13).

They also urge teachers to

engage in inquiry; work collaboratively by sharing knowledge and skills; observe, discuss and evaluate their own and others' teaching; expand their perspectives beyond

their particular classroom and embrace new leadership roles (Collison & Ono 2001, p. 13).

In-service strategies and scenarios pertaining to professional development have been developing gradually in Botswana, Swaziland and Lesotho in recent years. Although the activities within these strategies are quite diverse, the following common elements have been identified:

- Production of exemplary teaching materials, teaching support materials and in-service materials
- Workshops and seminars at national, regional and school level
- Support and guidance to teachers in school
- Supply of materials to schools or support to resource centres with materials on loan to schools
- Training courses for in-school mentor teachers or heads of science and mathematics departments or for resource teachers operating at a district or regional level
- Support to teachers' associations (e.g. in production of newsletter or organisation of science fairs) (De Freiter et al. 1995, p. 10).

In South Africa, according to Dunlap, for professional development to be effective, programmes must be based on the following principles:

- Educators are learners and they need the necessary opportunity to learn continually about their practice, their students and their discipline
- Collegiality and collaboration in a collegial context require the necessary support.
- Professional development is a long-term investment and commitment.
- The focus on professional development is educators' questions, needs and concerns.
- The organization of professional development requires the necessary infrastructures as well as innovative approaches to it (cited in Steyn, 1999, p. 211).

A striking characteristic in the comments by the experts referred to above is the degree of similarity in their views on the features of effective professional development.

Numerous researchers stress that professional development in education should be a continuous process requiring commitment and investment, firmly embedded in the teaching occupation. The process must be strongly collaborative in nature providing ample opportunity for exchange of knowledge and collective reflection on the outcome of professional development activities. As such it should contribute to new knowledge regarding both teaching practices and effective professional development, ultimately leading to improved teacher competence and student learning.

However in South Africa there are no relevant national or provincial strategies regarding professional educational development available. This fact is highlighted in the statement by Shermain Mannah, of the South African Democratic Teachers Union (SADTU) in the report of Commission 4 of the Department of Education (n.d). She states that

we need a coordinated strategy that is informed by other processes. There is also a lack of co-ordination and collaboration between the different directorates. There is a structural mismatch with no communication or co-ordination between the curriculum, teacher development and quality assurance directorates. Concerns were raised about the location of teacher development. We need school-based teacher development programs.

Programs have been imposed on teachers and we therefore need a process that identifies teacher needs. There are too many activities running at the same time, sometimes duplicating each other. There is also no support after training initiatives are completed.There is a need for follow-up sessions so that teachers can talk about their attempts to implement new methods.

2.6 Recommended features of Professional Development Programmes

There is a great deal of similarity in the characteristics described by various authors (see 2.5.1 and 2.5.2) in the literature for effective professional development. Yet, there is little direct evidence on the extent to which these

characteristics contribute to better teaching and improved student achievement (Hiebert 1999; Loucks-Horsley et al. 1998 as cited in Garet et al 2001, p. 917).

In an effort to provide information to fill this gap, a three year study was undertaken jointly by researchers from the Vanderbilt University, the University of Wisconsin and the American Institute of Research. This research was funded mainly by the USA based Eisenhower Professional Development Program, an organisation aimed at supporting professional development of teachers (Desimone, Porter, Garret, Yoon & Birman 2002, p. 81).

Using a selected sample of 207 teachers, the features of the teachers' professional development and its effects on changing their teaching practices were examined. The results indicate that the following three core features of professional development activities have significant positive effects on the teachers' knowledge and consequent changes in their classroom practice, (Desimone et al. 2002, p. 83):

- Content
- Active learning
- Coherence with other learning activities.

Through these core features the following structural features significantly affect teacher learning:

- Type of activity
- Collective participation of teachers from the same school, grade or subject
- Duration of the activity.

Each of these features is discussed in the following sections.

2.6.1 Content

According to Garet, Porter, Desimone, Birman and Yoon (2001, p. 923) research suggests that the content covered during professional development activities mainly varies as follows:

- Emphasis on subject matter and the teaching methods:
Some activities are primarily to improve teachers' content knowledge of the subject, some to improve general teaching practice, for example classroom management and lesson planning and some to improve the teachers pedagogical content knowledge (PCK)².
- Emphasis on changes in teaching practice:
Activities are designed to help teachers to use particular curriculum materials such as new textbooks, science kits or curriculum replacement units.
- Emphasis on goals for student learning:
Activities are designed to help teachers to improve student performance in the basic skills, for example memorising facts and mastering procedural skills. Other activities focus on helping teachers to improve students' conceptual understanding.
- Emphasis on the ways students learn particular subject matter:
Activities are designed to help teachers to improve their understanding of how children learn by focusing for instance on student pre-conceptions, misconceptions and solution strategies.

Notwithstanding these emphasises, for science and mathematics in particular

² Pedagogical content knowledge (PCK) according to Shulman (1986, p. 9) "goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching."

...there is some indication that professional development that focuses on specific mathematics and science content and the ways students learn such subject matter is especially helpful, particularly for instruction designed to improve students' conceptual understanding. (Cohen & Hill, 2002; Fennema et al., 1996) cited in Garet et al., (2001: 917 – 918).

The importance of subject content knowledge is also acknowledged by the South African Government. It regards the development of new programmes for teacher development as of utmost importance. Such programmes are needed to strengthen subject matter expertise and pedagogical mastery.

The quality and relevance of the training programmes should be reviewed to ensure that when trainees complete, they are competent in both subject content knowledge and teaching skills and strategies (pedagogic content knowledge) – that is, knowing how to teach specific scientific, mathematical and technological concepts and principles to young people at different stages of development. The training programmes should reflect a strong 'discipline' component balanced with a good understanding of what they are teaching, as well as how to teach. Mastery of content knowledge and good classroom practice would enhance confidence of educators (Department of Education 2001a, p. 19).

2.6.2 Active learning

The importance of active learning (Garet et al. 2001, p. 925 – 926) is given by focusing on four dimensions, namely:

- Observing and being observed:
Observing expert teachers and being observed when teaching and obtain feedback.
- Planning classroom implementation:
Classroom practices are the result of the influences of a number of variables: textbooks may differ from school to school; assessment criteria may not be the same in every province; learning material covered in previous grades may not be the same for all learners; the characteristics of learners in every class are unique. Adaptation to all

these variables and integration thereof in one's teaching approach and practice, represent an extremely active learning and development experience for every committed teacher.

- Reviewing learners' work:
Examining learners' written responses to problems, teachers may gain an understanding of their learners' assumptions, reasoning and solution strategies. (Garet et al. 2001, p. 926).

Examining and discussing examples of their learners' work, may help teachers to develop skills in diagnosing problems experienced by the learners. It will also help the teachers to design lessons at an appropriate level of difficulty.

- Presenting, leading and writing:
Teachers could be given opportunities to give presentations, lead discussions and produce papers on relevant issues. This could lead to improved outcomes by obliging teachers to delve deeper into substantive issues.

2.6.3 Coherence

A major point of criticism of professional development activities for teachers is the lack of coherence and interrelatedness between the various activities, in other words individual activities do not necessarily form part of a coherent programme of teacher learning and development.

The coherence of teachers' professional development activities could be assessed in terms of: (Garet et al. 2001, p. 927 – 928)

- Connections with goals and other activities
Each activity must build on preceding activities and must be followed by more advanced work.

- Alignment with national curriculum and assessment
The content and pedagogy emphasised in the activities must be aligned with national, provincial and local frameworks.
- Communication with others
All professional development activities should encourage professional communication among teachers who are engaged in efforts to reform their teaching in similar ways.

If teachers start to communicate with colleagues regarding their successes in their classrooms, a professional community can be developed and the program designers can be assured of sustainability.

2.6.4 Form/type of activity

Previously the most common form of activity was a workshop. It usually occurred outside the teacher's classroom and involved a leader or leaders with special expertise and participants who attended sessions at scheduled times. It was normally scheduled after school, or over weekends or during holidays.

However, currently there is a growing interest in the reform types of professional development such as study groups or mentoring and coaching. Such reform activities often take place during the regular school day and can easily be linked with classroom teaching. These types of reform activities are easier to sustain over time (Garet et al. 2001, p. 920 – 921).

2.6.5 Participation

According to Garet et al. (2001, p. 922), there seems to be advantages if professional development programmes are designed for groups of teachers from the same school, department, or grade for the following reasons: teachers are more likely to discuss concepts, skills and problems which arise during their professional development experiences; they can share common curriculum material, course offerings and assessment requirements; the

programmes could also sustain changes in practice over time, if or when some teachers leave the school and are replaced by new teachers. Teachers who share the same learners can discuss their needs across classes and grade levels.

Although few research results are available on the effects of collective approaches to professional development, Newmann & Associates reported that collective participation “reinforce teachers’ sense of commitment to their school’s goals” as cited in Garet et al. (2001, p. 923).

A combination of actions, such as teachers constructing their knowledge through interaction with peers, through applying ideas in practice and through reflection on and the modification of ideas, could greatly contribute towards the acceptance of new ways of teaching. Similarly, active assistance, support and encouragement to teachers as they attempt to enact new practises in their classrooms could greatly enhance the process of professional development (Marx et al. 1998, p. 670).

2.6.6 Duration of activity

Professional development must be sustained over time. Activities of longer duration are more likely to provide opportunities for in-depth discussion of content, for development of conceptions and identification of misconceptions as well as for the development of pedagogical strategies. In addition, activities that extend over time are also more likely to allow teachers to try new practices in the classroom and obtain feedback on their teaching (Garet et al. 2001, p. 921 - 922). Several studies showed that the intensity and duration of professional development programmes are related to the degree of teacher change (Shields, Marsh, & Adelman, 1998; Weiss, Montgomery, Ridgway, and Bond 1998) as cited in Desimone et al. (2002, p. 82).

The incorporation of these six recommended features in the construction of the HPD model is discussed in Chapter 7.

2.7 Summary of Chapter

In this Chapter the terms holistic, professional development and model were defined. In the following sections selected professional development approaches were reviewed. A distinction was made between professional development projects (2.3.1), programmes (2.3.2) and models (2.3.3). Projects such as PEEL, STEP, Discovery, MSSl and Learning for Sustainability Project; programmes such as CEER, the Japanese approach to professional development and professional development schools were discussed. Professional development models as proposed by Bell and Gilbert (1996) and Loucks-Horsely et al. (1990) were described. Comments on these professional development approaches were made (2.4).

Similarities between these professional development approaches pertaining to their limitations were identified (see 2.5). Recommendations by a number of authors on measures to enhance professional development were reviewed. Significant positive effects on the teachers' increase in knowledge and consequent changes in their classroom practice were described. The recommended features of professional development activities as formulated by Desimone et al. (2002, p. 83) which have significant positive effects on the teachers' knowledge and classroom practice were reviewed (2.6).

The framework for the design of a professional development model is discussed in Chapter 3.

Chapter 3 Research design

3.1 Background and Overview

3.1.1 Background

It is clear from the preceding chapters that designing a South African model for the professional development for science teachers is a complex task. Although there are challenging common critical issues related to the “big picture” of Mathematics and Science education reform internationally, unique circumstances exist in South Africa which needs to be carefully considered in the development of a local model. Taking the South African context into consideration, goals and plans were formulated in order to develop a professional development model. After the initial application of the model, results were analysed and were used to redesign elements of the model, therefore engaging in a continuous cycle of feedback and reflection. The final result of the iteration process is the Holistic Professional Development (HPD) model described in this study.

3.1.2 Overview of Chapter

In Section 3.2 the motivation for using the design framework by Loucks Horsley et al. (1998) is given as well as an outline of the features of the design framework described by these authors. In Section 3.3 a reflection on my views is given on the features of a framework for the South African situation.

3.2 A framework for designing Professional Development

The motivation for using the design framework for Professional Development for mathematics and science education suggested by Loucks Horsley et al. (1998) is that it is important to draw upon “practitioner wisdom” when developing a model for professional development (Loucks Horsley et al. 1998, p. 16). According to Loucks Horsley et al. (1998, p. xiii) their design framework

emerged from discussions with prominent professional developers on programmes for both mathematics and science teachers. They emphasised that what they had to offer were not “models” that others could follow unaltered. Their framework combines elements of different models that evolve and change over time.

I used as guidance the professional development design framework for Mathematics and Science education reform described by Loucks-Horsley et al. 1998, p. 16 – 24). The framework is presented in the form of a figure (see Figure 3.1). At the centre of the framework is a generic planning sequence which consists of four elements - goal setting, planning, doing and reflecting. This is referred to as the implementation process. In the next three chapters it will be shown how this process was applied in the development of the HPD model.

The circles (see Figure 3.1) represent important inputs into planning and goal setting. These help to facilitate informed decisions by pointing professional designers to the wide repertoire of existing professional development strategies as well as the critical issues that mathematics and science education reformers are most likely to encounter. Both the goal setting and planning processes are influenced by the programme designer’s understanding of the unique features of his/her own context and the knowledge base (knowledge and beliefs) (p 16).

Finally, Figure 3.1 indicates multiple feedback loops from the “reflect” stage to illustrate how design continues to evolve as practitioners learn from doing. Reflection can influence every input which, in turn, affects the creation of a new and better design. This is elaborated in Chapters 5 and 6 which deal with the changing of the design and retrialling of the programme.

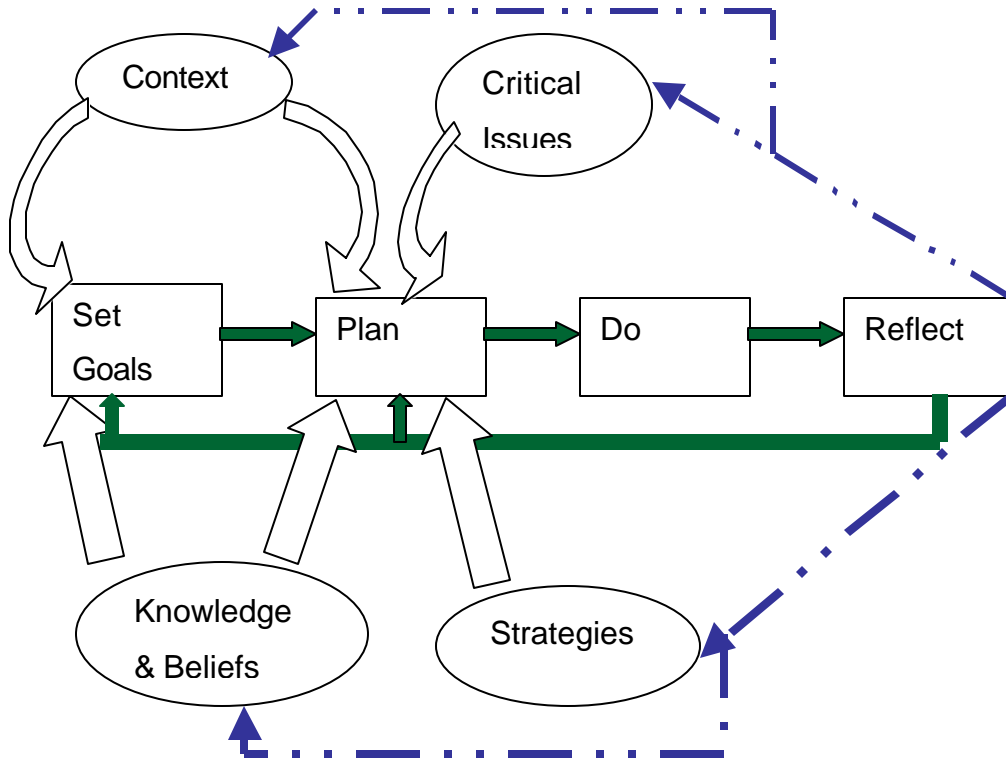


Figure 3.1: Framework for Designing Professional Development
(Loucks-Horsley et al. 1998, p. 17)

In the sections below the views of Loucks-Horsley et al. (1998, p. 16 – 24) on each of these elements are discussed as a prelude to my views on them (see 3.3).

3.2.1 Knowledge and Beliefs

It is unnecessary for designers of professional development models to start blindly and make costly mistakes in doing so. They can take advantage of existing knowledge about effective professional development for mathematics and science education which is based on the results of years of research and practice (p 38 & 42) (see 2.5.2 & 2.6).

The following two categories, knowledge and beliefs, comprise the programme designer's knowledge base that can help him or her to make informed decisions. They will be discussed separately.

3.2.1.1 Knowledge

The work of the programme designers is informed by five distinct but related knowledge bases, namely knowledge about:

- learners and learning in general
- teachers and teaching
- the nature of the disciplines of science
- the principles of effective professional development
- change and the change process

Based on research done on each of these knowledge bases, consensus on what is known in each of these domains is growing. More detail on these knowledge bases is given in sections 3.3.1 and 3.3.2.

3.2.1.2 Beliefs

Beliefs are pieces of knowledge embraced by professional developers as their own. Thus it is the ideas people are committed to, also referred to as “core values”.

If designers clarify and articulate their beliefs, these beliefs become the “conscience” of the programme which “shapes the goals, drives decisions, creates discomfort when violated and stimulates ongoing critique”. Beliefs are regarded as a critical input into goal setting and planning (Loucks-Horsley et al. 1998, p.18).

3.2.2 Strategies

Programme designers are in a much better position to come up with a workable strategy or combination of strategies after a repertoire of strategies has been considered. In order to help planners to match strategies to their own context, the authors listed fifteen different strategies and recommended a set of conditions required for success and implementation.

3.2.3 Context

The context in which the research is undertaken must be made very clear. Designers of a programme must make sure that they understand the context in which they are working. The authors feel that skilful designers have to have one foot planted firmly in theory (knowledge, beliefs and strategies) and the other in reality. “They must be influenced by their vision of what science teaching, learning and professional development should” ideally be but they are also part of a community within which they have to design a program (p 20).

“Context is also complex, composed of many interconnected and dynamic influences” (p 20). Firstly, planners should clearly determine who the learners and teachers are. They must be sure they are well informed with the state of practice including curriculum statements, assessment and the learning environment. They must be well acquainted with current policies, and the state of available resources such as time, money, the expertise of the professional designers and community support. A description of the context within which the programme has to be designed is not enough. Critical issues which mathematics and science reformers are likely to encounter must also be addressed (Loucks-Horsley et al. 1998, p. 20).

3.2.4 Critical issues

When the authors examined professional development programmes in the USA, common issues which seemed to be critical to the success of such programmes regardless of the context, were identified. These issues are: (Loucks-Horsley et al. 1998, p 21)

:

- Equity and diversity
- Professional culture
- Leadership
- Capacity building for sustainability
- Scaling up
- Public support

- Effective use of standards and frameworks
- Time for professional development
- Evaluation and assessment.

3.2.5 The Implementation Process

In the centre section of Figure 3.1 the four aspects of the generic planning process are shown. These elements, goal setting, planning, doing and reflecting will be referred to as the implementation process.

Before starting to develop a professional development programme, designers need a structure for planning and decision making. In general, they must determine who will make the decisions, who has input into the decisions, what decision makers need to know and be able to do effectively to carry out their role, how decisions are to be made and how designers will communicate with stakeholders and build support for the plan.

3.2.5.1 Set Goals

Once the structure of decision making is in place, goals can be set. If professional development is to be linked to learner achievement, two kinds of goals are necessary - goals for students and goals for teachers.

If designers set their goals for student learning, they

must have knowledge about teaching and learning as well as knowledge about the nature of science treated explicitly in the national and some state standards (Loucks-Horsley et al. 1998, p 22).

In the South African context this would correspond to the outcomes outlined in the National Curriculum Statement (Department of Education 2001b).

Goals for teachers flow directly from goals for learners. If learners have to “develop a set of understandings, skills and predispositions”, teachers need to know what to do to accomplish those outcomes for learners.

Goals for teachers are also informed by referring to the standards and data about teacher performance, needs and supports available (Loucks-Horsley et al. 1998, p. 22).

In the South African context it is given, amongst others, in the *Norms and Standards for Educators* (National Educational Policy Act 1996).

3.2.5.2 Plan

To plan is to “sketch out your design”. All the other inputs including critical issues, knowledge, beliefs and strategies “come into play in the planning phase”. In this phase “planners scan their context”. They uncover important factors which they considered as they “tailored their program to their own circumstances”. They may even decide to do more research on learning, teaching, mathematics or science, professional development and change. They can also “revisit and clarify the beliefs that underlie the program”. Planners have to consider how to confront critical issues such as scaling up, evaluation or leadership. Furthermore, “during planning, professional designers think strategically about which strategy or combination of strategies” to use (Loucks-Horsley et al. 1998, p. 23).

3.2.5.3 Do

After making decisions, programme designers, according to Loucks-Horsley et al. (1998, p. 23)

move from the “sketching” to “painting” – the actual implementation of their plan. In this phase, they draw on their skills as change facilitators and knowledge about implementation and the change process

What programme designers know is that in order for fundamental change to happen, “teachers need to experiment with new behaviour and gain new understandings and that takes time” (p. 23). Teachers will “move through predictable developmental stages in how they feel and how they are using

new approaches” (p. 23). However, the teachers’ feelings, which can be unpredictable, have to be taken into consideration.

3.2.5.4 Reflect

It is rare that an entire programme is carried out exactly as planned. “As the action unfolds, designers discover what works and what does not”. The designers can “go back to the drawing board” after some feedback has been given. Programmes change when a better way has been figured out or when conditions change. “None of the inputs remains static over time. The knowledge base is constantly growing. As professional designers learn from their experiences, they become active contributors to the knowledge base”. As “their needs and interests change they look to research for new ideas”. Beliefs can also change while “critical issues are just as dynamic”. New issues can arise as deeper understandings are gained on the issues being struggled with.

After designers have reflected by using the feedback they received, they can refine the programme, and start with revised goals, planning, doing and reflecting again. Therefore designing professional development is a continuous iterative process (Loucks-Horsley et al., 1998, pp 23 - 24).

3.3 My own interpretation and application of the framework

I followed a constructivist orientation mainly because presently it is the dominant learning theory in science education. In the constructivist theory of learning, teaching focuses on the learners’ understanding, while keeping in mind that knowledge is a network of conceptual structures which cannot simply be transferred by the use of words. It cannot exist in some complete form outside the learner and be internalised, stored and reproduced at some later time. Knowledge has to be constructed by each individual. Teaching is a social activity which involves others whom the teacher intends to influence. Although learning is a personal activity, in the sense that it has to take place in the learner’s own mind, teachers have to guide learning and will have to have

some notion of the concepts the learners already have and how they are related (Von Glasersfeld 1992, p. 33).

3.3.1 Knowledge

In the following sections I will give my view on my knowledge about learners and learning; teachers and teaching; the nature of science and mathematics; principles of effective professional development and the knowledge base of change and the change process. Some of these views are in line with the views of the authors Loucks-Horsely et al. (1998).

3.3.1.1 *Learners and learning*

When learners' conceptions are investigated, insight is gained into their ways of thinking about and their understanding of science and mathematics.

Learners and learning are therefore entities which are difficult to separate (Duit, Treagust & Mansfield 1996, p. 17).

In order to understand learners' ways of thinking, the following aspects are distinguished.

- **Learning is influenced by what learners know**

What learners know influences what they learn. According to Ausubel

The most important single factor influencing learning is what the learner already knows. Ascertain this and teach..... accordingly (Ausubel 1968, p. v)

For example, if a learner has a specific picture in his mind about the concept electric current, this picture influences any additional learning about this topic, even if his/her conception is inconsistent with accepted knowledge. Learning is therefore influenced by the learners' existing knowledge and it is often difficult to change his/her conception and to build a new understanding.

- **Knowledge is constructed by learners**

Learners construct their knowledge using their own processes. The process of creating meaning is the construction of links between new ideas and what the learner already knows. This could be done by creating ideas for the first time, making sense of their intuitive ideas or extending existing views. No one can do it on their behalf.

In addition, personal reflection is also an aspect of the process of learning. Learners must be “able to monitor their own ideas”. This can be done through processes such as comparing or contrasting their views with other views, or providing reasons why one viewpoint is more acceptable than another. Thus, learning is a “personal activity” “embedded” in “social interaction” (Loucks-Horsley et al. 1998, p. 28).

- **The construction of new knowledge is a process of change**

Hewson (1996, p. 132) describes learning as a

process in which a person changes his or her conceptions by capturing new conceptions, restructuring existing conceptions or exchanging existing conceptions for new conceptions.

Only dissatisfaction with existing conceptions can prompt a learner to change them. Learners must have reason to believe that their current knowledge is inadequate. Therefore learning is a process of construction not only involving additions to knowledge but sometimes involving remodelling of existing knowledge.

- **New knowledge comes from experience**

There are different types of experiences which contribute to the construction of a learner’s knowledge, for example dealing with problematic situations, reflecting on one’s own ideas and thoughts and indirectly using resources like books, television, radio, or by having a conversation. Therefore, learning is greatly influenced by others and is not self-contained (Loucks-Horsley et al., 1998, p. 30).

- **All learners are capable of understanding and doing science**

All learners have the capability to understand and do science “regardless of race, culture and gender”. This ability is rooted in their curiosity about natural phenomena and their desire to inquire into and making meaning of science (Loucks-Horsley et al., 1998, p. 30).

- **Reflective practice and Metacognition**

Learners actively construct knowledge. However these learning processes need to be facilitated. Reflective practice helps learners to develop metacognitive strategies which promotes the understanding of the learning process and the development of responsible lifelong learners. According to Gunstone and Northfield (1994:526) metacognition means having an informed and self-directed approach to recognizing, evaluating and deciding whether or not to reconstruct.

Learning of science can be promoted when laboratory experience are integrated with other metacognitive learning experiences such as “predict-explain-observe” demonstrations and when they incorporate the manipulation of ideas instead of simply materials and procedures (cited in Lunetta 1998, p. 251).

3.3.1.2 Teachers and teaching

In order to break away from the view of teaching in a typical classroom where teachers “provide authoritative explanations and expect learners to memorise” a broader view on teachers and teaching is captured under the following concepts: (Loucks-Horsley et al., 1998, p. 30)

- **Teaching must facilitate learning**

All over the world emphasis is being shifted from teacher-centred to learner-centred approaches. “Changes from previously implemented practices to those required for constructivist teaching/learning approaches do not take place all at once” (Hand 1996, p. 212).

When teaching is based on a constructivist view of learning, the teacher is a neutral facilitator who does not intervene or tell the students any science....In teaching based on a constructivist view of learning, the teacher interacts with the students' thinking and facilitates the students' thinking and learning (Bell & Gilbert 1996, p. 55).

The teacher is involved in ways such as explaining the science to learners but does not tell the science to learners immediately. He/she would rather ask questions or suggest some activities in order to stimulate them to think.

Therefore, learning lies at the heart of teaching. This implies that teachers must know on what level the learners are, where to start, ensure that the work they teach is in line with the present curriculum and presented in such a way that the learners can grasp it. On the other hand, learners also have a responsibility to make the connections between where they are and where they intend to be. Learning is the sole responsibility of the learner, and if he/she does not intend to learn, no learning will take place. For this reason, teaching does not imply learning and it cannot be said that "without learning teaching did not happen" (Loucks-Horsley et al., 1998, p. 31).

- **Professional teachers have specialised knowledge**

Loucks-Horsely et al. emphasised the following:

Excellent science and mathematics teachers have a very special and unique kind of knowledge that must be developed through their professional learning experiences. Pedagogical content knowledge – that is, knowing how to teach specific scientific and mathematical concepts and principles to young people at different developmental levels – is the unique province of teachers and must be the focus of professional development. Knowledge of content, although critical, is not enough, nor is knowledge of general pedagogy. There is something more to professional development for science and mathematics teachers than generic professional development opportunities are able to offer. (Loucks-Horsely, et al., 1998, p. xviii)

Furthermore, Shulman has outlined categories of knowledge from which teachers draw during their teaching:

- Content knowledge

- General pedagogical knowledge with specific reference to those broad principles and strategies of classroom management and organisation that appear to transcend subject matter
- Curriculum knowledge, with particular grasp of the material and programs that serve as “tools of the trade” for teachers
- Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teacher, their own special form of professional understanding
- Knowledge of learners and their characteristics
- Knowledge of educational contexts, ranging from workings of the group of classroom, the governance and financing of school district, to the character of communities and cultures
- Knowledge of educational ends, purposes and values, and their philosophical and historical grounds (Shulman 1987, p. 8).

However, teachers as professionals should realise that their learning about teaching does not stop after they have obtained their teaching qualification. They are expected to learn continuously throughout their teaching career through participation in appropriate professional development learning opportunities. Only then would they succeed in achieving an uninterrupted improvement of their teaching capabilities (Loucks-Horsley et al., 1998, p. 32).

3.3.1.3 Nature of Science

Acquiring scientific knowledge about how the world functions does not necessarily lead to an understanding of how science itself works. Neither does knowledge of the philosophy and sociology of science alone lead to a scientific understanding of the world. The challenge for teachers is to integrate these different aspects of science in such a way through creative planning of their teaching that they reinforce one another.

Science is dynamic due to the fact that our understanding of the world is constantly changing. For example, the structure of the atom has not changed; what have changed are our models or ways of thinking about the atom. Through the practicing of science, it is attempted to build a picture of the real

world in terms of concepts, principles, theories or constructs that can be used to explain what has been observed and predict what has not.

In the science classroom, the question does not stop at “what do we know?”, but “how do we know it?” This can stimulate dialogue between learners, between learners and teachers, between learners and the natural world, with the ideas of experts as well as within themselves. Through dialogue the learners can construct new meanings and formulate arguments which contribute towards their development as critical thinkers (Loucks-Horsley et al. 1998, p. 34).

3.3.1.4 *Principles of Effective Professional Development*

The Professional Development Project of the National Institute for Science Education in the USA set about to explore whether the science, mathematics, and professional development communities share a common understanding of what effective professional learning experiences look like and how teacher development should be nurtured (Loucks-Horsley et al., 1996). According to their shared vision, the best professional development experiences for science and mathematics educators include seven principles (see section 2.5.2).

In Chapter 7 it will be shown how these principles have been addressed in the HPD model.

3.3.1.5 *Change and the change process*

“The crux of change is how individuals come to grips with reality” (Fullan 1991, p. 30). All real change involves loss, anxiety, struggle and even resistance. To change is not an easy process. It takes time and persistence. Research on teacher change indicates that changes in attitudes often result when teachers use a new practice and see their students benefiting. Active engagement with new ideas, understandings and real life experiences seem to cause fundamental changes (Loucks-Horsely et al., 1998, p. 38 - 39).

The new paradigm for professional development requires teachers to engage in inquiry; work collaboratively; share knowledge and skills; observe, discuss and evaluate their own and others' teaching; expand their perspectives beyond their particular classroom; and accept new leadership roles. Such a shift requires major changes in practice for which teachers have no tradition and little preparation (Collinson & Ono 2001, p. 234).

Contrary to teacher change, educational changes are far-reaching and comprehensive. Such changes imply changes affecting every teacher, school and tertiary institution and even the design of the professional development programmes. The domino effect of educational change is easily noticeable. For example in the classroom, new or revised materials will have to be used, new teaching approaches (e.g. new teaching strategies or activities) will have to be implemented and beliefs or programmes will have to be altered (e.g. pedagogical assumptions and theories underlying particular new policies will possibly have to be assimilated.) All these changes are necessary because together they represent the means of achieving a particular educational goal or set of goals.

Therefore, to improve teaching, change is unavoidable. Professional development of teachers is an indispensable mechanism to effect change and, as such, professional development is a critical component of reform. To facilitate the implementation of change, professional development programmes should therefore also provide opportunities for the preparation and motivation of teachers to accept change.

3.3.2 Beliefs

3.3.2.1 *Content Knowledge influences Teaching*

It is my belief that the greater grasp of content a teacher has, the more open he/she is to innovative teaching approaches. Such teachers are more confident and are eager to go to class and to engage in a wider range of professional practices. Generally they are much more positive in their approach to teaching.

The following authors also support the view that teachers' knowledge of content has an effect on their teaching:

- Brophy states the following:

Where [teachers'] knowledge is more explicit, better connected and more integrated, they will tend to teach the subject more dynamically, represent it in more varied ways, and encourage and respond fully to student comments and questions. Where their knowledge is limited, they will tend to depend on the text for content, de-emphasize interactive discourse in favour of seatwork assignments, and in general, portray the subject as a collection of static factual knowledge (cited in Fennema 1992, p. 15).

- Fennema reported that her research showed that content knowledge influences the decisions teachers make about classroom instruction. "The nature of the impact and the impact on their students' learning was less clear". However in the area in which the teacher was more knowledgeable, instruction and subsequent learning were richer (Fennema 1992, p. 149).

- Carlsen maintained that a high level of teacher content knowledge resulted in fewer questions asked by the teacher and more questions asked by the learners. This resulted in higher levels of learner participation. On the other hand, low levels of teacher content knowledge, seemed to relate to low learner participation levels and to low-level teacher questions (cited in Fennema 1992, p. 153).

- According to Jane Butler-Kahle, research funded by the NSF showed that improved teacher content knowledge might change teaching practices and improve student learning.

.. when teachers cover topics about which they are well prepared, they encourage student questions and discussions, spend less time on unrelated topics, permit discussions to move in new directions based on student interest, and generally present topics in a more coherent way – all strategies described as standards-based teaching. However, when teachers teach topics about which they are less well informed, they often discourage active participation by students, keep any discussions under tight

reign, rely more on presentation than on student discussions and spend time on tangential issues (Kahle 1999, p. 3).

- In her review of research on Effective Teaching of Science in Scotland (see sections 1.2 & 1.3) Harlen reported that

... studies lead to the conclusion that, although the research leaves little room for doubt that increasing teachers' own understanding is a key factor in improving the quality of teaching and learning in science, there are other factors which have to be taken into account. There are strong arguments to support the view that the reason why understanding is needed is not so that teachers can convey factual information didactically to pupils. Rather it is so that they can ask questions that lead children to reveal and reflect on their ideas, so that they can avoid "blind alleys", so that they can provide relevant sources of information and other resources, so that they can identify progress and the next steps that will take their learning further (Harlen 1999, p. 80).

- Lockheed and Verspoor (1991, p. 62) also maintained that effective teaching was determined by the individual teachers' knowledge of the subject matter and mastery of pedagogical skills.
- Taylor and Vinjevold, elaborated as follows on the South African situation:

teachers' poor grasp of the knowledge structure of mathematics, science and geography acts as a major inhibition to teaching and learning these subjects, and this is a general problem in South African schools (Taylor & Vinjevold, 1999, p. 142).

3.3.2.2 *Relationship between Professional Attitudes and Teaching*

It is my belief that there is a direct relation between teachers' professional attitudes and their teaching. This was also found by Lockheed and Verspoor when they reported that

Lack of motivation and professional commitment produce poor attendance and unprofessional attitudes towards students (Lockheed & Verspoor, 1991, p.101).

Grayson et al. indicated in their study that

Qualifications and resources are not the only factors that influence teachers' effectiveness. Equally important are teachers' motivation and commitment (Grayson, Ono, Ngoepe & Kita 2001, p. 3).

Cliff Malcolm et al. (2000, p. 9) place a high premium on professional attitudes. They did a study in the rural areas and townships in South Africa to find out why certain schools still perform well "in spite of the poverty around them and often appalling lack of facilities and resources." They found that teachers at successful schools, regardless of the circumstances, generally had a high level of commitment and dedication, worked hard and for long hours and were available for learners outside of class time (Malcolm et al. 2000, p. 23 - 24).

This could be a reason why Japanese learners outperformed learners from other countries. In their comparison between American and Japanese teachers, Collinson and Ono found that Japanese teachers were more committed than their American counterparts.

Japanese teachers' required duties and responsibilities extend far beyond classroom instruction and include activities such as coaching, student career guidance, student lifestyle guidance, home visits, administration and community roundtable conferences for better community-school collaboration. Teachers in Japan have a longer school year than their American counterparts and are 12 month employees (Collinson & Ono 2001, p. 21).

3.3.2.3 Summary

Therefore, I believe that a holistic approach must be followed in the construction of the HPD model. The teachers' content knowledge and pedagogical content knowledge (PCK), professional attitudes and teaching approaches cannot be separated. Therefore the HPD model has to be constructed in such a way to provide for the simultaneous development of these dimensions. If a holistic approach is not followed teachers' content

knowledge may be improved without developing their skills to transfer the knowledge to their learners. On the other hand, concentrating on the teaching method and classroom skills and neglecting content knowledge will also render teaching efforts less fruitful.

3.3.3 Strategies

A combination of strategies enriches the professional learning of teachers. Therefore a decision must be made about which strategies will be the best to follow when planning the HPD model, because different strategies are used to fulfil different purposes.

According to Loucks-Horsely et al. (1998, p. 42) regard a strategy

as a learning experience that has identifiable characteristics that make it recognisable when implemented.

In this study the aim of constructing the HPD model is to improve a teacher's content knowledge, the way he/she teaches and his/her professional attitude simultaneously. In order to achieve these aims the following strategies were employed:

- **Study material**

The study material was developed primarily for improving conceptual understanding, allowing teachers to experience an inquiry approach to science and improving their cognitive and experimental skills. It also provided different teaching approaches that were inquiry based and provided examples of a learner centred approach. Furthermore, the teachers' knowledge would be developed in a unique way by integrating content knowledge, pedagogy and pedagogical content knowledge. The study material was composed in such a way that it also developed metacognition, that is awareness on and reflection of the teachers' own learning and teaching.

- **Workshops**

Teachers usually teach following the example of how they were taught. The best way to stimulate teachers to change their teaching is to convince them that the new way of teaching is better. According to Eick and Reed (2002, p. 410)

evidence suggested a strong influence between teachers' beliefs about teaching and learning and how they taught science. In particular, their data and others suggested that a teacher incorporated his or her preferred learning style, based on learning history, into their approach to teaching.

The workshops were incorporated in the planning of the model to help teachers to learn new behaviours, to develop conceptual understanding and to demonstrate teaching and practical skills.

- **Assignments**

The teachers enrolled for the program had to submit assignments spaced throughout the year. This helped them to stay on task continuously. These assignments were compulsory and covered Grade 12 examination type questions. To integrate content knowledge and pedagogical content knowledge, the teachers, were required to write their solutions in detail and also to outline how they would explain their reasoning to their learners. In addition, they had to explain the difficulties they would anticipate their learners to experience and how they would address them.

The assignments helped the teachers to assess and reflect on their own understanding and were also regarded as a time management tool.

- **Journal writing**

The journals were compiled by the teachers to reflect on their own teaching and learning. They had to reflect on what they learned from their study material and what effect it had on their classroom practice, as well on ways in which they could change their classroom practice. Therefore this strategy has been chosen primarily for reflecting and secondarily for building knowledge.

3.3.4 Context

A specific professional development programme is distinguished from other similar programmes by the context within which it is implemented. Specific characteristics of situations influence the success of a programme. Seven context factors that influence professional development design are discussed below.

3.3.4.1 Learners

The personal and professional growth of teachers probably has the greatest impact on the skills development, self confidence and classroom behaviour of their learners. “When teachers stop growing, so do their learners” (Barth 1980, p. 147). The main goal of education, therefore, is to improve teaching and teachers for the benefit of the learners. Thus, to determine the growth path of teachers, careful stock has to be taken of the state of the learners: how they are performing, what do they know? Only once their shortcomings have been identified can professional development for teachers be steered in the right direction.

The state of performance of the Grade 12 South African learners in Mathematics and Science is unsatisfactory (see section 1.2.3.4). They also compare unfavourably with international standards like the TIMSS. Their lack of grasp of the content is cause of great concern.

The language issue could be offered as a reason for their weak performance. Only 23% of the learners who participated in the TIMSS test were proficient in Afrikaans or English (language of the test) while 77% indicated that they seldom or never spoke the language of the test. However, the performance of learners from other developing countries also participating in the TIMSS test did not seem to be hampered by having to write the test in their second or third language (Howie, 2001, p. 91). The reason for underperforming therefore seems to be much deeper than mere shortcomings in language proficiency.

The bridging of the gap between where the learners are and where they ought to be, therefore still remains the question to be answered. In my view it can only be done through equipping the teachers better.

3.3.4.2 Teachers

Teachers should be devoted to keeping up to date with new educational technologies, new teaching methods, new learning and assessment methods, and new curriculum policies and innovations within the subject/learning area. It is a career journey which starts with initial teacher training and ends when a teacher retires. At different stages of teachers' careers different development needs arise.

Teachers have to have good subject knowledge and have to be equipped with teaching strategies in order to teach the subject in such a way that the learners can make it their own. A range of problems is being experienced with science teachers in South Africa (see Chapter 1). Few of them are suitably qualified. Furthermore, 88% of learners are taught by teachers younger than 40 years, which indicates that teachers are in an early stage in their careers (Howie 2001, p. 105). Both nationally and internationally there appears to be a link between mature and experienced teachers and learner achievement in science (Howie, 2001, p. 97 & 105).

However, very often the conditions under which teachers teach are underestimated. Some teachers have to teach more than 250 learners per day, have to deal with large classes and consider themselves overworked. According to the White Paper on Education (Department of Education 1995, p. 10) the learner-teacher ratio for any given class in secondary schools should be 35:1. The average number of learners in science for Grade 8 is 49 per class while the international average is only 31 learners (Howie 2001, p. 108). In addition the teachers have to carry a full load of extra mural activities and have to attend teachers, parents and in-service meetings.

Still, teachers are the greatest single factor influencing students' learning and therefore should be the primary clients of professional development.

3.3.4.3 *Practices: curriculum, instruction, assessment and the learning environment*

The Constitution of the Republic of South Africa (Act 108 of 1996) currently provides the basis for curriculum transformation and development. The aims of the constitution are the establishment of a society based on democratic values, social justice and fundamental human rights and the improvement of the quality of life of all citizens. A foundation of a democratic and open society must also be laid.

In order to meet these aims, the entire education system needed to be changed. A new curriculum which was in line with the political and educational changes was accepted after the democratic election in 1994. The philosophy of this curriculum is outcomes-based education. It aims at enabling all learners to reach their maximum learning potential by setting learning outcomes which describe knowledge, skills and values to be achieved by the end of the education process. The prescribed learning programme specifies the scope of learning and ensures that learners achieve the learning outcomes as prescribed by the assessment standards for a particular grade. This "new" curriculum entitled The Physical Science National Curriculum Statement, Grades 10 – 12 (General) (Department of Education, 2001b) is currently in the process of being phased in. It will only be implemented for Grade 10 in 2006 and for Grade 11 and 12 in subsequent years. The "new" curriculum specifies the minimum standards of knowledge and skills to be achieved at each grade. The Assessment Standards are criteria describing what a learner should know and be able to demonstrate at a specific grade. Each subject also has its own Curriculum Statement. In addition there are Learning Programme Guidelines (Department of Education, 2004b) available to assist teachers and other learning programme designers to plan and design quality learning, teaching and assessment programs.

Since my study only deals with teachers teaching in the Further Education and Training (FET) band, Grade 10 – 12 the old curriculum was still in use when I undertook my research. This “old” National Curriculum is characterised by the following characteristics:

passive learners, exam-driven, rote-learning, syllabus is content-based and broken into subjects, textbook/ worksheet bound and teacher centred, see syllabus as rigid and non-negotiable, teachers responsible for learning; motivation dependent on the personality of the teacher, emphasis on what the teacher hopes to achieve, content placed into ridged time frames, and curriculum development process is not open to public comment (Van der Horst & Mc Donald 1997, p. 27)

Furthermore, currently there is one national examination written at the end of Grade 12. South Africans place a high premium on this examination. Passing the Grade 12 examinations can open doors for further training, however, when failing, doors are closed and alternatives have to be investigated.

3.3.4.4 *National and Provincial Policies*

One of the challenges facing a professional development designer is to have a professional growth plan. Such a plan will enable teachers who are at different stages in their career and development to design their own growth plan within the framework of such an existing comprehensive plan.

Wally Morrow and Michael Samuel serve on the South African Ministerial Committee on Teacher Education which is tasked to look at key issues in educator professional development. A discussion document, the National Framework on Teacher Education on Continuing Professional Teacher Development (CPTD) (Samuel & Morrow 2004) was drafted and is currently a lever for discussion before its implementation. At a conference on Educator Professional Development, Morrow (2004) explained how separate providers can contribute to establish a complementary system of CPTD in order to produce committed and competent practicing teachers.

However, the provision of CPTD opportunities by a variety of institutions gives rise to the problem of realistic validation of developmental training of this nature. Presently, only qualifications obtained at acknowledged higher education institutions are recognised. Recognition of a qualification is obtained through credit points being awarded to the qualification by the National Qualifications Framework (NQF). This has established the perception that CPTD activities are only worthwhile if they receive credit points which lead to qualifications. Once-off rewards for completion of a qualification provide the incentive for teachers to continue with this form of CPTD. No system of rewarding teachers for engaging in other forms of CPTD is currently available.

Registration of approved continuing professional development activities and inclusion thereof on a national list has been proposed as a solution. Each activity will be assigned professional development (PD) points and teachers will then have the opportunity to earn a certain number of points in each three-year cycle. A record of activities and of teachers' accumulated credits will be managed by the South African Council for Educators (SACE).

According to the Education Employment Act (Act 76 of 1998) the employer is entitled to require teachers to engage in professional development activities for up to a maximum of 80 hours per year. The employer is obliged to present or prescribe programmes that need to be attended by teachers. These activities are to be conducted outside the formal school day or during the school vacations. The system proposed above, allows teachers to accrue credit points through participation in teacher development activities. This would contribute a great deal towards motivating teachers to comply with the relevant stipulations of the above-mentioned Act, and at the same time ensure the building of capacity.

3.3.4.5 Available resources

The South African government strongly emphasises the seriousness of the problems the country is currently experiencing with education facilities:

The majority of schools that offer mathematics and science have a serious problem with regard to facilities such as laboratories and equipment to promote effective learning and teaching. The teaching of science remains at a theoretical level without any experiments to enhance understanding and application of knowledge (Department of Education, 2001a, p. 13)

According to Howie (2001, p. 117) the shortage of instructional material such as textbooks and the state of other facilities such as heating, cooling and lighting is reported by South African principals as worse than what their international counterparts are experiencing. They also complained about the lack of computers and computer software for both mathematics and science and a shortage of school buildings and grounds.

Although inadequate facilities and insufficient instructional material are easily defined problems, some authors regard their impact on teaching as not that severe. Lewin shows that

...investment in facilities and equipment ... cannot be shown to have a direct relationship to improved learning outcomes (Lewin 2000, p. 37).

Similarly, Taylor and Vinjevoid, agree that external resources do not have the impact that better school management and teaching practices have.

Thus improved pupil results do need external resources such as textbooks and laboratories, but with or without additional resources, better school management and teaching practices are also required, and there are many examples that demonstrate how these factors can make a significant difference on their own (Taylor & Vinjevoid 1999, p. 138).

3.3.4.6 History of Professional Development

A very interesting aspect in the history of professional development of especially science teachers is the role played by non-governmental organisations (NGO's). According to Rogan and Gray (1999, pp 373 & 384)

during the early 1970s NGO's, active in the field of science education, were almost non-existent. This could mainly be ascribed to the extremely tight control exercised by the then apartheid government over the schooling system. Access by any organisation other than a government institution to any South African school was virtually impossible. There was, therefore, practically no opportunity for NGO's to make any contribution whatsoever to any facet of teaching.

However, the inception of the Science Education Project (SEP) in 1976 as the first science and mathematics NGO, marked the beginning of a very slow process of erosion of the exclusive attitude of the education authorities towards NGO participation in and contribution towards science education. The SEP endeavoured to enhance science education through the provision of cheap but high quality science kits and laboratory manuals to schools and through the development of in-service courses and other support systems for teachers. Science being an ideologically neutral subject gradually undermined the efforts of the education authorities to deny SEP access to schools on grounds of principle. As a consequence SEP little by little strengthened its foothold and established itself as a prominent contributor to science teaching and the development of science teachers in the Ciskei at first from where it later expanded.

Apart from its role as promoter of professional teacher development, the SEP also made a major political contribution: it succeeded in breaching the walls of the education fortress in South Africa and, paved the way for other organisations outside government to contribute to science teaching. As a consequence, in 1994, the year of independence, more than one hundred NGO's were active in science and mathematics education providing support to teachers and students.

In addition in his speech at a conference on Educator Professional Development, Jansen (2004) reported that professional development in South Africa was funded mainly through foreign aid during the early 1990s. In that period the "focus was on changing people's behaviour rather than the

meaning which they attached to their work". In the later years the emphasis shifted to "performance-based pedagogy, where the focus was on changing the learners while later still the attention focused on changing schools". Unfortunately, regardless of the "focus or agency responsible for teacher development", very little change was brought about (Jansen, 2004).

3.3.4.7 Parents and Communities

Disrupted family units are fairly common in the South African society, especially amongst the country's rural population. The average international figure for both parents living with their families is 81%. In 87% of South African families only the mother lives permanently with their families while in only 60% of the cases both father and mother live permanently with the family. In 42% of South African families, grandparents are part of the family unit, and in 43% other relatives are also included, compared to the international figures of 24% and 16% respectively. On average, a South African family consists of seven people living in one home (Howie 2001, p. 89 & 90).

The geographic location of schools is important and the influence on the achievement of the learners in the different parts of the country. Fifty percent of South Africa's population live in rural areas (Howie, 2001, p. 113).

Only 8% of South African learners have three learning aids, such as a dictionary, a study desk and a computer in their homes. The international average is 41%. Parental education is often linked to learners' achievement. Only 15% of the Grade 8 learners who took part in the TIMSS test in South Africa reported that their mother or father had studied further at a university or technikon while 12% of learners did not know what the educational level of their parents were (Howie, 2001, p. 92).

3.3.5 Critical Issues

From the list of critical issues developed by Loucks-Horsely et al. (1998, p. 21) I addressed the following: the need for equity for teachers from a previously

disadvantaged background, the development of a professional community and building of capacity for sustainability.

- **Equity**

Due to South Africa's history and the nature of the South African society, the HPD model was mainly developed for teachers from a disadvantaged background. In so doing I could contribute towards equity in a diverse society.

- **Developing a professional community**

McLaughlin said the following:

Classroom practices and conceptions of teaching.... emerge through a dynamic process of social definition and strategic interaction among teachers, students and subject matter in the context of a school... (cited in Loucks-Horsely et al. 1998, p. 195).

Therefore initiatives must be designed in order to equip teachers to become leaders and build their own professional communities. Teachers have to learn new skills and strategies and are expected to return to their schools and teach others the same skills and strategies. This could be done by initiating dialogue about what they have learned and encouraging others to participate in similar complementary learning experiences.

However, Gray found in his 30 years of work in science education in a developing world context, that teachers in even the most difficult circumstances are "capable of amazing things"

if any degree of professionalism is to emerge, then the responsibility for ongoing professional development of teachers needs to be shifted fairly and squarely on teachers themselves, with the authorities and outside agencies playing a secondary, supportive role (Gray 1999, p. 265 & 266).

Therefore, opportunities must be facilitated for teachers to work collaboratively in order to break down isolation through coaching and mentoring, workshops

and networks. This could equip teachers with tools and techniques to build and maintain supportive professional communities in their schools and districts.

Thus the HPD model was aimed at developing teachers by improving their content knowledge, providing them with both information on and practical experience in different teaching approaches and strategies in order to build their professionalism and self-esteem.

- **Building Capacity for sustainability**

This critical issue is addressed to help the teachers to learn for themselves. They must be able to search and access other resources in order to improve their content knowledge and classroom practice. If their metacognitive skills are developed they can assess their own level of understanding and become aware of their shortcomings.

3.3.6 Implementation Process

The implementation of the design process is described in the following three chapters. In Chapter 4, the baseline study, in Chapter 5, the initial development of the HPD model and in Chapter 6 the refinement of the HPD model.

In each of these chapters the knowledge and beliefs, context, strategies and critical issues influencing the design of that intervention programme are spelt out. After setting goals, planning and doing by implementing the planning process for each phase, the results are analysed. This will have an influence on the process of reflection and change takes place. In the last section of each of these chapters the way forward is described.

3.4 Summary of Chapter

In the first section the background and overview of this chapter is given. The motivation for using the design framework for professional development by

Loucks Horsley et al. (1998) is given as well as the discussion of each feature of the framework (see section 3.2). My views on these features followed in Section 3.3. In the following chapter the baseline study is described.

Chapter 4 Baseline study

4.1 Background and Overview

A baseline study (Chapter 4) was undertaken by doing an in-depth case study with three teachers who took part in an INSET programme in order to identify problems in teachers' physics content knowledge, their teaching approaches and their professional attitudes.

To implement the design process for the planning of the baseline study, the context (4.2.2), knowledge and beliefs (4.2.1) critical issues (4.2.3) and strategies (4.2.4) were considered in the South African situation (see Figure 3.1).

Part of the design process is to reflect. Therefore the reflection stage (4.9 and 4.10) influences every input, which in turn affects the creation of a design for the development of the initial HPD model which is discussed in the following chapter (see Chapter 5).

4.2 Implementation Process

Before the goals could be set and the planning be done for the baseline study the following features had to be taken into consideration: knowledge and beliefs, context, strategies and critical issues (see Figure 3.1) and will be discussed in the sections that follow.

4.2.1 Knowledge and Beliefs

Knowledge and beliefs are considered as the knowledge base that can help to make informed decisions regarding professional development.

- Knowledge (see Chapter 3.3.1)
- Beliefs (see Chapter 3.3.2)

4.2.2 Context

The context in which a professional development programme is implemented distinguishes it from other programmes, therefore with each of the implementation processes the context changes. These specific characteristics of situations influence the success of a program and will be described.

- **Teachers**

Twenty five teachers enrolled in a one-year GDE Inset programme. The GDE programme was designed based on my own and former colleagues' experience and thinking. It was not based on research done. Only three of the 25 teachers, who were part of the GDE Inset programme, were selected for an in-depth study. This was done due to the financial restrictions. They were chosen randomly from different township schools in the Pretoria area.

The teachers were all teaching Physical Science from Grade 10 – 12 in urban schools in the Gauteng Province. A contract was signed between the teachers and Gauteng Department of Education (GDE), their employer. The GDE paid for the INSET programme and should the teachers decide not to continue with the programme they had to repay the GDE. The teachers who successfully completed the programme received a certificate of achievement.

The qualifications and teaching experience of the three teachers are discussed in sections (4.6.1); (4.7.1) and (4.8.1).

- **Learners**

The number of learners in the three teachers' schools varied from 525 to 1100. The Grade 12 Physical Science classes were relatively small in these schools. Two of the three teachers taught Grade 12 learners and of the 45 learners in the Grade 12 Physical Science classes, only four were taking Physical Science at Higher Grade level.

This is in accordance with the concern the Department of Education (Department of Education 2001a) expressed that the number of Higher Grade

passes in Grade 12 Physical Science was decreasing. This number had declined steadily from 27000 (of 76100 enrolled) in 1997 to 23300 (of 55700 enrolled) in 2000. On the other hand, the Standard Grade Physical Science passes increased from 35200 (of 65200 enrolled) in 1997 to 55000 (of 125100 enrolled) in 2000. Evidently, more learners are being channelled into Standard Grade Physical Science, presumably to increase the pass rates.

Therefore, although more learners are taking Physical Science, fewer do so at a level that could lead to tertiary science studies.

- **Curriculum**

The “old” National curriculum for Standard 8 – 10 (Grade 10 – 12) was used. This curriculum still emphasises memorisation of content, is examination driven and teacher-centred (see 3.3.4.3).

- **Available resources**

Only one of the three visited schools had a laboratory. The other two schools used normal classrooms for practicals. These schools were also better equipped with chemistry equipment than for physics. The few pieces of physics apparatus that were available were not used due to the fact that a layer of dust on the equipment indicated that they had not been using it for quite a while. A Van der Graaff generator with a perished belt was noticed, which indicated that it had not been in use for some time.

Although the learners possessed textbooks they were seldom brought to class. At two schools the learners had to share textbooks.

- **Community**

The community in which the schools were located were near the city and the average income of the parents was low.

4.2.3 Critical issue

A common issue which seemed to be critical to the success of a professional development programme, regardless of the context, is the need for equity in science education. Therefore, one of the critical issues that need to be addressed is to provide opportunities for high quality science education to people who were denied them in the past. This need is formulated in the three thrusts of the National Strategy for Mathematics, Science and Technology and again highlighted by our Minister of Education, Naledi Pandor (see 1.1).

4.2.4 Strategies

Strategies are chosen to enrich the professional learning of teachers. The following strategies were chosen for the baseline study:

- **Study material**

The main focus was to gather baseline data and not developing study material. However a prescribed textbook for Physics³ by Zealey, et al. (1994) was used which contained theory, examples and exercises. Additional notes on each chapter in the textbook were given and were used during the discussions in the workshops.

- **Workshops**

During the year, ten face-to-face workshops were held to improve teachers' content knowledge and experimental skills. These workshops in both Physics and Chemistry were presented on Saturdays. The duration of each workshop was 5 hours. Three hours were devoted to content knowledge and two hours to Teaching Method. All sections, namely content knowledge in Physics or Chemistry and Teaching Method, were handled separately.

³ Although similar workshops on Chemistry were presented simultaneously, only the physics component and related teaching method part are described in the study.

- **Assignments**

Assignments and regular feedback (every fortnight) on the assignments by means of memos were used to keep the teachers on task throughout the year.

4.3 Goals of Baseline Study

The goals of the baseline study were:

- To gather baseline information on teachers' content knowledge, professional attitudes and teaching approaches.
- To identify areas in which professional development is needed.

4.4 Plan

To construct a HPD model it is necessary to determine *what* the content knowledge of the science teachers is, as well as what teaching approaches they are following and what the state of their professional attitudes is.

Therefore data had to be obtained and only after analysis of the results, could the areas in which professional development is needed be identified.

4.4.1 General Programme

The one year GDE programme consisted of workshops presented on alternate Saturdays to improve the teachers' physics content knowledge and practice their experimental skills. The teachers did experiments relating to the topic of the day, using worksheets provided.

During the second section of each workshop the focus was on Teaching Methods. It was handled separately and not integrated with the physics content. The material for this section was compiled as Readers which were provided each Saturday during contact. The following topics were covered:

Reader 1A: The professional conduct of a Physical Science educator

Reader 1B: The work scheme, year plan and report

- Reader 2: What is science? Lesson planning
- Reader 3: The educator as facilitator and classroom climate
- Reader 4: The role of the learner in the physical science classroom
- Reader 5: Laboratory organisation and practice
- Reader 6: Practical work
- Reader 7: Portfolio assessment
- Reader 8: Assessment and Evaluation workshop

4.4.2 Planning for data on Physics Content Knowledge

To determine the teachers' content knowledge before the programme began the teachers were required to write two pre-tests. The first test was set by the Human Sciences Research Council (HSRC) in 1996 to test the knowledge and insight of potential Physical Science educators at historically black Colleges of Education. This test comprises questions on mechanics and electrostatics and was also used as the post-test, a fact the teachers were unaware of. The second test was the TIMSS (2000) Population 3 test Section A on Physics for Grade 8 learners. Since South African learners came last in Mathematics and Science of the participating countries (Howie 2001, p. xxiii), it was deemed appropriate to determine the teachers' performance in this test.

The teachers also received an assignment during each contact session for completion during the ensuing two weeks. It was marked and handed back to them with a memo. Finally, they were expected to pass a theoretical and practical examination at the end of the year.

4.4.3 Planning for data on Teaching Approaches

In order to provide baseline information on the teachers' teaching approaches, they were required to complete two self evaluation tests, namely a Personal evaluation test set by Dr ML Prinsloo of the Bureau for Curriculum and Evaluation and a test measuring the teacher's own appraisal of his/her Effectiveness as a Physical Science Educator (Trowbridge et al. 1981, p. 330-331).

The self analysis scale in the test on Personal Evaluation went from good (4) to poor (1), (Prinsloo, 1987). The subheadings in the test were preparation, management, communication, teaching strategies, evaluation, value assessment, attitudes and relationships.

The test on the Effectiveness of a Physical Science Educator comprised the categories subject knowledge, class management and organisation, teaching methods, personal relationships and enthusiasm. The self analysis scale covered the range from (5) always, (4) mostly, (3) sometimes, (2) seldom to (1) never.

Teachers also had to submit a work scheme for Grade 11, a year plan for Grade 12 and a one hour activity for Grade 11 learners. The last item comprised outlines of the intended outcomes of the activity, the teacher's preparation, the teacher's role, the learners' activities and assessment. The topic for this activity had to be chosen from Chapter 2 - Motion in one dimension - from their physics textbook. Another assignment required the teachers to provide and discuss five reasons why it makes sense to use a variety of teaching methods when teaching Physical Science.

In addition, they had to write paragraphs on how to handle a variety of situations in class. They had to give possible choices of action, criteria for handling the situations and implications of the choice of action.

4.4.4 Planning for data on Professional Attitudes

Only those three teachers selected for the more detailed case studies (see paragraph 4.2.2) were included in this section of the programme. To provide the baseline information on the teachers' professional attitudes they were required to complete the questionnaire on professional attitude (Grayson et al., 2001). This questionnaire was initially compiled as part of a survey of South African Science and Mathematics teachers' professional actions and attitudes. The initial data collected formed part of a comparative study of the

professional attitudes of teachers in South Africa and Japan (Grayson et al., 2001).

The questionnaire comprised three sections, namely (A) biographical information, (B) school information and (C) teachers' opinions. Section C comprised the following three questions, each with a number of sub-questions:

- (1) What should be expected of a teacher
- (2) Teacher conduct
- (3) Teacher-pupil interaction and classroom practice.

The questions in Section C consisted of a multiple choice component and a free-response component.

4.5 Do

The research was done on the three teachers and not on the GDE programme. Data was collected from a variety of sources and triangulated in order to create a picture of the selected teachers' content knowledge, teaching approaches and professional attitudes.

The reason for using multiple data sources is to ensure validity and reliability. The latter was further enhanced through the preparation of a case study which was a formal assembly of evidence distinct from the case study report. In this respect Yin (1989, p. 98-99) stated:

Every case study project should strive to develop a formal, retrievable database, so that in principle, other investigators can review the evidence directly and not be limited to the written reports. In this manner, the database will increase markedly the *reliability* of an entire case study. (Emphasis added.)

The following multiple data sources were submitted by the teachers: assignments, self-evaluation tests, work schemes, activities, year plan, discussions of the reasons why it makes sense to use a variety of teaching methods when teaching Physical Science, descriptions of the handling of a

number of situations in class, their pre- and post tests, their examination scripts as well as their professional attitude questionnaires. In addition my classroom observation notes and reflections were also interpreted, analysed and used.

The assignments submitted by all 25 teachers were evaluated and comments were given to each teacher on his/her assignment. A memorandum was included when the teacher received his/her assignment back. Only the three teachers' assignments were analysed.

To ensure reliability and validity, case studies were generated.

- **Case studies**

A convenient sample of three teachers was selected. The reason for their selection was based on convenience: their schools were within easy reach from the University. These Physical Science teachers referred to as teachers A, B and C, agreed to participate in the study. They all taught Grades 8-12 in different township schools in the Pretoria area. The number of learners in these schools varied from 525 to 1100. The Grade 12 Physical Science classes were relatively small. Teachers A and B were responsible for Grade 12 learners in Physical Science. The highest grade that teacher C taught was Grade 10. However he had taught Grade 12 learners in the past. Only four of the 45 learners in the two Grade 12 Physical Science classes, took Physical Science at Higher Grade level.

Five classroom observations were carried out during the year to obtain a different set of data regarding teachers' content knowledge and classroom practice. The following results were obtained:

4.6 Results: Teacher A

4.6.1 Content Knowledge

Teacher A's matric results showed that he did not have Physical Science as a subject and that he obtained an F symbol for Mathematics at lower grade. He did Physical Science HG and repeated Mathematics HG the following year and obtained a D symbol for both. During 1996 he obtained a Secondary Diploma in Education with Physical Science as his major. The problem identified by Lewin (2000, p. 28) that teachers choosing to teach science often had a low mark in secondary science, clearly applied in this case.

Teacher A's perception of his content knowledge as reflected in the self-evaluation test, was contradictory to what he actually achieved in the pre-test and TIMSS test. On a scale of 1 to 5, with five being the best, he awarded himself an average of 4,2 on questions such as the following:

- Am I well-read in the field of Physical Science? 5 - always
- Do I have a thorough knowledge of Physical Science? 4 - mostly
- Do I communicate facts that are valid and relevant? 4 - mostly
- Do I keep up with new scientific developments? 4 - mostly
- Am I aware of scientifically related social issues? 4 - mostly

The marks he obtained in the pre-test (46%) and the TIMSS test (28%) are in stark contrast with his self-evaluation.

This discrepancy suggested that, in addition to a real need to improve his content knowledge, teacher A also needed to develop his metacognitive awareness, in particular the ability to judge his own understanding (Flavell 1979, p. 906).

4.6.1.1 Interaction between Content knowledge and Teaching

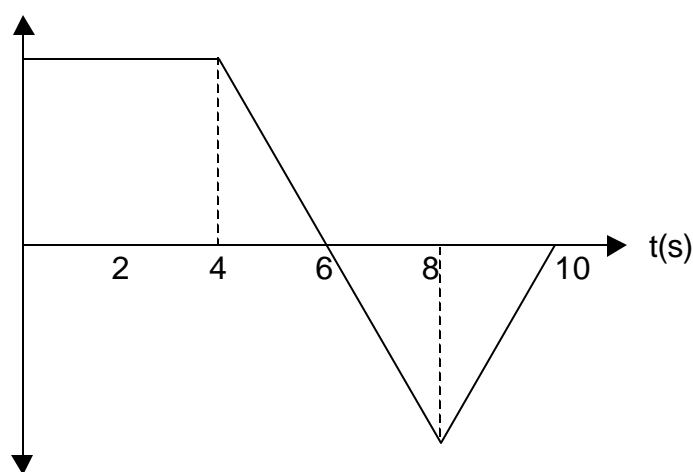
For the purpose of this discussion a section from Teacher A's pre-test was compared with what he had chosen to focus on during a classroom

observation as well as with the activity which he had compiled for Grade 11 learners.

It was evident from the data that Teacher A did not know the difference between distance and displacement. This represented a major shortcoming in his conceptual understanding, which influenced negatively on his teaching.

Example 1: Pre-test on Physics

The following question was taken from the pre-test given to the teachers at the start of the GDE programme



Question 1

The graph represents the velocity of an object moving horizontally towards the east:

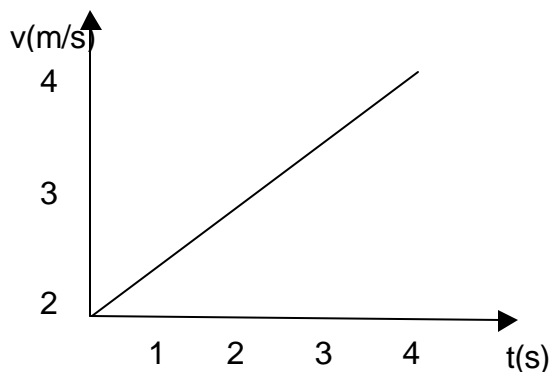
Calculate the magnitude and direction of the displacement of the object after it has been in motion for 10 s.
(Use the graph. Do not use the equations of motion.)

Velocity (m/s)
5
-5

Teacher A calculated the area under the graph correctly taking the signs into consideration but did not indicate the direction. Although this does not seem to be a big problem the scale of the problem became more apparent when analysing other data presented later.

Example 2: Classroom visit

Teacher A started his lesson to a Grade 11 class by drawing the following figure on the chalk board.



The following interchange took place between teacher and class:

Teacher: "What graph is this?"

Class (in chorus): "Velocity graph".

Teacher: "What is the unit for velocity?"

Class (in chorus): "Metres"

Teacher: "And time?"

Class (in chorus): "Seconds"

Teacher: "What conclusion can you make from this graph? How could you find acceleration from the graph?"

Class: No response

Teacher: "How can you get m/s^2 ? It is maths. Do you know maths?"

"By obtaining the gradient of the line. How do you find the gradient?"

Class: Again no response.

At this stage the teacher reverted to the chalk board on which he wrote the following:

the slope of the line at $t = 3 \text{ s}$ is⁴

$$\begin{aligned}
 m &= \frac{y_2 - y_1}{x_2 - x_1} \\
 &= \frac{3 - 0}{3 - 0} \\
 &= 1 \text{ m/s}^2
 \end{aligned}$$

$$a = 1 \text{ m/s}^2 \text{ at } t = 3 \text{ s}$$

⁴ A different font (technical) will be used throughout the thesis to indicate what was written by the teachers.

Teacher: "Write down a conclusion."

Class: No response

Teacher: "The gradient of the velocity-time graph gives the acceleration of the object.
What is distance or displacement measured in? What is the unit for velocity?
For acceleration?"

Failing to elicit any meaningful response from his learners the teacher again reverted to the chalkboard and wrote the following down:

Displacement - m
distance - m
velocity - m/s
acceleration - m/s²

Teacher: "How can we calculate the area of the graph?"

(This was followed by other questions, presumably directed towards arriving at the equation $(\frac{1}{2})$ base \times height)

Again in an effort to prompt his learners to respond, he wrote the following on the chalk board:

Data: Base: 4 s
Height: 4 m/s

$$\text{Area} = \frac{1}{2} (4) (4) = 8 \text{ m}$$

Teacher: "Use the law of exponents and make a conclusion by using the graph."

$$\text{He meant: } \frac{1}{2} (4\text{s}) (4\text{m}\cdot\text{s}^{-1}) = 8 \text{ m}\cdot\text{s}^1\cdot\text{s}^{-1} = 8 \text{ m}$$

Teacher A asked only low level questions such as: "What is distance or displacement measured in?" Although this was in itself not significant, it clearly indicated his inclination towards not focusing on the central concepts but on minor aspects such as: What type of graph is this? Or what is the unit of velocity? He only focused on that with which he is comfortable, namely the units. To remain within his comfort zone, he asked low level questions, controlled the questions and did not allow his learners to ask any questions.

This was a manifestation of the problem that had been identified by Harlen (1999, p. 76) namely that teachers with a low confidence in their ability to teach stressed process outcomes rather than conceptual understanding. Lockheed and Verspoor (1991, p. 67) also reported that such teachers preferred lectures, required students to copy from the blackboard and offered them few opportunities to ask questions or participate in learning.

In addition, Teacher A focused on mathematics and not on physics. This could be seen when the teacher determined the slope of the line in the velocity-time graph. He used “ x” and “ y” in stead of “ v” and “ t”.

Example 3: One hour activity for Grade 11 learners

Teacher A's lack of deep-level content knowledge is confirmed further by his choice of subject matter for this exercise. Instead of concentrating on central physical concepts, he opted to focus on simple mathematical manipulations. In this assignment for the GDE Inset programme the teachers had to compile a one hour activity for Grade 11 learners. The teachers had to outline the intended outcomes of the activity, their preparation and role, the learners' activities and assessment of the learners' achievements. Each section had to be discussed and criteria on its assessment had to be given. A topic from the physics textbook: Physics - The forces of life, Chapter 2 - Motion in one dimension, (Zealey et al., 1998) had to be selected.

Teacher A formulated the intended outcomes of the activity as follows:

Outcomes: At the end of the activity learners should be able to:

- (a) Calculate units of displacement (i.e. metres) from units of velocity and time
- (b) Divide any velocity -time graph given into familiar figures like triangles, rectangles or squares.
- (c) Calculate the area under the velocity versus time graph

His choice of focus revealed an inability to appreciate what was significant. He wanted learners to calculate the units of displacement and missed the importance of physical quantities. A lack of depth of conceptual understanding

was also evident in the following questions which he posed to learners in the introduction:

What are the units of velocity and of time?

(The answer he expected was m/s and s)

What can be done with the units above to find a metre?

(The answer he expected was to multiply)

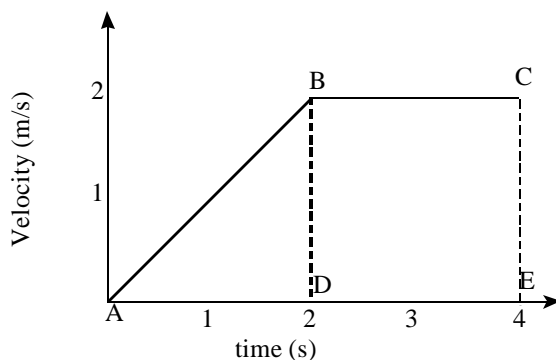
From what you have learned metres are units of _____.

(The answers he expected were distance and displacement)

The learners conceptual understanding and ability to relate concepts to one another need to be tested much more.

The learner's activities proposed by teacher A comprised the following:

Activity: I will prepare a chart with velocity versus time graph



He indicated that one of the learners would be required to calculate the area of the triangle and square formed in the graph and add them together. He then concluded the answer is in metres and metres are the units of distance and displacement.

His conclusion from the answer above was that the area below a velocity versus time graph gave distance or displacement. It was obvious that he did not fully grasp the distinction between these two concepts.

My observations above indicate a strong relation between teachers' content knowledge and the focus of their lessons. A lack of content knowledge leads

to low level questions on and superficial discussions of the subject matter in the classroom.

4.6.2 Professional Attitude

- **Background**

In the questionnaire on teachers' professional attitudes (Grayson et al., 2001) in the section of the questionnaire on "What should be expected of a teacher?" the teacher had to rate himself on a scale (a) always, (b) sometimes, (c) rarely or (d) never regarding various aspects of professional attitude. The teacher also had to give a reason for his choice. Due to the comprehensiveness of this questionnaire, I decided to focus on only four questions to illustrate the professional attitude of the teachers. The four questions as well as Teacher A's responses are given below:

The following questions were used:

- Question 1: To mark pupils' homework assignments, providing detailed feedback to pupils.

Response: Sometimes because I give learners homework almost every day so it is not always easy to mark and provide detailed feedback.

- Question 2: To produce worksheets and handouts for pupils

Response: Sometimes because it is not easy to prepare them for every lesson due to lack of facilities like photocopying machine.

- Question 3: To spend time in the evenings and over weekends on school work.

Response: Rarely because only weekends and evenings are times to be spent with the family except if I have special cases like marking.

- Question 4: To spend time during vacations on school-related work.

Response: Rarely because I only use some days of the holidays on school related work, the rest I spend with my family.

- **Comments on Teacher A's responses:**

Response to the first question:

I give learners homework almost every day.

During none of my two visits, in the beginning of the year and towards the end, did I observe any homework being dealt with. He did not check whether homework had been done, nor was homework marked or discussed. At first I thought that my presence might have caused a degree of uneasiness which prompted a deviation from his normal routine. However, an inspection of two of his learners' books revealed that their work had never been marked. This is a confirmation of the problem identified by Lockheed and Verspoor (1991, p. 67) that "little ongoing monitoring and assessment of student learning through homework, classroom quizzes, or tests" is done.

Response to the second question:

The first section of the question dealing with the production of worksheets is discussed in section 4.6.2.1.

In the section on "general comments" in the questionnaire, Teacher A wrote the following:

Most science educators are unable to do best in their work because of the work load they have. I know of a educator who teaches science alone in a school (he teaches Grade 10, 11 and 12) where each grade have two classes of 34 to 40 learners doing science. It is not easy to maximise your potential in such a situation

It is difficult to say whether the lack of facilities is a real problem in this case, or whether it is only listed as a handy excuse. I tend to agree with the latter, especially when Malcolm et al.'s (2000, p. 59) statement that community factors and external support are of lesser importance in successful schools, is kept in mind.

Response to the third and fourth questions:

The same response was given by Teacher A as reported by Grayson, et al., (2001), that to work over weekends and holidays is unnecessary.

4.6.2.1 *Interaction between Professional Attitude and Teaching*

An interesting relationship manifested itself when I compared the teacher's response on question 2 in the professional attitude questionnaire with the activity in the assignment for which he had to compile a worksheet. It was obvious that he did not possess the skill to compile a worksheet.

In the assignment the teachers were required to choose one or two outcomes they wanted to achieve when teaching electricity to Grade 12 learners. Six possible outcomes were provided. They then had to describe how they would prepare for the activity which would achieve the selected outcome, they had to describe the activity and had to compile a comprehensive worksheet for this activity. The criteria which would be used to assess the worksheet were given with the question.

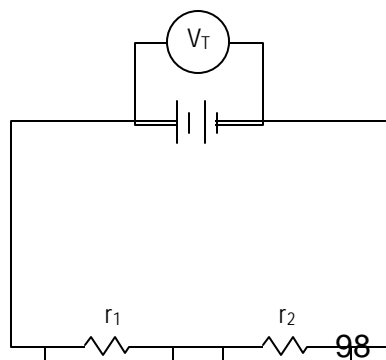
Teacher A chose the following outcome:

After completing this topic the learners should be able to draw and connect series and parallel circuits.

He described his activity as follows:

Series connection

In a series connection resistors are connected in such a way that they follow each other, resistors in series uses more energy since each resistor have its own potential difference. In a series connection current is the same at a point. Resistance in a series connection can be obtained by adding the resistors together using the formula $R_T = r_1 + r_2 + r_3 \dots$

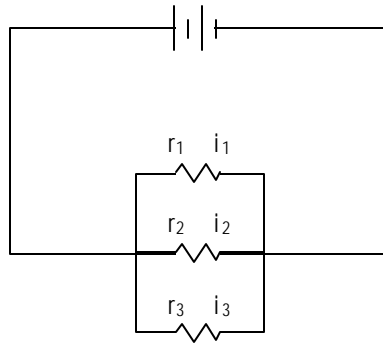


Parallel connection

In a parallel connection resistors are connected parallel to each other in such a way that each resistor have its own current but the total current in the circuit is found by adding the current from each resistor together using the formula: $I_T = i_1 + i_2 + i_3 \dots$. Resistors in parallel have the same potential difference.

Resistors in parallel give a resistance lower than any of them connected alone

when they are added together using the formula: $\frac{1}{R_T} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \dots$



Questions:

- 1(a) Draw a circuit board with three resistors r_1 , r_2 and r_3 connected in series.
- (b) If energy was supplied to the bulbs how will the brightness of the bulbs connected in series compare if they are identical?
- 2(a) Draw a circuit board with two cells connected in parallel
- (b) What do you know about potential difference of resistors in parallel?

• **Criteria for assessment of the teacher's assignment**

The following criteria were given to him so that he could see how he would be assessed in the activity for Grade 11 learners:

The outcome must:

- be written correctly according to what learners must be able to do, how well it must be done and the resources that will be used to comply with the stated outcome
- be suitable for the specific activity and topic/theme
- be stated in terms of an action verb
- include hands, heads and values

Criteria to assess the preparation of the teacher

- Is the preparation structured in a logical manner (introduction/body/conclusion...)
- Are the intended teaching and learning media specified?

- Are the intended teaching method and procedures mentioned?
- Are the intended activities mentioned?

Criteria to assess the intended role of the teacher during the introduction of the activity

- Is it an introduction or a complete activity?
- Is the introduction based on the topic?
- Does the introduction include an intention to draw on the prior knowledge of the learners?
- Are the type of introduction and its use suitable of the Grade and the topic?
- Is the language scientifically correct?

Criteria to assess the intended activities of the learners

- Are the activities clearly indicated?
- Are at least two different intended activities included?
- Are the activities clearly indicated by the learning outcomes?
- Are the activities suitable for the Grade and the topic?

Criteria to assess the intended assessment methods

- Are the instructions for homework given clearly?
- Are different methods for assessment used?
- Are different types of questions included?
- Are questions thought provoking?
- Is independent work by students included or expected from them?
- Is the language scientifically correct?
- Is a memorandum for any question-type assessment included?
- Is mark allocation suitable?

General aspects:

- Are the activities creative and original?
- Are the homework activities creative and original?
- Is the time allocation adequate for the activity?
- Are all the learning outcomes stated covered?
- What is the overall impression of the activity plan?

The criteria for the evaluation of the worksheet were not met at all. The questions were not varied, meaningful, or thought provoking. No observations had to be made, no conclusions had to be drawn, no results had to be interpreted and no applications had to be formulated. This clearly showed that Teacher A needed more guidance in the preparation of activities and compilation of worksheets.

A more meaningful approach would have been to ask learners to predict if bulbs in a series circuit would have the same brightness as in a parallel circuit. They then would have to do the practical investigations to discover independently what really happened and should make logical conclusions. To make the situation more practical, the relationship between a circuit with bulbs

or resistors and batteries and the circuit diagram with symbols indicating the components, could have been shown. This would develop their reasoning and thinking as well as their skills of translating between physical phenomena and representations.

My observations regarding Teacher A's professional attitudes, content knowledge and teaching skills revealed a clear interplay between these dimensions.

4.6.3 Teaching Approaches

The data on Teacher A's perception of his teaching in the self-evaluation test, my classroom observations and the evaluation of his assignments which were submitted as part of the programme, were triangulated to obtain a picture of his teaching approaches.

According to his self-evaluation test Teacher A regarded his use of visual media and ability to compile work sheets as worth a two on the scale from one to four with one being poor. On the use of individualised assignments, group work, demonstration skills and use of practical work he awarded himself a three. He also regarded himself as "good" in the use of the writing board and laboratory safety awareness.

It was encouraging to note that Teacher A's evaluation of his ability to compile worksheets was realistic, although he used the lack of facilities at the school as an excuse. The fact that he regarded himself as better in his use of individualised assignments, group work, demonstration skills and practical work, was rather worrying. When I did classroom observations, it was evident that he did chemical experiments but that physics experiments were neglected. The reasons could be that three schools I visited all seemed to be well equipped with chemistry apparatus, mostly micro chemistry kits, which were apparently used frequently. When Teacher A was asked about the availability of physics apparatus, he indicated a drawer in a cupboard in his class which contained only some loose electricity apparatus. The dusty

appearance of the apparatus clearly showed that it had not been used often. However, the teacher reported that a Medunsa bus equipped with physics apparatus visited selected schools once a month. Teachers had to inform Medunsa beforehand what apparatus should be brought along. The Medunsa advisor did all the demonstrations. Teachers did not get the opportunity to use the apparatus and to improve their skills in doing so, neither were learners allowed to handle the apparatus.

As part of one of the assignments teachers were asked to recommend what approach the Physical Science educator should adopt when faced with lack of facilities such as a laboratory, electricity, water, apparatus and chemicals. They were also requested to formulate practical solutions to such problems. Teacher A responded as follows to this question:

I will make sure that the learners understand the theory very clearly. For sections like momentum I will use toys of same mass to help learners have an idea of collision. For electricity, cells and batteries can be used e.g. when dealing with electromagnets an insulated conductor can be used to make turns around an iron nail which create an electromagnet when connected to a battery. For static electricity nylon clothes e.g. jerseys can be used to show the sparks of light when a jersey passes through the hair.

His answer indicates that he is more reliant on theory than on practical work. The example he gave regarding electromagnets was included as an experiment in one of the Saturday workshops. The apparatus was provided on that occasion.

In his self-evaluation test regarding his effectiveness, he awarded himself an average of 4,6 out of 5 for teaching method. His responses to the following questions were quite interesting:

- Do I adapt my teaching to the class? 4 - mostly
- Do I use a variety of techniques to teach Physical Science? 4 - mostly
- Do I create opportunities for different types of pupil activity in the classroom? 5 - always

- Do I use a variety of curriculum material and teaching strategies? 5 - always

This was contradictory to what I observed during my visits to his classroom. The only teaching method that he used was the “question and answer” method. In his notes in the GDE Inset Programme on the section teaching method, he was presented with concepts like cooperative learning and group work. He even answered questions such as what is the most important reason why learners should work cooperatively in the classroom, what is the difference between group work and cooperative learning and what skills of learners are enhanced by cooperative learning? Although he answered these questions correctly he never implemented different techniques in the lessons I observed.

4.6.4 Conclusion on Teacher A:

Although he showed an eagerness to improve his content knowledge, it is obvious from the data analysed and interpreted that Teacher A’s content knowledge is inadequate. His professional attitude can be improved while his teaching approaches are generally devoid of imagination and creativity.

What happened to Teacher A?

Teacher A’s matriculation results showed that he obtained an F symbol for Mathematics LG and that he did not have Physical Science as a subject. He returned to school the following year and repeated Mathematics and did Physical Science. He obtained a D symbol for both. Teacher A regularly attended the GDE workshops in Physics on Saturdays and achieved a mark of 65% in the post test. Therefore it could be concluded that he really wanted to improve his content knowledge.

However, this teacher resigned from teaching two years after this case study had been done to study to be a medical doctor.

4.7 Results: Teacher B

4.7.1 Content Knowledge

Teacher B obtained a Primary Teachers Certificate in 1978 and a Bachelor of Education (Specialisation in Educational Management) at UNISA in May 1998.

Similar to Teacher A, Teacher B's perception about his content knowledge in the self-evaluation test on his effectiveness had not been in accordance with what he actually achieved in the tests. Teacher B awarded himself an average of 4 out of 5 for knowledge of Physical Science while he scored 8% in the pre-test and 38% in the TIMSS test.

This teacher's perception of his knowledge of Physical Science and his actual test results clearly showed a need for development of his metacognitive awareness.

To indicate his lack of content knowledge, his answers in the pre-test are discussed below.

Example 1: Pre-test on Physics

The following questions were asked in the pre-test:

Question 4

A traffic patrol car stops at a red traffic light along a straight road. A truck, maintaining a constant velocity of $9 \text{ m}\cdot\text{s}^{-1}$ passes the patrol car and goes through the red light. The traffic light turns green 10 seconds later and at this instant the patrol car accelerates uniformly at $2 \text{ m}\cdot\text{s}^{-2}$ and chases the truck.

4.1 Calculate the time the patrol car took, from the moment it left the traffic light, to overtake the truck.

(HINT: At the moment of overtaking both vehicles have travelled the same distance from the traffic light.)

4.2 Calculate how far both vehicles were from the traffic light at the moment of overtaking.

The candidate's responses are as follows:

$$4.1 \quad u = 0 \text{ m/s}$$

$$a = 2 \text{ m/s}^2$$

$$v = 9 \text{ m/s}$$

$$v = u + at$$

$$9 = 0 + 2t$$

$$t = 4,5 \text{ sec}$$

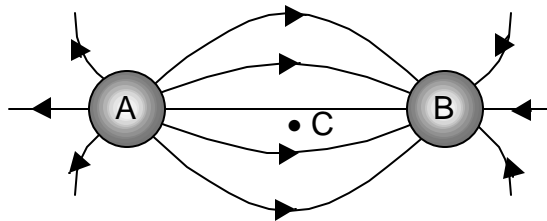
The time the patrol car took to overtake the truck is 4,5 seconds

$$4.2 \quad \text{The distance from the traffic light} = 9 \text{ m/s} \times 4,5 \text{ seconds} = 40,5 \text{ m}$$

His answers clearly revealed a lack of ability to solve a multi-step problem. The motion of the truck and the patrol car had to be considered separately. He was unable to solve the problem. He also thought that to overtake the truck, the patrol car must have the same velocity, rather than the same position, indicating confusion between position and velocity.

Question 6:

The diagram shows the electric field between two point charges A and B:



6.1 State the nature of the charges carried by A and B.

6.2 In what direction will a positive test charge placed at point C move?

The candidate's responses are as follows:

6.1 A carried a positive charge, B carried a negative charge, C carried a neutral charge

6.2 At A

The nature of the charges carried by A and B was answered correctly but there is no way that you can say what the nature of charge C is. His response in 6.2 also clearly indicated a problem with conceptual understanding. If you had to indicate the direction you would indicate it as "towards A" and not "at A". However a positive charge cannot be attracted by

a positive point charge A, in this case, as could be seen from the direction of the field lines of the charges indicated in the figure above.

Question 8:

When two identical positively charged point charges are a certain distance apart they repel each other with a force of 1×10^{-3} N.

8.1 Make a freehand sketch to show the pattern of the electric field formed by the two charges.

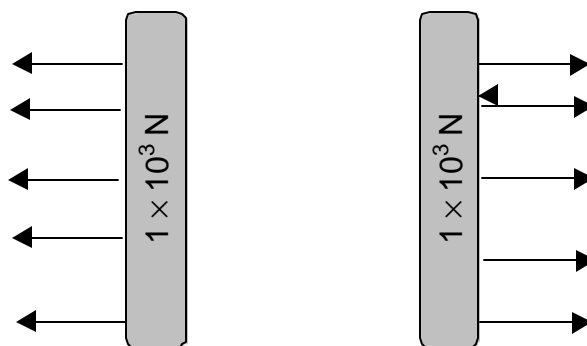
The point charges are now moved 3 mm closer to each other and this time they repel each other with a force of 4×10^{-3} N.

8.2 How far apart were the charges originally?

8.3 What was the magnitude of each charge?

His responses to question 8:

8.1 He made the following sketch



Again the answer showed a lack of content knowledge; he did not have the faintest idea how to indicate the pattern of electric field lines formed by two charges.

8.2 They were 4 mm apart

8.3 The magnitude of each charge was

$$\frac{4 \times 10^{-3}}{2} = 2 \times 10^{-3} \text{ N}$$

His answer to 8.2 and 8.3 again demonstrated his inability to solve a multi step problem. However this is not the only problem he has. He also cannot do proportional reasoning. If the force increases fourfold, the distance is halved. Furthermore, his concepts of force and charge are completely muddled, the magnitude of charge cannot be measured in Newton, as seen in his answer.

The example below demonstrated the strong interaction between the teacher's content knowledge and what he chooses to focus on in his lessons.

Example 2: One hour activity for Grade 11 learners

A topic from the physics textbook, Physics - The forces of life, Chapter 2 - Motion in one dimension, had to be selected. He had to compile a one hour activity for Grade 11 learners and had to describe the intended outcomes of the activity, the educator's preparation and role, the learners' activities and assessment thereof.

He selected "Describing Motion" as the topic.

Activity Plan

The intended outcomes of the activity

At the end of the activities the learners should be able to explain the following terms:

frame of reference, kinematics, dynamics, linear motion, vector and scalar quantities. Learners should also be able to calculate and draw for example, a train moving at 30 m/s parallel to a car moving at 10 m/s in the same direction and opposite in terms of either scalar or vector quantities. Learners should, at the end of this activities, be able to draw one dimensional motion in which an object with respect to a fixed reference point as well as the time at which observation is made.

It can be seen that the outcomes envisaged by Teacher B clearly lacked focus. Not only did he cover mixed broad concepts but he also included very detailed cases.

The teacher's preparation

I prepare worksheets and watches and meter-rules. On the work-sheets learners will be able to measure and to record the distance and time taken by a ball when it rolls from point A to point B. Time will be measured in seconds and the distance travelled in metres. Thereafter, the speed at which the ball travels along the meter-rule will be taken as distance travelled by the ball divided by the time it has taken to travel that distance. The unit of speed will be m/s or $\text{m}\cdot\text{s}^{-1}$. I will also explain to the learners what is vector and scalar quantities. They will also know the difference between distance and displacement after I have taught them with practical examples. I can explain to students by using the following example: Atteridgeville is 9 km from Pretoria - this indicates the distance between Atteridgeville and Pretoria - it is a scalar quantity. But if I say Atteridgeville is 9 km west of Pretoria - i.e. distance and direction are included - this is a vector quantity.

Unfortunately he did not submit the worksheet that he had “prepared”. Again he did not get to the main difference between distance and displacement. (Displacement is independent of path, just a change in position.)

The teacher's role

I will ask my learners about the distance travelled by a learner, for example from home to school. The teacher can for example say John travels 1 km to get to Peter on his way to school. From there they go to call Jonathan who is 2 km from Peter's place. From there they go to buy vetkoekies. Vetkoekies place is 1 km from Jonathan's place. If the school is 1 km from the school (*sic*), calculate the distance travelled by John from home to school. If John takes 1 hour to travel to school, calculate the speed travelled by John to school. How far away is the school from both Peter and Jonathan?

If Peter takes 30 minutes to travel to school, what is his speed? What is the speed of Jonathan if he takes 15 minutes to reach the school? Find the speed of the three boys when they travel to school.

This example is very confusing and complicated. Furthermore, he concentrated only on basic calculations of “speed” and “distance” and did not include the concept of average speed. He also focused on low-level questions, most probably due to his lack of conceptual understanding.

The learners' activities

Learners will be divided into a group of five each. Each group will choose its own scribe as well as its leader who will represent it by giving the group's answers and explanations to the class. The leader of a group will be helped by group

members when s/he goes astray. After each group has given answers, the whole class will discuss the answers. The teacher serves as a facilitator to see to it that everything goes according to plan. Where the groups disagree, the teacher gives a clearer explanation to the problem under discussion.

Teacher B teaches lower grades where OBE is fully implemented and great emphasis is placed on group work. This could be the reason why he selected to use the example of group work.

Assessment

My intention is to give the learners homework immediately after a lesson. (I did not observe this during my attendance of his classes.) Questions that should be given as follows:

Question 1

Explain the following terms and/or words

- 1.1 Kinematics (2)
- 1.2 Linear motion (2)
- 1.3 Frame of reference (2)
- 1.4 Differentiate between a vector and scalar quantities (4)

[10]

Question 2

If there are two cars, X and Y, where X is moving at 50 m/s parallel to but in opposite direction to Y which is moving at 20 m/s, calculate

- 2.1 speed of car X relative to car Y, and (5)
- 2.2 speed of car Y relative to car X (5)

NB consider motion to right as in positive direction and motion to the left as in a negative direction. Also use diagrams to or in solving the problems.

[10]

Question 3

Supposing a train is moving at 50 m/s parallel to a car moving at 20 m/s in the same direction.

- 3.1 What would be the speed of a car relative to a train? Use the diagrams to help you in your calculations. Show all the diagrams and calculations. (5)
- 3.2 From 3.1 above, what would be a speed of a train relative to a car? (5)
Show the diagrams in all answers.

[10]

The questions in the test were not varied at all. Questions 2 and 3 were of the same type. There were also a complete disjunction between the topic of his

lesson and the topic of the assignment. He did not discuss relative velocity at all but rather focused on displacement and speed.

As in the case of Teacher A, my observations again confirmed an interaction between Teacher B's content knowledge and the focus of his lessons.

4.7.2 Professional Attitudes

The answers to the four questions from the professional attitude questionnaire were given but Teacher B failed to give any reason for his answers. The questions and his answers are given below:

- Question 1: To mark pupils' homework assignments, providing detailed feedback to pupils

Response: Always

- Question 2: To produce worksheets and handouts for pupils.

Response: Sometimes

- Question 3: To spend time in the evenings and over weekends on school work.

Response: Sometimes

- Question 4: To spend time during vacations on school-related work.

Response: Never

Comments on Teacher B's responses:

As in the case of Teacher A, Teacher B also indicated that teachers should not be expected to spend time on school related work during holidays.

4.7.2.1 Interaction between Professional Attitude and Teaching

Again the same interesting relation manifested between professional attitude and teaching when I compared Teacher B's answers in the professional attitude questionnaire with the activity in the worksheet which he had to compile for the assignment. It was evident that he did not have the ability to compile a meaningful worksheet.

In the assignment, the teachers were asked to choose one or two outcomes they wanted to achieve when teaching electricity to Grade 12 learners. Six possible outcomes were given to choose from. They then had to describe how they would prepare for the activity aimed at achieving the outcome, to describe the activity and to compile a comprehensive worksheet for this activity. The criteria (see 4.6.2.1) used to assess his worksheet had been given with the instruction for the assignment.

Teacher B chose the following outcome:

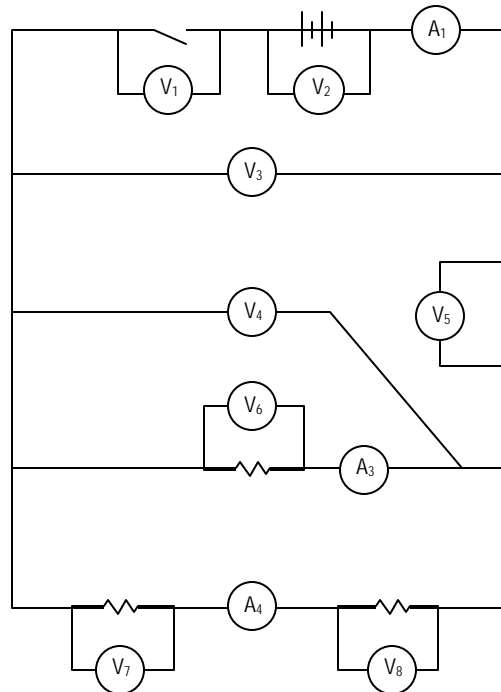
Connect volt and ammeters in the correct place in a circuit to obtain data about the circuit

Included logistics:

Copper wires, electric bulb, circuit board, connectors with switches, crocodile clippers, ammeters, resistors and voltmeters.

In the given

diagram below;



compare

- (i) the different ammeter readings
- (ii) the different voltmeter readings

Questions

Fill in the missing words

- (1) In series _____ stays constant

- (2) In parallel _____ stays constant
- (3) Compare the different ammeter readings
- (4) Compare the different voltmeter readings

There were no clear instructions and no indication of A_2 . I was unsure whether the learners were expected to set up this circuit and take readings or use fictitious values and do calculations in order to compare the volt and ammeter readings

The second choice of the outcomes of Teacher B:

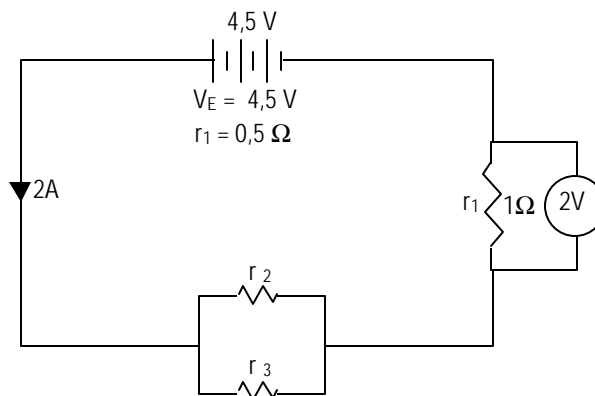
Recall and use Ohm's law in calculations

The following circuit is made. Three cells with an EMF of 1,5 V each and a total internal resistance of $0,5\Omega$ for the three, are connected in series. A resistor r_1 of 1Ω is connected in series with a voltmeter reading of 2 V over it. Two resistors, r_2 and r_3 are connected in parallel. The two have the same resistance. Determine their resistance.

NB. Before calculating/calculation, draw a circuit diagram to show how the components in a circuit i.e. the voltmeter and resistor/s and the ammeter/s are connected. Also show how the position of the three cells connected in series in a circuit with the components in a circuit.

Solutions:

- (i) Diagram/circuit diagram



- (ii) Calculations

$$V = IR$$

$$I = 2A$$

$$V_E = I(R + r_1)$$

$$4,5 = 2(1 + x + 0,5)$$

$$4,5 = 3 + 2x$$

$$1,5 = 2x$$

$$x = 0,75\Omega$$

$$\frac{1}{R} = \frac{1}{r_2} + \frac{1}{r_3}$$

$$\frac{1}{0,75} = \frac{1}{y} + \frac{1}{y} = \frac{2}{y}$$

$$y = (2)(0,75)$$

$$= 1,5\Omega$$

Their resistance (i.e. $r_2 + r_3$) = 3Ω

The criteria for the evaluation of the worksheet were not met at all. The questions were generally without meaning, purpose or variety and provoked very little thought. No observations had to be made, no conclusions had to be drawn, no results had to be interpreted, nor had any applications to be formulated. It was obvious that Teacher B needed support and guidance in the designing of activities and the compilation of worksheets. In his circuit diagram the cells were also not connected to each other.

Again the interrelatedness between professional attitudes, content knowledge and teaching skills emerged in my observation of Teacher B's performance.

4.7.3 Teaching Approaches

In Teacher B's self-evaluation of his teaching strategies, he awarded himself for his use of visual media a mark of two on the scale from one to four, where one indicated poor. His use of individualised assignments, his group work skills, his ability to compile work sheets, his demonstration skills, his application of practical work, and his laboratory safety awareness were all awarded a three. He also regarded himself as "good" in the use of the writing board.

The mark he allocated himself for the use of practical work is rather unrealistic. He evaluated his teaching method (under effectiveness) at an average of 3,8 out of five. On the question...."Do I give learners enough opportunity to do their own practical work?" he awarded himself a four

(mostly). However, during my classroom observation, Teacher B said that he did no practical work because the laboratory was not in working condition. In the self-evaluation test he also indicated that he applied a variety of techniques to teach Physical Science most of the time. In the assignment for the GDE Inset programme, he even elaborated on how a range of different teaching methods could be implemented. However I observed him only using the “question and answer” teaching method.

In one of the assignments, Teacher B had to give five reasons why it made sense to use a variety of teaching methods when teaching Physical Science: He replied as follows:

Certain goals and outcomes are achieved more effectively by using a particular method. For example questioning, problem-solving and demonstration methods may be used when explaining ionic bonding

The use of variety methods provides learners with more opportunities to learn. For example a number of methods such as questioning, problem-solving; demonstration, use of teaching and learning media- resources, may be used in one lesson e.g. ionic bond.

The nature of subject content can determine the appropriate teaching methods. Demonstrations, questioning may be used to explain the difference between acids and bases

The use of several methods creates variety and prevents boredom from setting in. Transparencies and overhead projector, problem solving and questioning may be used in a lesson to demonstrate the difference between vector and scalar quantities.

Every educator has his/her own style and preferences, and so many find some methods more effective than others.

He tends to be repetitive in his answers.

4.7.4 Conclusion: Teacher B

As with Teacher A, it can be concluded that content knowledge, professional attitudes and teaching approaches are interlinked and influence each other. Teacher B has insufficient content knowledge and therefore cannot teach the subject correctly or present it in a variety of ways. Furthermore his professional attitudes can improve.

What happened to teacher B?

Teacher B stopped attending the course after six months, his reason being that he had, “too much to do at school.” He further indicated that “everything is too much” for him.

4.8 Results: Teacher C

4.8.1 Content Knowledge

Teacher C obtained a Secondary Diploma in Education with Physical Science as his major in 1998. He achieved a mark of 80% for Physical Science III, 68% for Physical Science Practical II, and 80% for Physical Science Didactics III.

From all the respondents of the GDE programme who wrote the pre-test in Physics, only two passed. He was one of them. He achieved a mark of 54%. However, with this record of achievement the mark of 31% which he obtained for the TIMSS test, was disappointing.

In the self-evaluation test about his effectiveness he awarded himself an average mark of four out of five. Some examples of questions and his responses are given below:

- Am I well-read in the field of Physical Science? 4 - mostly
- Do I have a thorough knowledge of Physical Science? 4 - mostly
- Do I communicate facts that are valid and relevant? 5 - always
- Do I keep up with new scientific developments? 4 - mostly
- Am I aware of scientifically related social issues? 3 - sometimes

These marks conflicted drastically with his performance in the two tests. This could be due to a lack of metacognitive awareness. Answers to some of the questions in the test is given below to illustrate that he is overconfident about

his effectiveness but if it is compared to his actual answers in the test, he is unable to answer Grade 12 type of questions.

Example 1: Pre-test Physics

Question 4

A traffic patrol car stops at a red traffic light along a straight road. A truck, maintaining a constant velocity of $9 \text{ m}\cdot\text{s}^{-1}$ passes the patrol car and goes through the red light. The traffic light turns green 10 seconds later and at this instant the patrol car accelerates uniformly at $2 \text{ m}\cdot\text{s}^{-2}$ and chases the truck.

- 4.1 Calculate the time the patrol car took, from the moment it left the traffic light, to overtake the truck. (14)
(HINT: At the moment of overtaking both vehicles have travelled the same distance from the traffic light.)
- 4.2 Calculate how far both vehicles were from the traffic light at the moment of overtaking. (4)

The candidate answered as follows:

4.1

<p>Car:</p> <p>$t = 10 \text{ sec}$</p> <p>$a = 2 \text{ m/s}^2$</p> <p>$s =$</p> <p>$u = 0$</p>	<p>truck:</p> <p>$s = \underline{\hspace{2cm}}$</p> <p>$u = 9 \text{ m/s}$</p> <p>$a = 0$</p> <p>$v = u + at = 9 + (0)(10) = 10 \text{ m/s}$</p> <p>$v^2 = u^2 + 2as$</p> <p>$(9)^2 = v^2 - u^2/2s$</p>	<p>(14)</p>
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He knew that he had to consider the two vehicles separately. The fact that he indicated $a = 0$, showed that he knew that the truck moved with a constant velocity. However, using $t = 10 \text{ s}$ for both car and truck indicated that he was unable to interpret “the traffic light turns green 10 seconds later”.

4.2 He could not solve this part of the problem at all.

Question 5

Which ONE of the following statements is false?

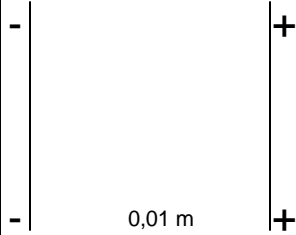
An object can have, at some stage of its motion:

- A. constant speed, even though its velocity is changing
 - B. constant acceleration, even though its velocity is changing
 - C. constant velocity, even though its speed is changing
 - D. zero velocity, even though its acceleration is not zero
- (3)

He indicated B and C as true and A and D as false. An object cannot have constant velocity when its speed is changing.

Question 7

A potential of 1 000 V exists between two parallel metal plates 0,01 m apart in vacuum:



- 7.1 Sketch the electric field pattern between the plates. (3)
7.2 Calculate the work done by the electric field on a positive charge of 8×10^{-19} C that moves from the positive plate to the negative plate. (3)
7.3 Determine the magnitude of the electric force acting on the positive charge. (3)

7.1 He sketched the field pattern between the plates correctly.

$$7.2 W = V \times d = 1\,000 \times 0,01 = 10 \text{ J}$$

He showed a lack of conceptual understanding of the difference between work done on an object by a constant force calculated by $W = Fs$ (if the force and the displacement is in the same direction) and work done by the electric field on a charge calculated by $W = Vq$. He could have corrected himself by checking the units because joule is not the same as volt times metre.

$$7.3 W = QEs \therefore QE = 10/0,01 = 1\,000 \text{ N}$$

He used the wrong values but determined the force.

Example 2: TIMSS: Section A

10. The water level in a small aquarium reaches up to a mark A. After a large ice cube is dropped into the water, the cube floats and the water level rises to a new mark B. What will happen to the water level as the ice melts? Explain your reasoning.

The water level will move further up B because of the amount of water formed by ice.

According to Archimedes' principle the volume of the water displaced by the ice is equal to the volume of the water produced when the ice is melted. This means the water level will stay the same.

12. A car moving at constant speed with a siren sounding comes towards you and then passes by.
Describe how the frequency of the sound you hear changes.

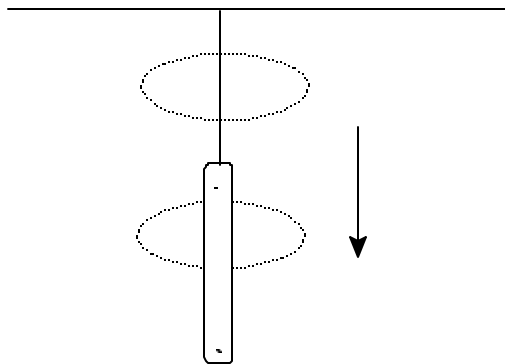
Approach - sound is low pitched

Next to me - sound is high pitched

After leaving me - sound is lower than when approaching me

The frequency will be higher as the car approaches and then lower as the car moves away.

18. A strong bar magnet hangs from a string with its north pole upwards. A light ring of aluminium is held above the magnet and allowed to fall down to the ground, as shown in the figure.



Explain why the ring takes longer to fall to the ground with the magnet present than it would without the magnet.

Attraction of the fields (magnetic fields)

North pole to the ring.

This is the mass of ring + magnet.

He should have indicated that an electric current was induced in the ring. According to Lenz's law, this created a force acting in opposition to the movement (upwards) decreasing the acceleration of the ring. A comparison between his answer and the correct explanation clearly indicated that he had a deficient concept of the physical principles involved.

4.8.1.1 *Interaction between Content knowledge and Teaching*

Example 3: One hour activity for Grade 11 learners

Teacher C formulated the outcomes of this exercise as follows:

Outcomes: At the end of the lesson learners must be able to:

- (a) Calculate the displacement of an object using the velocity-time graph
- (b) Divide the graph into sections in order to calculate the displacement.

These outcomes showed that he did not appreciate significant concepts. Instead of focusing on salient physical concepts, he concentrated on relatively simple mathematical manipulation, such as “dividing the graph into sections.” Also (b) is a sub-task of (a).

Sections of the worksheet which he compiled are given below to illustrate his lack of grasp of the various concepts:

Worksheet: [Introduction:]

From the equation $v = s/t$, say what each quantity stands for and give its unit.


v = velocity ($m.s^{-1}$)

s = change in position (displacement)(m)


t = change in time (s)

Linking the pre-knowledge with new knowledge

Question: How do we calculate the area of a square or rectangle?

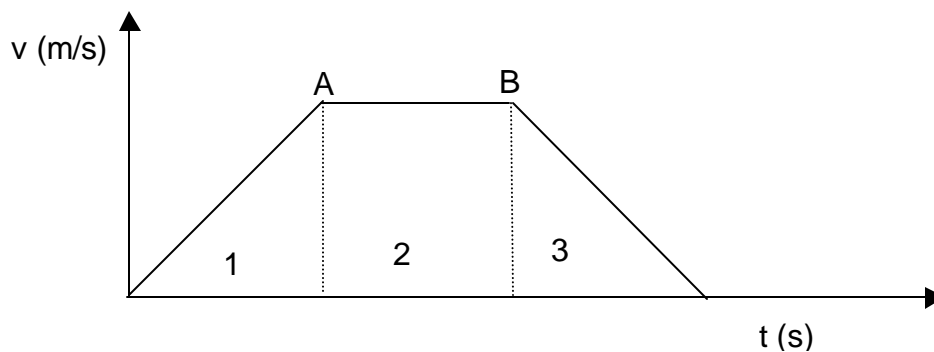
 Answer: Area = $l \times b$

Question: what about the area of a triangle?

 Answer: Area = $\frac{1}{2} bh$

From the following graph, identify

- (a) square/rectangle
- (b) triangle



Answer: 1 and 3 are triangles;
2 is a square

From the equation: $v = s/t$

$$s = vt$$

then $s = (v \times t)$ as in 2

units: s metres

proof: $s = vt$

$$= \text{m/s} \times \text{s}^{-1}$$

$$= \text{metre}$$

The conclusion which can be drawn now is?

The area under the velocity-time graph represents the displacement in metres.

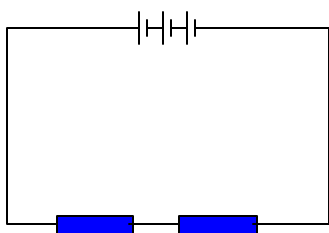
Hint: When given the v - t graph, divide it into sections and then identify squares/rectangles and triangles. The area under those figures will give the displacement (s).

The example given above clearly shows Teacher C's deficient conceptual understanding. He focused on mathematical manipulations rather than physics concepts, and muddled quantities and their units. Identification of the area of squares and rectangles are a trivial task for Grade 12 learners. It is inappropriate for this level and in a physics course. He concluded that, because the units were metres, the quantity involved had to be displacement. This was of course an invalid conclusion as there are numerous examples of different quantities with the same units, such as density and concentration or work done and kinetic energy.

Example 4: Classroom observation

I was present in Teacher C's classroom during a lesson on electricity to a Grade 12 group. A description of the progress of the lesson is given below:

He drew the following circuit diagram on the chalk board.



The drawing of the diagram was followed by a question and answer session which went as follows:

Teacher: "How many cells are there in this circuit?"

Learner 1 with hand raised: "Two"

Teacher: "In what direction does the current flow?"

Learner 2 with hand raised: "From negative to positive."

Teacher: "Yes, from negative to positive. What is the unit for current?"

Learner 3 with hand raised: "Ampere."

Teacher: "If the resistors were bulbs what would happen to them?"

Learner 4 with hand raised: "It will light"

Teacher: "Remember, it won't light. It would glow. What does a resistor do in a circuit?"

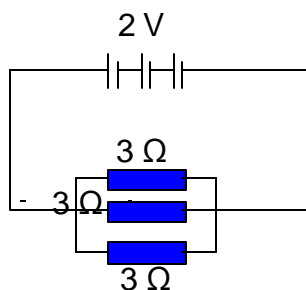
Learner 5 with hand raised: "It gives resistance"

Teacher: "What can you say about the current in a series circuit?"

Learner 6 with hand raised: "It stays the same."

Teacher C did not correct the learner who replied that "the current flows from negative to positive". He actually agreed! Conventional current is regarded as the flow of positive charges in a conductor from the positive terminal of a source through the circuit to the negative terminal of the source.

The teacher then drew the following circuit diagram on the chalk board which was followed by the interchange below:



Teacher: "What is the current in each of the resistors? Remember, the current in parallel resistors is shared amongst the resistors"

Learner 1: "Two amperes in each"

Teacher: "How do you calculate the current in each resistor? What formula do you use?"

Learner 2: "Ohm's law."

Learner 3: "If the resistors are not the same, how do you determine the current?"

This was one of only a few occasions where a question was asked by a learner. Teacher C referred the question to the rest of the class. Failing to elicit a satisfactory response he continued in his mother tongue which I did not understand. I presumed that he briefly explained how the current was determined. It was disappointing however, that he did not use this opportunity to clarify misconceptions.

Teacher C then proceeded and wrote the following on the chalk board.

$$R = V/I.$$

Teacher: "Define Ohm's law".

Learner: "The potential difference is directly proportional to the current."

Teacher: "Provided that the temperature of the resistor remains constant. What factors have an effect on the resistance? We have already done it in Chapter 9."

He obtained the answers (length, thickness, type of material) from the class.

Teacher: "What is the difference between electrostatics and current electricity? Any one? What is the difference? Is there a difference?"

At this stage the bell went and the question remained unanswered.

Teacher: "Here is your homework"

He wrote the following on the chalk board

1. Derive the equation for $R_T = r_1 + r_2 + r_3$

2. Derive the equation for

$$\frac{1}{R_T} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$

Teacher: "You are writing a 15 minute test tomorrow on today's work."

The learners moaned, packed their books and left.

Grade 12 learners should be confronted with much more challenging problems than the ones Teacher C came up with. Again he focused on mathematical manipulations and neglected conceptual understanding. This topic could have been handled in a much more stimulating and practical way. Firstly, the learners could have been asked to predict the brightness of bulbs in a series and parallel circuit. They should then have been allowed the opportunity to do practical investigations to test their predictions. Instead, Teacher C faced his class with his textbook as the only aid, which resulted in a limited learning experience for his learners.

4.8.2 Teaching Approaches

According to the self-evaluation test Teacher C regarded his use of individualised assignments, group work, visual media, practical work and laboratory safety awareness as worth a 2 on the scale from 1 to 4 with 1 being poor. He awarded his ability to compile work sheets and his demonstration skills with a better mark and he felt he was "good" in the use of the writing board.

Although he gave himself a 3 for his ability to compile worksheets and for his demonstration skills, he indicated on his questionnaire that he only sometimes considered it necessary to prepare worksheets.

In his self-evaluation test regarding his effectiveness, he awarded himself an average of 2,6 out of 5 for Teaching method. Example of his responses to certain question, are as follows:

- Do I adapt my teaching to the class? 3 - sometimes
- Do I use a variety of techniques to teach Physical Science? 4 - mostly
- Do I create opportunities for different types of pupil activity in the classroom? 2 - Seldom
- Do I use a variety of curriculum material and teaching strategies? 3 - sometimes
- Do I give learners enough opportunity to do their own practical work? 1 - never

I think his answers are honest and his marks consequently realistic.

My observation during the class visit confirmed that Teacher C mainly relied on the “question and answer” teaching method. Although questioning as a teaching method is vital in the teaching of Physical Sciences, the function of questions is, in addition to the creation of a favourable atmosphere for discussion, also to stimulate the learners’ curiosity and interest and to motivate them to come forward with creative, new ideas in their search for information.

4.8.3 Professional Attitudes

Teacher A and B’s responses to the questions on how they would handle a variety of problem situations in class were not noteworthy. However, I consider it worthwhile to devote some attention to Teacher C’s responses.

In his self-evaluation test determining his effectiveness, it was interesting to note that Teacher C awarded himself an average of 4,2 out of five for personal relationships. Examples of his responses to certain questions are as follows:

- Is my relationship with the learners in my class good? 5 - always

- Do I recognise the unique needs of my learners? 3 - sometimes
- Do I get on well with my learners - both individually and as a group? 4 mostly
- Do I sincerely want to help my learners? 5 - always
- Do I listen to learners' questions and ideas in class? 4 - mostly

This was compared to the answers he gave in the paragraphs on how he would handle a number of problem situations in his class. He had to give possible choices of action, criteria on handling the situation and implications of the choice of action. The descriptions of the situations and his answers are given below:

a You have a class of 40 Grade 8 boys and girls gathered round the demonstration bench on stools to watch you carry out an experiment requiring careful manipulation. One boy continues to play with a water tap on the bench after you have asked him to refrain from doing so. How would you discourage his actions further?

Get hold of his attention by asking him one question (directed) to him. The chances are that he might not be able to answer and will therefore be embarrassed in front of his friends. He must then be asked to ensure that all the taps are closed, it is possible that all taps are not tightly closed.

b After a physics practical, the entire class is occupied in writing up the experiments. As you walk round the lab, you discover two gas taps not quite turned off, three dripping taps, one bench covered with iron filings, and broken glass in the sink of another bench. What would you do?

If each learner has a task in the lab, those that are responsible for safety, must be reminded of their task. The whole class will have to go through the laboratory rules again. The important fact of broken equipment must be re-emphasized because if broken equipment is hidden, by the time of stock-taking some equipment will not be traced. Hazardous issues like leaking taps bring out danger

c Your learners are looking drowsy towards the end of a lesson, and you wake them up by banging on your desk with a textbook. One girl continues to sit with her head resting on her arms which are folded on the desk. You angrily call out her name; she looks up and burst into tears. What would you do?

Go on giving her a tongue-lashing. It is possible that she is spoilt. If you talk to her nicely, she might in future do exactly the same, the others will make it a trend. Make it clear that for every wrong-doing one must be punished, and

crying never got anyone out of hot water, but the risk might be that she is having emotional problems at home.

d	Four 15 year old girls tell you at the end of one of your lessons that you are too strict with their class. In particular they think that you should allow them to talk quietly in lessons “like the other educators do”. How would you reply to their criticism?
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When they talk, they must talk about the subject as a group. They must realise that educators are different - There comes a time when some learners continue talking during lessons and by that end up disturbing the lesson and this may cause ill-discipline in future.

His answers given above and his responses in his self evaluation of his personal relationships are to a certain extent contradictory. Although he regards himself as a socially skilful teacher, his descriptions of how he would handle the problem situations in his class reveal himself as a rather unsympathetic, task - orientated teacher.

He awarded himself an average of five out of five for enthusiasm. A few responses to some of the questions are given below:

- Do I enjoy teaching Physical Science? 5 - always
- Am I enthusiastic about teaching Physical Science? 5 - always
- Do I get excited when learners gain insights into Physical Science? 5
always
- Do I make every effort to help learners understand Physical Science? 5
always
- Am I energetic and enthusiastic about my subject when I teach? 5
always

However, his responses to the questions below, especially to questions 3 and 4, are not responses expected from a truly committed Physical Science teacher. The focus is again on the four questions from the Professional Attitudes questionnaire.

- Question 1: To mark pupil's homework assignments, providing detailed feedback to pupils

Response: Always because I identify the problem areas.

- Question 2: To produce worksheets and handouts for pupils

Response: Sometimes because not all topics are suitable for worksheets.

He disagreed that teachers should prepare worksheets for pupils because learners should take notes during the lesson.

- Question 3: To spend time in the evenings and over weekends on school work.

Response: Never because there is a need for being social too.

- Question 4: To spend time during vacations on school-related work.

Response: Never because there is a need for being social too.

Comments on Question 1:

Although I observed during the classroom visit that he gave homework, little evidence could be found of detailed feedback. This is a manifestation of the problem mentioned by Lockheed and Verspoor (1991, p. 67) reporting on a study of improving primary education in developing countries, that "little ongoing monitoring and assessment of student learning through homework, classroom quizzes, or tests" is done.

Comments on Question 2:

I became aware of a perception amongst some teachers that the learners have to work and not the educators. This could be a consequence of their own experiences when they had been at school.

Comments on Question 3 and 4:

In view of the regular occurrence of responses similar to those of Teacher C, the generally held view seemed to be that evenings, weekends and holidays are for family and social enjoyment. Consequently, little time was available to prepare worksheets, or to maintain the laboratory.

General comments by Teacher C on teaching in general

In the final section of this questionnaire, teachers were requested to write general comments. Teacher C wrote the following:

Cuban teacher. They can help, but who will be responsible for their financial affairs, DET/GDE? What about the poor well trained lecturers in RSA, why aren't they give the very same task as Cubans.

I was encouraged by the fact that he felt the problem could be solved within the South African teachers' corps, without having to rely on foreign teachers.

4.8.3.1 Interaction between Professional attitudes and Teaching

The teachers had to describe how they would prepare for an activity for Grade 12 learners on electricity that would achieve the outcomes given, and had to compile a comprehensive worksheet for the activity. As previously stated the criteria that would be used to assess the worksheet were supplied with the instruction (see 4.6.2.1).

He wrote the following:

Recall and use Ohm's law in calculations [outcome]

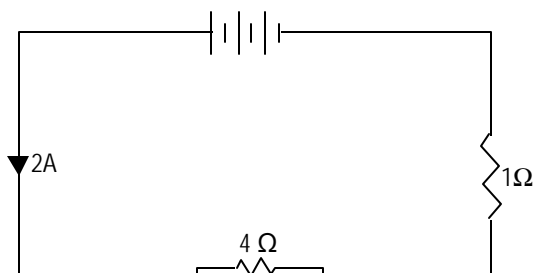
- (a) Values for V (potential difference) and I (current) are obtained and set-out on the graph table. The graph is then drawn and the relationship will then be made
- (b) After drawing up the table, learners draw a graph of V against I. If the graph is a straight line, the relationship will be that $V \propto I$. If V increases I increase as well. They must then say that relationship is called Ohm's law.

(c) Worksheet for Grade 12 Date: 14/05/2001

Topic: Ohm's law

Outcome: recall and use of Ohm's law

- (i) State ohm's law in (a) words
(b) with the aid of mathematical relationship.
- (ii) From the equation $R = \frac{V}{I}$, say what each quantity stands for and give its unit
- (iii) Is R, the total resistance or the resistance of an individual resistor?
- (iii) Consider the following circuit, and answer question that follow.





- (a) What is the total resistance?
- (b) Calculate the potential difference across the terminals of the battery
- (c) What is the voltage at $r = 1 \Omega$ and $r = 2 \Omega$
- (d) Why are resistors in parallel called current dividers?

He expected the following answers:

- (i) (a) the potential difference across a metal (i.e. conductor is directly proportional to the current, in the circuit, i.e. $T = \text{constant}$)
(b) $V \propto I$ (T constant)
- (ii) $R = \text{total resistance}$ unit \rightarrow Ohm
 $V = \text{potential difference}$ unit \rightarrow Volt
 $I = \text{current}$ unit \rightarrow Amp
- (iii) No, it is the total current (*sic*)
- (iv) (a) $R_{\text{series}} = 1 \Omega + 2 \Omega = 3 \Omega$
$$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{4} = \frac{4 + 3}{12} = \frac{7}{12}$$
$$R_p = \frac{12}{7} = 1,7 \Omega$$

$$R_{\text{total}} = R_{\text{series}} + R_{\text{parallel}} = 3 \Omega + 1,7 \Omega = 4,7 \Omega$$

$$R = \frac{V}{I}$$

(b) $V = IR$
 $= 2A \times 4,7\Omega$
 $= 9,4V$
(c) $V_1 = Ir_1 = 2 A \times 1 \Omega = 2 V$
 $V_2 = Ir_2 = 2 A \times 2 \Omega = 4 \Omega$ (*sic*)
(d) the current is shared amongst the resistors.

The worksheet compiled by Teacher C clearly indicated that he needed guidance in this respect. Question (ii) was not meaningful or thought provoking. In part (iii) he asked a question on resistance but gave the answer

as current which is incorrect. Furthermore, no observations had to be made, no conclusions had to be drawn, nor had results to be interpreted or applications to be formulated and it was expected from the learners to do only calculations in part (iv).

4.8.4 Conclusion: Teacher C

Teacher C needed deeper conceptual understanding, a development of skills in a variety of teaching approaches and guidance in the design of worksheets. He also needed to be motivated to do school-related work outside formal school hours.

What happened to teacher C?

Teacher C obtained a mark of 45% in the post test. Out of the eight contact sessions in the second half of the year he only attended three. He wanted to quit teaching. When asked why he replied, "I have been temporary for 10 years. I have been to an interview for the post I am in, but six months (November 2001) later I haven't heard if I got the permanent post. I don't want to work in such an uncertainty. I want to study Industrial Chemistry at the Technikon."

4.9 Reflection: Goal 1

Goal 1: To gather baseline information about teachers' content knowledge, professional attitudes and teaching approaches

The design of the GDE Inset programme was based on my own and former colleagues' experience and thinking. It was not preceded by any research. From the 25 teachers participating in the GDE Inset programme only three teachers were selected for an in-depth study aimed at determining the extent of their content knowledge, professional attitudes and teaching approaches.

4.9.1 Content Knowledge

Typical problems evident from the pre-tests were that neither Teacher A, B or C could solve a specific multi-step problem. In one specific problem they had to consider two separate vehicles and determine how long it would take one to overtake the other. In the post test, Teacher A considered the vehicles separately, but got lost in the mathematics of the problem. Teacher C wrote down two equations of kinematics for constant acceleration and “went ahead blithely to combine the numbers in the problem statement and produce answers” (Schoenfeld1991, p. 316).

The variety of forms of data suggests that it is not possible to separate the development of content knowledge and teaching approaches. Whilst the three teachers obtained low marks on the written content tests, further weaknesses in the teachers' content knowledge were revealed in the questions they asked their learners and the responses they gave. It seems reasonable to surmise that if the teachers had a deeper understanding of the subject matter then the types of questions they would choose to focus on would have been different. This was seen from the different examples given in the paragraphs on integration of content knowledge and teaching.

The results of those components of the programme pertaining to content knowledge are summarised in the table below. However, the results of the pre- and post-tests, assignments and summative examinations were inconsistent: Teacher A improved and could be attributed to his commitment of attending the workshops. Teacher C's marks decreased between the pre and post tests and could be attributed to the low frequency of attendance of workshops towards the end of the year, but he passed the examination. Teacher B quitted the GDE Inset programme.

	TIMSS (%)	Pre-Test (%)	Post-Test (%)	Examination
Teacher A	28	46	65	passed
Teacher B	38	8	Not available	Not available
Teacher C	31	54	45	passed

4.9.2 Professional Attitude

The teachers used for the case studies had to fill in the Professional Attitudes questionnaire compiled as part of a survey of South African Science and Mathematics teachers' professional actions and attitudes. The initial data collected formed part of a comparative study of the professional attitudes of teachers in South Africa and Japan (Grayson et al., 2001).

The data recorded from the questionnaires in order to obtain the baseline information were very interesting. In response to the question in the Professional Attitudes questionnaire (Grayson et al, 2001) where the respondents had to indicate whether they thought it was reasonable to expect a teacher to "spend time in the evenings and over weekends on school work," or "to spend time during vacations on school related work" all three of the teachers indicated "rarely" or "never", viewing these periods as time to socialise or to spend with family.

These types of professional attitudes are in sharp contrast with the results of the study on effective schools (Malcolm et al. 2000, p. 23 & 24). Some of the teachers in these schools regarded attitude as the foundation of such a school.

...the school has a culture that is strongly focused on learning, personal growth, discipline, working hard, taking responsibility and caring for one another.

Other teachers in these schools regard the commitment of teachers to be the key to success,

not only for their hard work in the classroom (which is traditional in style), but their teamwork, their direct involvement in all aspects of the school and the long hours they worked.

The professional attitude questionnaire comprises of a whole spectrum of questions. Due to the comprehensiveness of the questionnaire, I decided to focus on only four questions.

One question contained in the questionnaire but which had not been referred to requested teachers to indicate the extent to which they agreed or disagreed with the statement: “if teachers do not understand a section of the curriculum well, it is their responsibility to study and learn that section themselves.” Their responses had to be indicated using a five point Likert scale. Teacher C selected three (which means neither agree nor disagree). However he suggested that someone had to give the lesson on that topic on his behalf. This indicated that he considered that he could not be held responsible. As part of professional development, it would be important for the teacher to change his attitude and regard content knowledge as his responsibility prompting him to study to enable him to teach all sections of the curriculum.

Another question which needs to be mentioned refers to teacher conduct. Teachers are asked to indicate: “How often have you heard of teachers coming late to class?” All three teachers responded “often”. I also observed this fact during classroom visits. Some teachers only returned to their classrooms 20 minutes after break. Furthermore, it was observed that Teacher C frequently left his classroom before the end of a period. When asked why he replied, “I usually leave a few minutes before the class ends to prepare for the following class.” These practices steadily occurred throughout the year.

4.9.3 Teaching Approach

Although a variety of topics were discussed (see 4.4.1) in the GDE programme and notes on different teaching approaches were provided in one of the readers, it was evident during classroom observations that the only teaching approach applied was teacher-talk. Either a lecture technique or a simple question and answer routine demanding only basic recall from the learners, often as single words or short sentences, were used. Questions

requiring the learners to compare, infer, reason and evaluate were seldom asked. No models of higher order cognitive skills were present in the classroom. Although the teachers had to answer questions on different teaching approaches in their assignments I did not see them implemented in their classrooms at all.

Only correct answers were accepted by the teacher and acted upon while incorrect answers were often simply ignored. All the lessons were characterised by an almost total lack of learner questions or exchange of thoughts. Very little practical work was carried out, often because of lack of time or equipment (see 1.3.2).

It was distressing to observe the same teaching practices during classroom visits in the beginning and at the end of the year. It was also noted that resources such as textbooks were not used. The learners did not bring textbooks to class and at two schools the learners had to share textbooks. The teachers did not use textbooks as teaching aids which could be the reason why the learners did not bring them along. Only Teacher A gave homework from the textbook.

4.10 Reflection: Goal 2

Goal 2: To identify areas in which professional development is needed along these dimensions

The results provided insights into problems pertaining to content knowledge, professional attitudes and teaching approaches as experienced by Physical Science teachers. The results also suggested that it is not possible to separate the development of content knowledge and teaching approaches. Whilst the three teachers obtained low marks on the written content tests, further weaknesses in the teachers' content knowledge were revealed in the questions they asked their learners and in the responses they gave. It seems reasonable to surmise that if the teachers had a deeper understanding of the

subject matter then the types of questions they would choose to focus on would have been different.

From the classroom observations, it was clear that there is considerable room for improvement in the application of teaching methods that would allow learners to be more actively engaged, including getting learners to use their textbooks and do physics practicals themselves.

Responses to questions about professional attitudes indicated that there is a need for the teachers to spend more time on school-related work, including improving their own content knowledge.

4.11 The Way forward

The reflection on the baseline information regarding physics teachers' content knowledge, professional attitudes and teaching approaches clearly showed deficiencies in all three dimensions that need to be addressed. Social issues such as the reluctance of teachers to work over weekends and their lack of punctuality have an impact on professional development and need to be addressed.

The teachers described in Chapter 4 received bursaries. This enabled them to attend face-to-face contact sessions. Unfortunately this cannot always be the case due to financial restrictions in all education departments. Therefore an alternative needs to be considered. Distance education seems to be a feasible alternative to enable more teachers to develop themselves. Amongst other things, the implications of changing from face-to-face contact to distance education mode would be to change the study material and approach completely.

The intervention programme to be introduced must address the areas in which professional development is needed, and, in addition, investigate the effect of the intervention programme on the teachers.

Suggestions for the intervention programme:

- Study material

Change the study material to fit a distance education mode, include worksheets and address the need for problem solving experiences

- Content knowledge

In order to improve the teachers' content knowledge which in turn, influences their teaching, the integration of content knowledge and pedagogical content knowledge in the study material is essential.

- Teaching approaches

A way must be found to stimulate teachers to apply a variety of teaching approaches.

- Journals

Regular journal writing should be done to provide opportunities for teachers to reflect on their learning and on what is happening in their classroom.

- Workshops

Newly structured workshops must include a different way to improve teachers' physics content knowledge and teaching approaches. They must experience new teaching strategies themselves.

- Professional Attitude

Conduct interviews to determine why unprofessional practices are prevalent.

- Metacognition

The need for metacognition must be addressed. Teachers must be stimulated to master new material on their own and to evaluate their own understanding and effectiveness.

These items formed the starting point for the next phase in the research, namely the initial development of a holistic professional development model for physics teachers.

Chapter 5 Initial development and testing of the model

5.1 Introduction and Overview

The aim of the study is to construct and test a Holistic Professional Development (HPD) model for Physics teachers. Baseline data (discussed in Chapter 4) was obtained by using a case study approach to determine if there were problems with the South African teachers' physics content knowledge, teaching approaches and professional attitudes before the initial development of the model could be started. It was evident that development in all three dimensions needed attention.

It also became clear that, due to a lack of funds, the approach followed in the baseline study of regular contact sessions throughout the year with classroom observations, could not be maintained in a broader professional development programme. Therefore a new approach through distance education would have to be followed to make it feasible for more teachers. This would require the development of new study material, redesigning of the format of the workshops and the implementation of journal keeping.

In the second phase of this study, the initial development of the HPD model began. Before the implementation process of the initial model could start several features had to be considered (see 5.2). Thereafter the goals (see 5.3) could be set and the planning (see 5.4) could start. The planned intervention program was then trialled on a new group of teachers. Different data sources were used to determine the success of the intervention programme on the teacher's content knowledge (see 5.6), teaching approaches (see 5.7) and professional attitudes (see 5.8). The success of a professional development programme for teachers is not only dependant on

the changes they experience but also how much their learners improved (see 5.9).

In the questionnaire on professional attitudes Grayson et al. (2001) found that unprofessional practices were prevalent and I wanted to determine why. Data was obtained from a formal interview with a teacher from a rural area and is described in (5.10).

In order to trial and test a revised model, the intervention program had to be analysed. The different proposed elements were examined and recommendations made for implementation in the further development of the HPD model (5.11).

5.2 Implementation Process

Before the goals could be set and the planning be done for the initial development and testing of the HPD model several features, including the context in which the model is developed, critical issues that contribute to the success of a professional development programme regardless of the context as well as strategies, had to be taken into consideration.

5.2.1 Context

Specific characteristics of situations influence the success of a program. Therefore the program must be placed into context. Five context factors that influenced the initial design of the professional development model are discussed below.

- **Teachers**

In the initial development of the model (the second phase of the study), nine teachers from a rural area in the Limpopo province of South Africa participated in the intervention. All these teachers taught Grade 10 – 12 Physical Science, and all had eight or more years of teaching experience.

Another two teachers who participated in the intervention were from township schools in an urban area. One teacher did not teach Physical Science but wanted to qualify herself to teach the subject in future. She was at that stage teaching Mathematics. The other teacher taught Physical Science up to Grade 11.

- **Learners**

The number of learners in these teachers' school varied from 300 to 1000. The number of Grade 12 learners in Physical Science classes was relatively small, and varied from six to 49 learners per class.

- **Curriculum**

The "old" National Curriculum for Standard 8 – 10 (Grade 10 – 12) was used (see 3.3.4.3).

- **Available resources**

The rural school visited in the Limpopo Province

The problems identified in schools in developing countries (Chapter 1), such as lack of resources and facilities, were found at the two schools visited. I selected two schools but the circumstances of only one school⁵ will be described. During our first visit, some learners were sitting outside which was strange because it was during school hours. However we found that the school had only 16 classrooms for its 29 teachers. Thus it was not possible for everyone to be in class at the same time.

There were only pit toilets for the teachers and learners. Access to a toilet with running water outside the school grounds could be arranged if needed. The school had no running water because the water tank was not filled regularly by the government. The school did have electricity.

⁵ The reason for using this school in particular is due to the fact that the Physics teacher at the school was enrolled for the modules Physics for Teachers I and II over two years. Two formal interviews were held with him and I followed the learners' performance from 2001 to 2003. In future he will be referred to as Teacher X.

The classrooms were litter free, but had dirty walls and not enough desks and chairs, especially for the learners in the lower grades, so some of them had to share.

The storeroom was a small room opposite the staff room, perhaps 4 m by 2 m. There were shelves on one side, some of which had collapsed, and a table near the door with some chemistry equipment on it. In the back of the room we saw several boxes labelled Scientific Teaching Aids, three STA balance kit boxes and one electricity box underneath a defunct ripple tank.

The textbooks the teacher showed us were more than 10 years old. He mentioned that the school had not received any textbooks for Further Education and Training (FET) since 1998. The only textbooks the school received were for Grade 8 and 9 for Outcomes Based Education (OBE).

The urban school in visited Gauteng

The school had several laboratories, but two store rooms seemed to be unused and were dirty and full of dust. Another storeroom, which was tidy, was used by other teachers as a “staff room” where they could work. This school was later assisted with the organising and sorting of the equipment in the storerooms.

- **Community**

The communities in which the rural schools were located were very poor. In one case a learner said both her parents died from AIDS and her older sister was looking after them. The community in which the urban school was located was not as poor, but in their case the school faced problems typical for township schools, such as parents working long hours and not having time to spend with their children.

5.2.2 Knowledge and beliefs

- Knowledge (see Chapter 3.3.1)
- Beliefs (see Chapter 3.3.2)

5.2.3 Critical issues

Promoting equity and building of capacity have been chosen as critical issues that could contribute to the success of this professional development programme.

The performance of historically disadvantaged learners has to be addressed (see 1.1) and one of the ways is to ensure equity in a diverse society. The HPD model is constructed to develop teachers from a disadvantaged background.

Furthermore, teachers must be stimulated to master new material on their own, and to evaluate and judge their own understanding and effectiveness to become reflective practitioners. This is one way to ensure the building of capacity, i.e. through developing metacognition.

5.2.4 Strategies

The HPD model was developed within the context of distance education. One of the core features of distance education is the development of high quality stand alone study material. Due to the fact that the study material is the primary medium through which communication takes place, it is important therefore that a concerted effort be made to develop effective study material. Communication is a two way process and therefore the student communicates with the lecturer through the submission of assignments and the completion of journals projects. However, the students can still feel isolated and a way to address this issue is to present workshops which can also address several other issues, such as developing experimental and teaching skills.

Therefore the following strategies were carefully chosen for the initial development of the HPD model.

5.2.4.1 Study material

A grant from the Carnegie Corporation of New York, USA, was approved to establish a Centre for the Improvement of Mathematics, Science and Technology Education (CIMSTE) at Unisa. One of the aims of CIMSTE is to develop courses that will help teachers deepen their own subject matter and assist them in acquiring pedagogical content knowledge to help them to help their students to better understand the subject matter. The following courses were developed: Biology for Teachers I & II, Chemistry for Teachers I & II, Mathematics for Teachers I & II, Physics for Teachers I & II and Computing for Teachers I & II. Each of these courses comprises two distance education modules.

The first module Physics for Teachers I was developed by an outside consultant. This was done due to the fact that study material had to be available already at the inception of CIMSTE in 2002 to be provided to the enrolled students.

In the development of Physics for Teachers I and II we have moved away from only solving numerical problems but expanded it to following of a problem solving strategy. The teaching of skills was also included in the development of the study material. Content and skills were intertwined and embedded in specific content and not handled as separate entities.

Experimental, cognitive and metacognitive skills were regarded as essential in Physics and were addressed in the study material.

- **Experimental skills**

According to Grayson (1996, p. 996) the manipulation of simple apparatus, taking accurate measurements and recording them correctly, making correct and careful observations, analysing and appropriately displaying data, controlling variables and designing experiments are some experimental skills

needed in Physics. (Note that many of these skills are not restricted to physics.) All of these skills were addressed in the study guide.

- **Metacognitive skills**

Nickerson (1985, p. 105) identified planning, predicting, checking, reality testing and monitoring and control of one's own deliberate attempts to perform intellectually demanding tasks as examples of metacognitive skills. These skills were also addressed in the study guide.

- **Cognitive skills**, such as reasoning and thinking and problem solving skills:

Reasoning and thinking skills

Arons regarded the following as thinking and reasoning skills required in physics: to distinguish inferences from observations, to distinguish an influence from a determining factor, to formulate and test hypotheses, to make appropriate approximations, to interpret abstract representations, such as graphs and equations, to translate between physical phenomena and representations, to give phenomenological explanations, to recognise limits of applicability of models/theories, to perform proportional reasoning, to perform hypothetico-deductive reasoning, to reason by analogy and to generate a logical argument (as cited in Grayson 1996, p. 1005).

The following skills were not addressed in the study guide, namely to formulate and test hypotheses and as well as to recognise limits of applicability of models/theories.

Problem solving skills

According to Schultz & Lochhead (1991, p. 100 - 101) problem solving skills are the ability to organise quantitative calculations through an understanding of qualitative relations, to represent a problem situation via diagrams or drawings, to organise one's knowledge according to principles that bear on the solution of the problem at hand, and the ability to evaluate the validity of a

provisional physical (or other) model through an analogy or chain of analogies.

As a secondary aim the study material was to allow teachers to use the study materials interactively with their learners in their classrooms. As such it could serve as an additional resource and could contribute towards the development of teaching skills.

- **Teaching skills**

In order to broaden the teachers' teaching approaches, different teaching skills, strategies as well as pedagogical content knowledge was included. Therefore the following teaching skills were incorporated in the design of the study material: listening and questioning, designing experiments, using incorrect answers of learners, stimulating learning as a group activity, teaching for conceptual understanding, discussing concepts often taught incorrectly, setting problems to develop problem solving skills, applying physics in daily life, involving learners in experimental work, using predictions to expose current understanding and facilitating conceptual change where there are misconceptions.

Of these skills the designing of experiments were not included in the study material but the teachers had to design an experiment as part of one of their assignments.

5.2.4.2 Workshops

The workshops had several purposes. Firstly they were used to clarify sections the teachers needed assistance with in developing their conceptual understanding. Secondly they were used to enable the teachers to experience a particular teaching approach, namely cooperative learning, while presenting the topic "work and energy". Thirdly, the workshops gave the teachers the opportunity to meet their fellow students.

5.2.4.3 Assignments

The students were asked to submit four assignments spaced throughout the year. These assignments were compulsory and covered Grade 12 examination type questions. To integrate content knowledge and pedagogical content knowledge, the teachers, had to write their solutions in detail and also had to outline their explanation of their reasoning to their learners. In addition, they had to explain what they thought their learners' difficulties would be and how they would address them.

5.2.4.4 Journals

Teachers were expected to keep a journal through the course of the programme and submit it twice a year. They had to provide their own A5 hardcover book for this purpose. In the Tutorial Letter the following was given to the students on Journals:

A journal is a record of your learning experience. It is intended to help you form a habit of thinking regularly and systematically about physics teaching and learning. Your journal is intended to provide documentation of a continuous cycle of inquiry. Some of the things you may want to write in your journal are:

- Your feelings (frustration, excitement and confusion) as you are working through a unit.
- You may like to reflect upon a physics interaction with you and your peer.
- Ideas you get along the way about how to teach a certain topic.
- Any suggestions (also misprints or mistakes) and remarks about the course. Things that you find confusing or not clear. This could only improve this course.
- Remarks about the time it took to work through the study units, the project and the assignments.
- Questions, observations, conjectures, more questions, etc.
- Reflection upon a conversation between groups of students in your class. These reflections will help us understand the issues you are facing in school and ways in which we may support your development as a physics teacher.

The marks they received for the journals were not dependent on whether their physics was correct or not, but on how regularly they wrote in their journals, and how much careful thought and honesty, as well as effort, went into the keeping of their journal.

5.2.4.5 Project

The aim of the project was for the teachers to share their knowledge and experience and was also aimed at providing teachers with the opportunity to think more deeply about how they would teach a topic in physics. They could choose any of the following topics: work, energy and power, Newton's laws, kinematics or heat and temperature. They had to include the following:

- You must give details for a set of lessons for this specific topic.
- You need to give the following:
 - What the objectives are for each lesson
 - What materials, worksheets, equipment etc, you are going to use
 - What the teacher's preparation is going to be
 - How you are going to use the prior knowledge of the learners
 - What the learners' difficulties are likely to be in this lesson and how are you going to address them
 - What the teacher and the learners are going to do in the lessons
 - The assessment (A test or other form of assessment with answers, showing how you will assess this topic.)

In the assessment of the project, each of the items was evaluated. A list of marking criteria was provided beforehand.

5.3 Goals of the initial development and testing of the model

The following goals were set for the initial development of the model. The section where each separate goal was addressed is indicated in parentheses.

- To integrate the following in the study material:
Development of teachers' content knowledge, PCK, teaching -, experimental -, cognitive - and metacognitive skills as well as presentation of different teaching approaches (5.5.1)
- To deepen the teachers' conceptual understanding and to present different teaching approaches during workshops (5.5.2)
- To determine the change in teachers' content knowledge (5.6), teaching approaches (5.7) and professional attitudes (5.8) at the end of the programme.
- To determine the reasons for unprofessional attitudes held by teachers (5.10)

- To extract elements for a revised model (5.11)

5.4 Plan

An intervention program was planned using 11 teachers who were teaching Physical Science in Grade 10 – 12 at that stage. All these teachers were enrolled in a distance certificate course, Physics for Teachers I. On registration, the students received a tutorial letter explaining what was expected from them during the year. As part of the program they had to submit four assignments, a project and a journal. They received three Study Guides with topics that covered Grade 11 and 12 Physics as prescribed by the current “old” curriculum for Physical Science.

The book “Conceptual Physics” by Paul Hewitt was the recommended textbook. The teachers could buy the book at a subsidised price. The modules started in January and the students had to write an examination in January the following year.

Baseline data on the three dimensions for each one of the new set of teachers had to be collected in order to determine what the effect of the intervention would be. It was compared with the data collected after the intervention.

The teachers had to complete a confidence questionnaire at registration. The confidence questionnaire covered a list of topics included in the Grade 10 – 12 Physical Science curricula, namely waves, light, sound, electricity, heat and mechanics. The teachers had to indicate their content confidence level for each topic on a 4-point scale (1 indicated very confident and 4 very uncertain). For example, under the topic “Waves”, teachers indicated their level of confidence for each of the sub-topics “Vibrations and pulses”, “Transverse and longitudinal waves” and “Characteristics of waves”. These individual confidence levels were combined into an overall confidence level for the topic, expressed as a percentage.

To determine the state of the teachers' content knowledge before the intervention programme, the teachers wrote a pre-test during the first workshop. The same test that had been set by the HSRC in 1996 (see 4.4.2) was used.

Three teachers were asked at random to complete the same questionnaire on professional attitudes which was used for the baseline study to determine whether the same attitudes were still prevalent.

5.5 Do: The Intervention Program

5.5.1 Study material

A variety of features were incorporated in the developed in the study material, Physics for Teachers I, such as an inquiry approach into science as well as an integration of content knowledge and pedagogical content knowledge.

Furthermore, for the sustainability of the program the teachers' metacognitive skills were also developed as well as teachers' and the learners' experimental skills, because they were noticeably deficient in this regard. The study material included examples of experiments, descriptions of how to do the experiments and worksheets that could be used by the teachers during their lessons.

Different teaching skills, strategies as well as pedagogical content knowledge were included in order to broaden the teachers' teaching approaches.

Conceptual understanding as well as cognitive skills, such as reasoning and thinking and problem solving skills, had to be addressed. Therefore, stimulating questions which made the material interactive and demand a certain level of thinking throughout the guides had to be included. To make it more suitable for distance education, the answers to the questions were given and discussed at the end of each study unit.

The following examples from the study material of Physics for Teachers I illustrate the how conceptual understanding and different skills are developed:

Example 1: Appendix A: Study Unit 1 p 8

In the first part of Study Unit 1 of Physics for Teachers I the quantity position is explained using different examples in one and two dimensions. Thereafter, displacement as a quantity that deals with change in position is dealt with (see Appendix A). The definition of displacement is not only given, but it is also applied in a daily life situation for the teachers/learners to understand that displacement has direction and therefore is a vector.

This example was specifically chosen as a result of the lack of conceptual understanding of distance and displacement shown by Teacher A (see section 4.6.1.1). However by including this example it is indicated how one of the teachers used the same reasoning in his first assignment as in this example to explain a more complex situation to his learners (see section 5.6.3 later).

Example 2: Appendix B: Study Unit 1 p 9

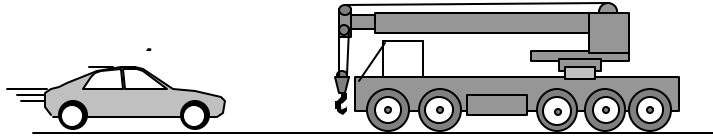
Several features are illustrated in this example: the teachers' conceptual understanding was developed by stimulating them to answer questions as well as highlighting the importance of determining the frame of reference. The teachers are also faced with the importance of dealing with their own understanding as well as by introducing a teaching strategy of creating confusion first which is then followed by solution of the problem.

Example 3: Appendix C: Study Unit 1 p 7

This example is included to illustrate that when teaching physics, care should be taken not to create confusion by not being explicit. When explaining the motion of a ball being thrown upward, allowing it to drop to the ground it must be made clear that the motion comprises different motions, one following the other and that physicists split these motions into different parts.

Example 4: Study Unit 6 p 9

In the following example the questions guide the teachers to develop a conceptual understanding and not only follow their intuition. In part (b) a common misconception is addressed and in part (c) this misconception is dealt with.



- Car A is about to collide with a stationary crane B. Compare the magnitude of the forces: $F_{A \text{ on } B}$ and $F_{B \text{ on } A}$
- The damage done to car A is much bigger than the damage to crane B, so people say that Newton's 3rd law really cannot be true. What is your response?
- Statement: *People confuse cause and effect.* Check your answer to (b) and explain what is meant by the statement in this particular problem.

Example 5: Study Unit 7 p 15

Teachers and learners have difficulty in solving physics problems. However, following a problem solving strategy could simplify solving problems. Therefore, the following example of a problem solving strategy was included.

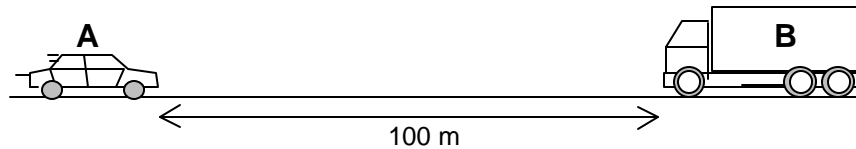
Problem solving strategy

- Step 1. Carefully read the question and make a sketch of the situation presented.
- Step 2. Show all information given in the drawing.
- Step 3. Ask yourself: Which object (or objects) plays the central role in the problem.
- Step 4. Draw a free-body diagram, that is, draw the main object only, and draw all the forces **on that object**.
- Step 5. Determine what is unknown and decide what you need (kinematics, 3rd law, 2nd law, etcetera) to find the unknown quantities. This often requires more than one step.

Example 6: Study Unit 5 p 6

Content knowledge and the mastering of skills are intertwined. Cognitive skills are developed by conceptual understanding and vice versa. To illustrate the development of conceptual understanding with cognitive and metacognitive skills, consider the following example:

The drawing below shows two vehicles approaching each other. Let us call the time for this situation $t = 0,0$ s. Car A moves with a velocity of 15 m/s and the velocity of A is constant. At $t = 0,0$ s truck B starts to move from rest with an acceleration of $1,5$ m/s².



- When and where do they meet?
- What is the velocity of A and the velocity of B when they meet?
- Draw the x-t graph of A and B in one diagram. Check whether your answer found in (a) is in agreement with the graph.
- Draw the v-t graph of A and B in one diagram. Check whether your answer found in (b) is in agreement with what the graph shows.

In the example above, various problem solving skills were developed. The teachers have to organise quantitative calculations through an understanding of qualitative relations, as well as represent the problem situation via diagrams or drawings. They also have to organise their knowledge according to principles that bear on the solution of the problem at hand.

In answering (c) and (d), the following reasoning and thinking skills are developed. In particular they have to translate between different kinds of representations as well as translate between physical phenomena and representations. They also have to plan, check whether their answer is in agreement with the graph, do a reality test and monitor and check their own deliberate attempts to perform this intellectually demanding task. In doing all of it their metacognitive skills are developed.

Example 7: Study Unit 7 p 2

Several teaching tips are given in the study material in the sections on pedagogical content knowledge. Discussions on how to teach different

physics topics in the classroom as well as different teaching strategies are presented.

The following example illustrates the development of a teaching strategy:

The three phases of the teaching strategy

The teaching strategy employed in this unit, which can be used in school as well, aims at attaining a deep understanding. The phases in this approach are similar to teaching approaches used in earlier units namely:

1. The awareness phase

By means of suitable questions pupils' are made aware of their own ideas.

2. The disequilibrium phase

Create learning experiences that challenge these ideas where necessary.

3. The reformation phase

Work towards a new understanding and give applications through which pupils experience the explanatory power of the new understanding

Example 8: Appendix D: Study Unit 6 p 10

This example is given to demonstrate that to apply physics in daily life requires real understanding. It is also included to illustrate that it is not necessary to use expensive apparatus to illustrate conceptual understanding.

5.5.2 Workshop

Three face-to-face workshops were presented in the afternoons after school at locations with the greatest concentration of students. The workshops lasted two hours.

Presenting workshops had several purposes namely developing conceptual understanding, experiencing different teaching approaches and meeting fellow students enrolled for the same programme.

Development of teachers' content knowledge

In Chapter 4 (Baseline study) it was clearly seen that the teachers had a problem with the distinction between distance and displacement. Hence it was

decided to address this issue in one of the workshops using graphs, a topic with which the teachers also experienced problems.

During this workshop on graphs, teachers had to draw amongst other things a distance-time, speed-time, displacement-time, velocity-time and acceleration-time graph of the following situation:

- a. The car is stationary. (Show two possible distance and displacement-time graphs)
- b. The car travels at a constant speed.
- c. The car accelerates uniformly from rest.
- d. The car moves from rest and accelerates uniformly for 4 s. It remains at a constant speed for 6 s. The car brakes uniformly and stops in 2 s.
- e. The same process as in d but after the car had stopped it remained stationary for 1 s and accelerated uniformly backwards past the point where it started.

The teachers experienced problems in drawing the graphs. Some teachers were given the opportunity to draw what they have written in their scripts on the chalk board. A discussion followed and in this way numerous misconceptions on the drawing of graphs were clarified.

Development of teaching approaches

The reasons why it was decided to introduce the teachers to cooperative learning were:

Results show that cooperative learning promote higher achievement than do competitive and individualistic learning experiences (Johnson, Maruyana, Johnson, Nelson & Skon 1981, p. 50).

The low and medium-ability students especially benefit from working collaboratively with peers from the full range of abilities. But there is also evidence that high-ability students are better off academically when they collaborate with medium- and low-ability peers than when they work alone. (Johnson, Johnson, Roy & Zaidman 1986, p. 307).

In the baseline study, it was found that although the teachers could answer questions on cooperative learning (see section 4.6.3) they did not introduce it as a teaching practice in their classrooms. It was clear that providing information about cooperative learning was not enough. An opportunity should

be created during a workshop to allow the teachers to experience it as a teaching approach. Notes were compiled (Johnson, Johnson & Holubec 1994) and distributed at the start of the workshop.

The following topics were discussed during the workshop:

- What is cooperative learning?
- When is learning not cooperative?
- Why use cooperative learning?
- Requirements for successful cooperative learning
- The teacher's role in cooperative learning
- Examples of roles for group members
- Some effective group behaviours to be encouraged

To actively experience cooperative learning, the teachers were divided into groups with each teacher in the group being assigned a different role. To promote a spirit of cooperation and to allow the teachers to become better acquainted with each other, the groups were composed of teachers living in the same area. Each group then had to complete one of the problems on "Work and Energy" given in the notes which they received at the start of the workshop. With each new problem they attempted, new roles were assigned to each teacher. The groups remained unchanged throughout the course of the workshop.

Development of professional attitude

During the workshops and informal discussions it was also found that teachers did not share what they did in the classroom with each other. They did not discuss their work with each other, which could indicate that their relationships lack professionalism.

5.6 Improvement of Teachers' Content Knowledge

In the planning of the initial development of the HPD model, the teachers were asked to complete a confidence questionnaire on how confident they felt with

certain sections from Grade 10 – 12 Physical Science (see section 5.4). I decided to focus on one section namely mechanics, to determine if there was a change in their confidence.

Data was collected from the different levels in the confidence questionnaire into an overall confidence level for mechanics in Grade 11 and 12. It showed that the average confidence level of the enrolled teachers was 65%. This indicated that the teachers felt confident about their knowledge of mechanics.

A pre-test was given on the same work. The questions used for the pre-test were taken from old Matric examination papers. The average achieved by the class was 22%. This clearly indicated that there was a discrepancy between the confidence the teachers had in their content knowledge on mechanics and what they actually knew.

After the intervention the three assignments that covered the section on mechanics were evaluated separately. The following results were obtained:

- The average for Assignment 1 was 53%. (The content covered in assignment 1 was Grade 11 mechanics.)
- The average for Assignment 2 was 60%. (The content covered in assignment 2 was the remainder of Grade 11 mechanics and part of the Grade 12 mechanics.)
- The average for Assignment 3 was 51%. (Assignment 3 covered the remainder of Grade 12 mechanics)

Unfortunately a post test could not be written due to limited time available during the third and final workshop. However, a comparison between the pre-test results and the marks obtained for the assignments shows a considerable improvement in the teachers' average marks indicating an improvement in their content knowledge.

The final examination comprised three sections, of which the first two covered kinematics. The questions regarding content were similar to the questions in

the pre-test. Questions on PCK were also included in the examination. Unfortunately, breakdowns of the different sections were not made due to the fact that the examination scripts had to be returned. The average mark of the class was 45% which indicated an improvement in the teachers' content knowledge from the initial 22%.

5.6.1 Study material

When the study material was developed a variety of features was incorporated (see 5.2.4.1). I wanted to determine if it had any effect on the improvement of the teachers' content knowledge.

Journal entries were used to illustrate how the study material helped teachers in improving their content knowledge:

11 April 2002, Study Unit 1, page 7

.....The answer to the question on page 7 (question 6) helped me understand the upward motions. For instance, that initial velocity from A to B is zero. I have been of the understanding that since the ball is given a push at A, the ball has an initial velocity at A. I really enjoyed this part, realizing that if one throws something upwards, the throwing does not start where the hand rest, but further. It is more practical and it was an easy thing to explain to my pupils and they understood the procedure of throwing, the initial and final velocities of the ball as it leaves the hand until it comes back to the ground.

12 April 2002

...I understand almost everything from the study units. They have been of great help in teaching my learners, especially the PCK's on p 7, 9 and 10. It simplified my teaching and built a good foundation in my learners understanding....

Another teacher indicated how helpful the problem solving strategy was in the study material, not only for him but also to the benefit of his learners.

12 April 2002

....The fact that we have to make sketches for our problems to be solved did not only help my learners, but me too. I do not hate Physics any more. I love it. The graphical representation is a life saver....

From the data obtained from the confidence questionnaire, assignments, pre- and post tests during the workshops and from the journal entries it was evident that there was a positive change in the content knowledge of at least some of the teachers. Because their content knowledge had been developed, they have a more realistic confidence which relates to the development of their metacognition

5.6.2 Workshops

In this section an improvement in content knowledge as a result of the workshops will be illustrated by using journal entries. After the workshop on graphs this teacher wrote the following in his journal:

24 April 2002

During our workshop on the said date at Hoxani college, which was our very first workshop, I found it stimulating and challenging. It was conducted by Mrs J. Kriek. The workshop was mainly about graphs: -

- The distance-time graph
- The speed-time graph
- The displacement-time graph
- The velocity-time graph
- The acceleration-time graph

At first I thought it was a waste of time since it appeared to me that graphs were simple problems, but I was wrong. This I discovered when she gave us a chance to plot graphs of different quantities. There was a lot of confusion but it was a controlled one since Mrs Kriek knew her subject matter well. We shared a lot of experiences with my peers.

... At the end of the workshop, I developed a completely new outlook in kinematics and graphs in particular.

Not only is there an improvement in the teacher's content knowledge, but he experienced a new teaching approach, one of confusion first. After being confused a clearer picture is formed by engaging in the content.

He even shared his experiences with peers which is a development which was not anticipated in the planning of the workshop.

19 April 2002

We started our workshop..... The workshop was very interesting. Jean involved all of us during the workshop, because she gave all of us chalks and inform us to go to the board drawing different graphs and explain how we could explain to our learners. We had drawn different graphs and explain. She corrected us where we had done mistakes but all in all, the workshop were very interesting in such a way that we felt we can get more time than two hours in a day. I got more knowledge as far a graphs is concerned since from that day. This brought to me a confidence and I feel I can handle the section very well now. The workshop also installed the spirit of peer tutoring and also afforded the educators opportunity to discuss their problems in physics teaching.

As a result of improvement in his knowledge after the workshop, the teacher had more confidence in the classroom to handle this section. This supports the belief that if teachers are more confident in their subject matter they have more confidence in their teaching.

In addition, in all the evaluation forms submitted after the workshops, the teachers indicated that they needed more workshops. In the reflection phase the feasibility of running more workshops has to be considered.

The above two journal entries clearly illustrate the effect of the workshop on the teachers and it was also confirmed by the pre-test before the workshop started and a post-test after the completion of the workshop. The pre - and post - test were the same but the students had been unaware of that. The following question was included in both tests:

Draw a distance-time, displacement-time, speed-time, velocity-time and acceleration-time graphs for the following motion: A soccer ball is kicked straight up into the air by a player and returns to him.

The average mark achieved by the eight teachers in the pre-test was 20% while the average for the post-test was 95%, which indicates a marked improvement in the teachers' content knowledge as a result of this workshop.

5.6.3 Assignments

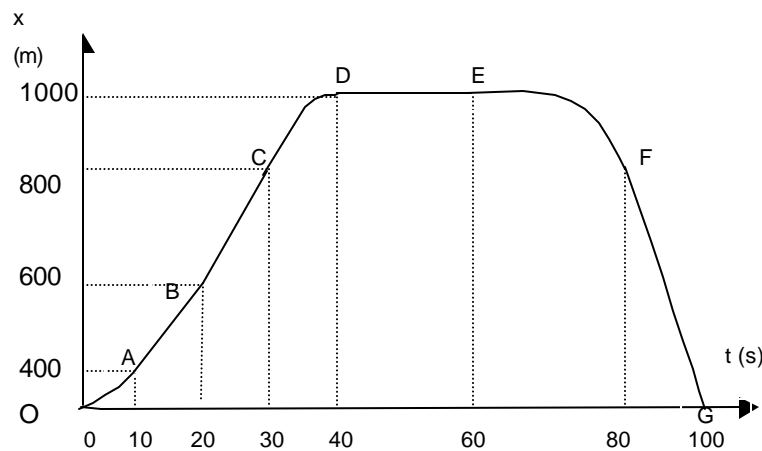
The following example was taken from one of the teacher's first assignment. It is used to illustrate the conceptual understanding of that teacher.

Example: (See Appendix A)

In the first assignment the following question was asked:

Write your solution in detail on how you would explain the following to your learners. Explain what their difficulties would be.

2. Observe the following position-time graph for a car starting from rest



moving northwards on a straight road.

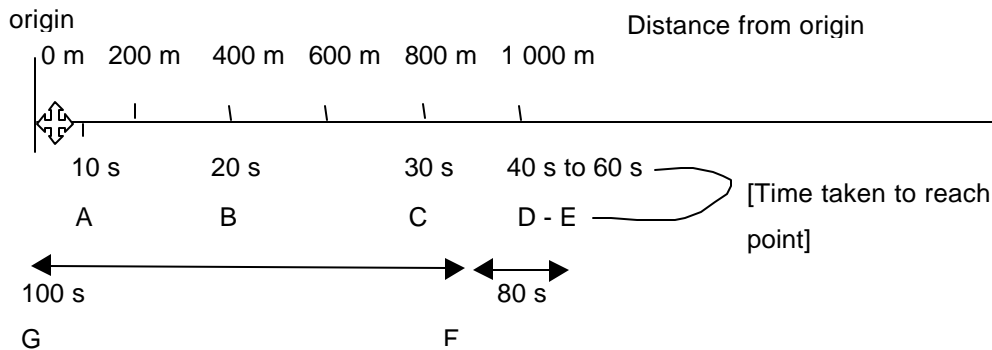
- 2.1 Describe the motion of the car over the following intervals:
2.1.1 BC 2.1.2 CD 2.1.3 DE 2.1.4 EF (8)
- 2.2 Calculate the velocity of the car over the interval BC. (3)
- 2.3 Use the answer in 2.2 to calculate from basic principles the acceleration over the interval AB. (3)
- 2.4 Use values taken directly from the graph and an equation of motion to calculate the acceleration over the interval AB to confirm your answer in 2.3 (3)
- 2.5 What is the car's velocity at D? Explain your answer. (3)

The teacher responded as follows:

To ensure that the learners understand the solutions, I will first present the x-t graph on a linear number line where I will represent the distances where the object is positioned from the origin and also indicate during which time intervals was the object at that point. Further the point AB will also be indicated. This will enable

learners to at least have a concrete feel of the whole problem. (See linear graph or number line below).

The teacher wanted to illustrate the change in position by using the study material. He wrote the following in his assignment as an illustration:



From the graph it can be noted that
 AB = about 300 m and it took 20 s
 BC = 400 m and it took 10 s
 CD = 200 m and it took 10 s
 DE = 0 m (no change in position) for 20 s
 EF = -100 m for about 20 s
 FG = -900 m for about 20 s

Now we can present the solutions:

- 2.1.1 The curve BC is almost a straight line, thus there was uniform motion. Equal distances were covered in each second since there is a uniform change in position.
- 2.1.2 For the interval CD, only 200 m were covered in 10 s, which shows a difference of 200 m. Compared to the previous interval BC where 400 m was covered in 10 s, thus, there is a decrease in the velocity of the object and the curve confirms that because it is parabolic, the object was decreasing in speed during this time interval.
- 2.1.3 For the interval DE, you can obviously see from our linear number line that there had been no change in position for 20 s since the curve of DE is parallel to the horizontal axis, thus we can say with all the confidence that there was no motion; the object was stationary for 20 s
- 2.1.4 For the interval EF there was an acceleration of the object towards the origin as can be seen from our linear graph of the number line that the change in position is minus, 100 m etc

His ability to relate the graph to motion relative to a number line is also evidence of his improved conceptual understanding. However, I do not think his explanations in the above situation are always clear. For example in 2.1.4

the car accelerates in the opposite direction, the velocity is negative and increases. Furthermore, I am pleased with the way in which he integrates what he learned in the study material (see Appendix A) with his teaching.

5.7 Improvement of Teachers' Teaching Approaches

5.7.1 Study material

The following changes in the teaching approaches were recorded by teachers in their journals as a result of the study material:

12 April 2002

By this time I was also trying to apply pedagogical content knowledge. I also apply the peer group discussion to the learners. I very excited I had applied this method and tested them and got increment on the new marks than before.

20 April 2002

They [the learners] argued about concepts such as distance and displacement, speed and velocity. At the end of it, I tried to explain to them how these quantities differ. And as I was explaining to them I found that I started to understand it even more.

I also found that the strategy of creating confusion indeed makes pupils to think. But of course it has to be a controlled one.

The passages below were extracted from one journal of a teacher to illustrate the effect of teaching strategy given in the study material (see 5.5.1):

14 April, Applying my gained knowledge

I intend applying the teaching strategy in Unit 1 page 17, i.e. confusion first, then solving the problem, tomorrow on Monday. I have positive feeling that my learners are to be helped – through this. So, I prepare my lesson in accordance with this teaching strategy.

15 April,

It is after school hours. I just finished marking the class work I gave to my learners. No one can believe how well they have performed. It is because of the strategy I used

5 May, Study Unit 6, page 10:

The PCK on page 10 is useful, I use to give moderate questions to learners. Now I intend giving questions that need thinking them through. Learners enjoyed doing Experiment 3 on page 10. They then understand. There was an argument on the learners, some arguing that the force exerted by pupil P to Q is greater that the force Q exerts on P in experiment A on page 10. They accepted Experiment B as real and A not.

Not only did this teacher follow the “strategy” but the first signs of a change in professional attitude could be seen. He stated that he was working “after hours” and even that he was “marking the class work”.

The following are examples of responses from Teacher X⁶ during a formal interview to determine the effect of the intervention on his teaching approaches as a result of the study material. (The complete interview is given later in section 5.10)

The questions asked to him during the formal interview were:

I: How have ideas from the study guide affected your teaching?

T: In the study guide we have more illustrations, more sketches and even the handling of the problem, the writing of the data, the information we have before we solve the problem. To make the sketches helps one to picture the problem e.g. the boat go in that direction, the current go in that direction – then it gives you an idea how to solve that particular problem.

I: Do you feel you have changed your teaching approaches at all this year?

T: Yeah, like I said I did not have this groups in the past but now I have introduced it.

⁶ I selected Teacher X due to his pre-test result of 8%. He was teaching Physics to Grade 12 learners in a rural school in one of the provinces for the past 12 years. I thought it would be a good idea to see what the programme meant to him. He was interviewed twice and the transcript is given in section 5.10 and in section 6.9.

5.7.2 Workshop

Two different workshops were held; one on graphs and the other on illustrating a new teaching approach, cooperative learning. In total three were held but one was repeated.

All the teachers indicated on their evaluation forms after the workshops that they were very positive about cooperative learning. In an effort to establish whether the teachers who attended the workshop implemented the principles of cooperative learning in their classroom they had to complete a feedback form for the following workshop. Unfortunately during the latter, none of these forms were submitted. The teachers indicated however that they implemented cooperative learning in their classrooms.

One teacher recorded the following in his journal:

26 July 2002

On the 25 July 2002 I have tried to apply this method [cooperative learning]. I have realised that the method that we were doing in workshop is in the line of the OBE teaching method where learners need not to be spoon-fed.

Not only did the teachers use the newly introduced teaching approach but also use the workshop materials in their classroom, as confirmed by the following:

20 April 2002

I introduced to my Grade 11 and 12 learners what I learnt in the workshop. I first gave them one example in each time graph. Afterwards I gave them tasks to do in class. I arranged them in groups and each group had to do the same problem. Believe you me, it was interesting. I even gave them a chance to argue amongst themselves.

Using journal entries, data from a formal interview as well as feedback after the workshops it can be concluded that the study material and workshop had a positive effect on the teachers' teaching approaches. The implementation of new teaching strategies even caused the learners' marks to improve. From the journals and interview it can be deduced that there was a change in some

of the teachers' teaching approaches. However, it could not be verified by classroom observations due to prohibitive costs and the lack of time due to the fact that only three classroom observations could be carried out.

5.8 Improvement of Teacher's Professional Attitudes

Three teachers randomly selected completed the same questionnaire on professional attitudes. Again, due to the length of this questionnaire I decided to focus on the same four questions (see 4.6.2) to illustrate the professional attitudes of the teachers.

Teachers did not regard working in the evenings and over the weekends or during holidays as necessary, because teachers need time for their families as well and also need to go on a holiday. They thought that teachers should only sometimes produce worksheets and handouts for pupils because a teacher should encourage learners to do some of the work themselves.

The following journal entries taken from one teacher after the intervention shows that the teacher's professional attitude improved. Instead of "rarely or never spending time during vacations on school related work" as indicated earlier, he now realises that he has to work after hours. In addition the first signs of an emerging professional community are shown. This teacher was starting to discuss some of his physics problems:

29 March 2002

It was interesting to me because during this holiday I went to school and help my students, diseasing their problems based on science. We were also doing practicals....

24 May 2002

On 18 May 2002 I started with the Saturday lessons from physical science in Grade 11 and 12. It was an enough time to me because I manage to do practicals in physical science during this Saturdays. It is difficult to do experiments in class during the school periods, because practicals needs more time.

...On 22 May 2002 I gave the grade 12 learners a test. They wrote and I marked the test **in the very same day**. I went to my friend, Mr Y to discuss some of the problems I encountered in physical science. I requested him to assist me on the chapter that gave me problems.

27 September 2002

On the 25 September 2002 (in his holidays) I took the grade 12 physics learners with revisions. We were busy with electromagnetic induction.

Before the intervention the teachers indicated that they seldom gave their learners any handouts. The following extract from a journal indicates that there was a degree of change:

17 March 2002

What I also do is that I also give my learners the assignments to do themselves...

26 April 2002

... I was please the way the grade 12 learners are responding to my teaching and I started to love my subject more and more. On the 23 April 2002 I gave this test to my learners and I also marked on the very same day since science students are not so many. About 60 % of the learners passed the test unlike previous tests where only 30% passed. This made me to enjoy group discussing of learners where they learn cooperatively.

Not only did this teacher hand out assignments, he even gave his learners work to do when he was away.

14 June 2002

On Monday 10 June 2002 as I was busy with gravitational forces I gave an assignment to the learners based on the very same chapter. I marked the assignment and we discussed after marking. These were done in grouping, during discussion I requested their leaders in their groups give explanation on how worked those problems on the assignment I gave them.....I had to attend a workshop for 3 days in Pietersburg. I left school and gave my learners a lot of work to be done while I was not present.

This teacher took initiative. He organised a tour to visit the science centre. In addition he compiled a worksheet, which is not found often, to make the excursion to the science centre meaningful.

21 June 2002

... Worksheet for learners were to be completed while visit science centre.

After the workshop on graphs there were some indications of growing communication between fellow teachers as the journal extracts below show.

12 April 2002

...I visited Mr Y [teacher he met at the first workshop] to discuss an assignment...

19 April 2002

I got more knowledge as far a graphs is concerned since from that day. This brought to me a confidence and I feel I can handle the section very well now. The workshop also installed the spirit of peer tutoring and also afforded the educators opportunity to discuss their problems in physics teaching.

24 August 2002 I visited my friend, Mr Z. I requested him to assist me in a section where I do not understand. Together we discussed the section for volumetric analysis in Chemistry...

On the bases of the journal entries of some of the teachers a gradual change in their attitudes towards teaching can be seen.

The absence of a professional teaching community is a critical issue that needed to be addressed. Although it was not envisaged in the planning of the initial development of the HPD model, the teachers started spontaneous discussions on the problems they are experiencing. Therefore, in the development of the revised model the building of a professional community is an additional issue that will have to be addressed.

5.9 Improvement of learners as a result of intervention

A professional development programme can be regarded as successful if it also has a positive effect on the learners. Two different data sources, namely journal entries confirmed by actual results, indicated that the marks of the learners improved as a result of the intervention.

19 July 2002

I am also preparing a trial examination for my grade 10 and 11 science learners. Since they are also writing a common exam [set by one teacher and different schools use it] I had simply kept last year grade 10 and 11 final examination for them. As the time for writing trial arrived, I gave them those question papers to write. I was very excited because in paper one of science (physics) most of them were passed. The improved of the results in paper 1 to my belief I'm helped by the module I'm doing i.e. Physics for teachers I.

16 August 2002

As grade 12 learners were finished with their trial examination, I was busy marking physical science papers for them. I completed marking on 12 August 2002. The performance was much better so 50 percent of the science students were passed. I was very much impressive for the first time in my five years in teaching have learners passing trial examinations.

According to the matric results of the school of the teacher who was interviewed, Teacher X, the 2001 pass rate of the grade 12 Physical Science Higher grade was 43,2% compared to 61,1% in 2002. The improvement occurred in the year after participated in the intervention programme.

5.10 Reasons for unprofessional attitudes held by teachers

According to Grayson et al. (2001), information obtained from their Professional Attitude questionnaire showed a discrepancy between practices teachers regard as acceptable and actual practices in schools.

To investigate this discrepancy a formal interview was conducted with Teacher X at whose school I did classroom observations and whose learners' results I followed over two years. Interesting information was obtained from this interview as is reflected in the interview extracts below:

(I: interviewer, T: teacher)

The teacher's views on Teacher conduct:

I: Teachers think it is not acceptable to come to class late, but they still do it. Why?

T: Laws are made but they are broken. It is morally [important] not to come late to school, you don't set a good example but they still do. I don't have a clear cut example. Could be delayed by transport but the work ethics for Africans as far as time is concerned, ah, example, if you have a party and you say it starts at 10 o'clock, it starts at 1 o'clock. The question of time is a problem.

I: How can you address the time issue?

T: Maybe you must start at the learners. It is easier to teach young people than old people. Like they say you can't teach an old dog new tricks. I am still young, but I refer to teachers in general. You must teach the teachers but put more emphasis on the learners. It is not good to say to the learners to come to school at 7 and you are not there.

I: Teachers think it is not acceptable to stay in the staffroom when he/she is scheduled to be in class, but they still do it. Why?

T: A person does not have an interest in the work. Maybe, a person didn't want to become a teacher but because of circumstances that is why the teacher maybe don't have that interest. Maybe, unpreparedness, yeah. The people are discussing the increments of life no longer discussing education. They look at what the government is offering and they say yeah, they don't treat us as professionals so people develop a negative attitude towards their work. They only go to work because they need money. They don't longer have an interest. But now in our area many teachers have resigned.

I: Why?

T: They wanted to get the severance package. They want to leave.

I: Why?

T: Maybe because of the introduction of the new system like OBE (Outcomes Based Education). Because some of them find it difficult and they become frustrated and think, "Let me apply for the severance package. I can make a living out of that and do something else."

I: Teachers come to class drunk? Why?

T: It does happen, I should think you must go back to the question, it is not acceptable, but there is no work ethics.

I: How can you create work ethics?

T: We need people to counsel teachers. We need it because some teachers get frustrated they drink a lot. They have family problems. There is one friend of mine who drank this acid because he had problems with maintenance.

I: Should teachers get more money? Will it change the work ethics?

T: Yeah, more money plus counselling. They need to be advised. Rather advice than more money because if they have more money they will drink more.

The teacher's views on what is expected of a teacher:

I: To mark pupil's assignments and to provide detailed feedback to the pupils are essential. Yet many teachers don't do it. Why?

T: Maybe because of the demands outside. If you go out of the school, you don't have time. You do other things. I know it is not acceptable, because the learners need feedback for them to see where they lack. Let's suppose I am a teacher like I am, and after work I have another business to run, because some of them own taxis and go to the taxi rank. And some of them are welders. When they move out of the school premises they put on their overalls for extra income. Because of the demand.

I: To produce worksheets and handout for the pupils – they say it is good, but it is not done – why?

T: It is commitment. You will find that the person has not prepared and obviously you cannot give something if you have not had it. Like I say after school, I take my taxi and drive from town to town. I don't have any extra income – only small kids.

This formal interview showed that the problems experienced by teachers are much deeper than lack of content knowledge or deficient teaching approaches. Social issues, such as drinking and debts impact negatively on the professional attitude of teachers. Although these issues are beyond the scope of the intervention program they need to be addressed, as they no doubt will jeopardise the success of future intervention programmes.

5.11 Reflection: Revising the model

Grounded theory consists of

systematic techniques and procedures of analysis [to] enable the researcher to develop a substantive theory that meets the criteria for doing good science: significance, theory-observation compatibility, generalisability, reproducibility, precision, rigor, and verification (Strauss & Corbin, 1990, p. 31).

The aim of the study is to construct a HPD model for which “systematic techniques and procedures of analysis” are needed to determine the elements of the program. In the initial development of the model, strategies were chosen before the goal setting, planning and execution of the intervention programme. The programme was tested on teachers and in the reflection stage the effectiveness of the elements of the programme will be reviewed.

Study Material

The teachers’ comments on the study material obtained from their journals and from the formal interview were very positive.

It was decided therefore, that the same approach of developing conceptual understanding and intertwining different skills, including cognitive, experimental, teaching and metacognitive skills will be followed in the compilation of Physics for Teachers II (see 5.2.4.1).

Journal and project

The teachers responded positively regarding recording their reflections on their learning and teaching in their journals. This process of monitoring their own performance contributed to development of the teachers’ metacognitive skills and in so doing built their capacity. This was one of the critical issues to be addressed.

The writing of journals was a very time - consuming exercise which needs to be better structured in future. This point was also emphasised by the external evaluator of the project who was funded by the Carnegie Corporation of New York. She remarked:

... the following comments are a crystallization of all the comments made on the various tutorial letters and assignments in all the subjects, suggesting areas that may need additional development.

It will be interesting to see what kinds of journal entries teachers have been making, because open-ended, free writes are hard to do, particularly reflective accounts. Consideration might be given to using sentence stems as a way of promoting reflective writing (Report on CIMSTE from external evaluator).

It was decided to change the format of the journals accordingly. The evaluator commented as follows with regards to the project:

The project needs additional guidelines for the teachers. Lesson planning is a difficult task, and I am concerned that this has not actually been taught in the modules, but that it is being assessed in the work they must turn in for a grade. This skill and competence is not something that teachers will have intrinsically. Guidelines on lesson planning are needed, as well as on developing a unit (i.e. a series of lessons – which is essentially what the project is)....

In view of the comments of the evaluator that no guidance is given in the study material on the planning of lessons, it was decided to omit the project. However, as the ability to plan lessons surely represents the most basic skill with which every teacher should be provided with before joining the teaching profession, I regard this criticism as unwarranted.

Workshops

The workshops were considered to be very successful and need to be continued. Evidence was found from the journal entries and formal interview that the workshops developed the teachers' conceptual understanding and helped them to try new teaching approaches, as a result of experiencing it themselves. It also became evident, that a professional community was gradually developing as a result of the meeting between colleagues to discuss their physics teaching experiences. This was not anticipated when I planned the initial development of the HPD model.

In all the evaluation forms submitted after the workshops the teachers indicated that they needed more workshops. This is not always feasible, because of cost and time constraints. An alternative has to be considered to address the need for the development of a professional community.

Assignments

The teachers had to submit four assignments throughout the year to help them stay on task. The questions in the assignments were constructed in such a way as to develop the teachers' content knowledge as well as pedagogical content knowledge. However, teaching physics also entails experimental work. Therefore in the revised model, the teachers' experimental skills must be further developed by including questions on practical work.

Peer Support

Through analysis of the contents of the journal entries, additional problems experienced by the teachers were identified. These are reflected in the excerpts from journals given below:

10 April 2002

I wish I had a study group that we can discuss...

20 April 2002

I wish I have a group discussion...

12 May 2002

Still wish I have a group discussion.

7 July 2002

I feel bad. I need someone to help me. I feel so stupid

15 March 2002

... I almost travel about 10 km to another village to get a help from another science teacher.

There is a need to address peer support and the isolation of teachers. However, this should be a sustained effort which must be expanded beyond

the period of the teachers' enrolment in the programme. Lesson study and peer coaching could be introduced to try to alleviate this problem.

5.12 Summary and way forward

From the different data sources; assignments, pre-and post tests, journal entries, feedback forms after the workshops and interview, it was evident that there was a positive change in the teachers' content knowledge, teaching approaches and professional attitudes as a result of the intervention programme of the initial development of the HPD model. It was also apparent that the elements of the programme namely the study material, workshops, assignments and the keeping of reflective journals, were effective.

However, the need for peer support has to be addressed in the revised model. The building of a professional community was not envisaged when the initial model was planned, but the first signs of a slowly emerging professional community were apparent and were addressed in the revised model.

The next step was to develop the revised HPD model using the features of the model that were found to be effective and make adjustments to those that are not. Other issues that need to be addressed are support, building capacity and developing a professional community. The revised model was trialled with a new group of teachers and is discussed in Chapter 6.

Chapter 6 Further development and testing of the model

6.1 Introduction and Overview

From data obtained during the initial development of the HPD model (see Chapter 5), it was clear that the intervention programme had a positive effect on the teachers' content knowledge, teaching approaches and professional attitudes. This chapter focuses on the further development of the HPD model, in which some of the elements in the intervention programme of the initial HPD model are changed and some remain unchanged. In addition, unexpected issues emerged and therefore elements were added in order to create the final HPD model.

The elements of the intervention programme of the initial HPD model comprised the following: study material, assignments, workshops and the keeping of journals. An additional element proposed for inclusion in the model was the need for peer support for teachers. This was found to be of particular importance for teachers studying through distance learning. To structure peer support, a combination of peer coaching and research lessons was introduced in the revised model and is discussed (see 6.2.4.5) as the peer coaching pilot project.

Another issue that needs consideration is the provision of equipment since many schools in the rural parts of South Africa do not have laboratories or sufficient equipment. In addition the teachers also lack practical skills. Hence, I decided to compile a science kit with basic equipment that can be used by the teachers to improve not only their conceptual understanding but also their experimental skills (see 6.2.4.6).

The development of a professional teaching community is a critical issue which was not envisaged in the development of the initial HPD model. However, the regular contact between the teachers participating in the programme provided the spark for the spontaneous development of professional relationships which can be regarded as the frontrunner of such a community.

The further development and testing of the HPD model is continued in the third phase of this study. Again, the consideration of changes regarding the context, strategies and critical issues preceded the implementation process of the further development of the model (6.2). Thereafter the goals for this phase (6.3) could be set and the planning (6.4) could start.

The planned intervention program was trialled on a new group of teachers. Different data sources were used to determine the success of the intervention programme on the teachers' content knowledge (6.6), teaching approaches (6.7) and professional attitudes (6.8). The success of the professional development programme was again reflected in the results of the learners (6.10)

The last stage of the implementation process is the reflection stage (6.11) to analyse whether the proposed elements need to be changed or not. In Section 6.12 conclusions regarding the final HPD model are drawn.

6.2 Implementation Process

Before the goals could be set and the planning be done for the further development and testing of the HPD model on a new set of teachers, changes pertaining to the context of the teachers, critical issues and strategies of the HPD model had to be taken into consideration.

6.2.1 Context

The success of a programme is influenced by specific characteristics of situations and therefore the programme must be placed in context. Five context factors which influenced the further development of the HPD model are discussed.

- **Teachers**

The programme included 28 teachers teaching Physical Science from Grade 10 – 12. Eighteen enrolled for the module Physics for Teachers I and ten for Physics for Teachers II. The teachers were from urban and rural schools, mainly situated in the provinces of Gauteng, Limpopo, Mpumalanga and Kwa Zulu Natal.

Thirteen teachers from both rural and urban areas were selected for the peer coaching pilot project. These teachers received bursaries sponsored by the Carnegie Corporation of New York. Six classes with 224 learners were observed by the teachers and peers as part of the peer coaching pilot project. I thought that teachers working and living close to each other would act as peers when I made contact information available during the first workshops. However each teacher chose a peer in his/her school instead. Although I was sceptically about this choice initially it turned out to be very positive, as it stimulated interaction between peers during breaks and other contact opportunities during school days.

Unfortunately, only three (two urban and one rural) of the 13 teachers initially selected to participate in this pilot project returned their peer observation forms. I made it clear to the 13 teachers that it was voluntarily, but still thought more teachers would take part in the peer coaching pilot project.

- **Learners**

The number of learners in the 28 schools varied from 300 to 1600. The Grade 12 learners in Physical Science varied from six to 50 learners per class.

- **Curriculum**

The “old” National curriculum for Standard 8 – 10 (Grades 10 – 12) was followed (see 3.3.4.3).

- **Available resources**

Urban schools:

Three high schools were visited in Soshanguve in Gauteng. One school had several laboratories, and was equipped with facilities and textbooks. The second school, one of the oldest schools in Soshanguve had no laboratories but sufficient textbooks. The teacher in the third school was teaching in the afternoons only. His school was moderately equipped. However as he was not a member of the morning staff, he was not allowed to use any of the equipment.⁷

These three schools were chosen because they were situated fairly close to each other, which would facilitate contact between the three teachers in the peer coaching pilot project.

Rural schools:

The resources were the same as described in section 5.2. for rural schools.

- **Community**

The rural and urban communities are the same as described in section 5.2.

6.2.2 Knowledge and Beliefs

- Knowledge (see Chapter 3.3.1)
- Beliefs (see Chapter 3.3.2)

⁷ This teacher was teaching at an adult school in the afternoons that used the facilities of the specific school.

6.2.3 Critical issues

In the initial development of the HPD model only two critical issues were addressed, namely equity and building of capacity. However, although the development of a professional community was not envisaged in the planning of the original intervention programme, its need became apparent and I decided to address it in the further development of the model.

- **Equity**

The equity issue is addressed by providing opportunities for high quality science education to people who were denied them in the past.

- **Building Capacity**

The need for metacognition needs to be addressed in order for the teachers to learn new material on their own, and to evaluate their own understanding and effectiveness. By building the teachers' capacity and by stimulating them to learn on their own, sustainability would be ensured.

- **Building Professional Community**

To ensure the building of a professional community, the participating teachers must have the opportunity to discuss their teaching with their peers. They ought to be playing a leading role within their community of teachers and should be enabled to support teachers in their area.

6.2.4 Strategies

Strategies are chosen to enrich the professional learning of teachers. Therefore during the initial development of the model a combination of strategies was chosen but in the reflection stage I decided that some of these strategies needed to be altered and some had to be added during the further development of the HPD model. Therefore the strategies will be discussed individually, explaining why some were changed and some remained unchanged.

6.2.4.1 Study material

From the different data sources, particularly the journal entries and interview it can be concluded that the approach taken in the design of the study material for Physics for Teachers I was a success and should to be maintained.

Therefore it was decided that in designing Physics for Teachers II the same approach would be followed, as discussed in Chapter 5 (see 5.2.4.1).

6.2.4.2 Workshops

In the initial development of the model the aim of the workshops was mainly to develop the teachers' conceptual understanding, and to enable them to experience different teaching approaches and meet fellow teachers enrolled for the programme. However, in the further development of the model the need for practical work had to be addressed. I thus decided that during the workshop presented for the teachers enrolled for the Physics for Teachers II module the science kit which they received at registration would be used to develop teachers' conceptual understanding and experimental skills.

6.2.4.3 Assignments

The setting of four compulsory assignments with due dates spaced throughout the year to keep the teachers on task for the entire duration of the programme and enable them to work continuously was successful. In the initial version of the model, the assignments comprised typical Grade 12 problems and the teachers had to record how they would guide their learners to solve these problems. In addition they were now also asked to do a related experiment, which included measurements, analysis and the drawing of conclusions. A worksheet had to be compiled and completed for this experiment.

6.2.4.4 Journals

In order to develop the teachers' ability to reflect on their thoughts and feelings as they were working through the study material and to record their learning experiences, the teachers were required to submit four journals on the same completion dates as their four assignments. The journals were

analysed in terms of the teachers' reflection on their content knowledge, teaching and how they had grown and changed.

The format of the journals was changed from the one used in the initial model. The teachers had to complete journal entries on a weekly basis which were more structured than previously. Specific open ended questions which needed to be answered were included. Stapled books with dates were provided for this purpose at the start of the programme. Teachers were instructed to record their first thoughts upon reading the following questions:

- This week I learned that ...
- I learned this by.....
- The effect of this week's work on my classroom practice will be
- I feel (e.g. frustrated, excited, confused, etc.)
- A problem/issue I want to raise is
- This week I spent hours on my study.
- General comments.....

A rubric on the assessment of the journal was supplied in the tutorial letter. The teachers' comments were analysed (see 6.7.4 and 6.8.3) to establish the degree of success of the journals.

6.2.4.5 Peer coaching pilot project

In the reflection stage of the implementation process of the initial development of the HPD model, a need to address peer support and the isolation of teachers was expressed. However, this should be a sustained effort which must be expanded beyond the period of the teachers' enrolment in the programme. A hybrid of lesson study and peer coaching were introduced to try to alleviate this problem.

- **Lesson Study**

Research lessons, also called lesson study, is a technique for teacher professional development that is widely used in Japan (Lewis, 2002, p.1). According to Lewis and Tsuchida, (1997) it changed Japanese science

education from teacher-centred “telling” to a problem solving approach (cited in Lewis 2002, p.1).

In a Research lesson one teacher presents a lesson attended by several other teachers. According to Lewis and Tsuchida (1997, p. 315), “research in this context means teacher-initiated, practice-based inquiry.” Research lessons can take a variety of forms. The general format is for one teacher to present a lesson to a class while several colleagues observe. The lesson may have been planned by that teacher alone or by the group of teachers. After the lesson presentation, the teachers sit together and discuss the lesson. Both the teacher who presented the lesson and the others reflect on various aspects such as what went well, what did not, what could be improved, where did unexpected opportunities arise or where did unplanned activities occur.

- **Peer coaching**

Loucks-Horsely et al. (1998, p. 126) describe peer coaching as follows:

(peer) coaching and mentoring are professional development strategies that provide one-on-one learning opportunities for teachers focused on improving teaching practice. They take advantage of the knowledge and skills of experienced teachers, giving them, and those with less experience, opportunities to learn from each other.

Furthermore, According to Becker (n.d.)

Peer coaching is a process in which two or more professional colleagues work together for a specific, predetermined purpose in order that teaching performance can be improved as well as validated. The purpose may be to reflect on current practices or to expand, to refine, and build new skills. Peer coaching can be utilized to share new ideas; to teach one another; to conduct classroom observations; or to solve problems in the workplace. Peer coaching is non judgemental, and non evaluative. Peer coaching focuses on the collaborative development, refinement and sharing of professional knowledge and skills.

I decided therefore that a combination of peer coaching and research lessons could address the problem of teachers feeling isolated, the need for peer support as well as develop their teaching practices and start developing a professional teaching community. This strategy could also provide an

alternative for classroom observations by a programme designer. The peer coaching pilot project is a new strategy which was introduced in the further development of the HPD model.

6.2.4.6 Science kit

A science kit was included to stimulate the development of the teachers' conceptual understanding and their experimental skills through the performance of experiments. The teachers could also use the science kit in their classrooms to explain concepts, which would contribute to development of skills in their teaching practice.

Teachers in the rural areas seldom have a laboratory and very often do not have a specific classroom assigned to them. Consequently they have to move around the school grounds depending on where they have to teach next. Therefore, the science kit was the size of a "lunch box" to make it easy to carry from class to class. The "lunch box" contained basic physics equipment related to the content of Physics for Teachers II, including bulbs, batteries, magnets, iron fillings, a slinky and a tuning fork.

6.3 Goals of development and testing of the model

The following goals were set for the further development of the HPD model. The section number where each separate goal is addressed, is given in brackets.

- To determine the effect of the elements of the revised model on the teachers' content knowledge (6.6), teaching approaches (6.7) and professional attitude (6.8)
- To use an additional source of information: formal interview (6.9)
- To determine the effect of the intervention on the learners (6.10)
- To construct the revised model (6.11)

6.4 Plan

The development of the HPD model was trialled on all the teachers enrolled for either one of the distance certificate courses, Physics for Teachers I and/or II. Each entrant received a tutorial letter explaining what was expected from them during the year: four compulsory assignments with completion dates spaced through the year, four journals supplied as stapled books, a pre-test to be done at home and a confidence questionnaire to complete. (The confidence questionnaire is dealt with in section 5.4).

On registration they also received Study Guides for both modules. Physics for Teachers I covered the topics kinematics, statics and dynamics as well as heat and temperature. Physics for Teachers II covered waves, light and sound, electrostatics, current electricity and magnetism. These topics represent the “old” curriculum for Grade 10 - 12 Physical Science.

The teachers who enrolled for Physics for Teachers II also received a science kit containing basic electricity equipment as well as a slinky and magnets with iron filings. The same textbook (see 5.4), “Conceptual Physics” by Paul Hewitt, was recommended for both modules and could be obtained from UNISA at a subsidised price. The modules commenced in July and an examination was written in June the following year.

In the further development of the intervention programme only the elements that were changed will be discussed.

6.4.1 Obtaining data on Physics Content Knowledge

The effect of the intervention programme of the initial development of the HPD model regarding the improvement of the teachers’ content knowledge was discussed in section 5.6. The elements discussed were study material, assignments and workshops. The new strategy introduced was the use of a basic science kit. By using the different data sources, I discuss in this chapter the effect of the workshop during which the science kit was introduced, on the teachers’ content knowledge. During that specific workshop the teachers used

the science kit in experiments on waves and electricity. A pre- and post test were given at the start and end of the workshop, respectively, to determine the effectiveness of the workshop.

6.4.2 Obtaining data on Teaching Approaches

The effect of the intervention programme of the initial development of the HPD model on the teachers' teaching approaches was discussed in section 5.7. The peer coaching pilot project was introduced as a new strategy. Data will be obtained to determine what effect the science kit and the peer coaching pilot project have on the teachers' teaching approaches.

6.4.3 Obtaining data on Professional Attitudes

A formal interview was conducted to determine whether the teachers' professional attitude was affected by the changes made in the intervention programme of the revised model.

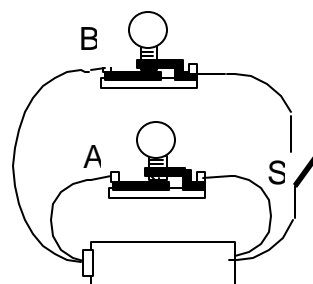
6.5 Do: Intervention Program

6.5.1 Study material

The same approach (see 5.2.4.1) was followed when the study material for Physics for Teachers II was developed. The following example from the study material illustrates how the development of conceptual understanding and the different skills were integrated.

Example: Study Unit 5 pp 177 - 178

The teachers were presented with the following circuit. Bulb A was connected to the battery and was lit. They were asked to predict what would happen to the brightness of bulb A when switch S was closed. Then they had to



do the investigation in order to determine whether their prediction was correct. The prediction had to be compared with the results which they obtained after performing the investigation. They had to explain the difference. Furthermore, the teachers were asked to draw a standard circuit diagram of the above representation.

The following misconception of using “currents only” was discussed in the study material.

PCK: Reasoning by using 'currents only'

In thinking about circuits most people use the concept current. The reason for doing this is that people can easily form a mental picture about current (a flow of charged particles). Therefore in the above experiment learners give answers like: “When the switch is closed the current is shared by A and B, so the brightness of A becomes less”. The experimental results contradict this answer as the brightness remains (nearly) the same.

Discussion:

In this example the teachers' conceptual understanding was developed. In performing the experiment their experimental skills were developed by manipulating the apparatus, making correct and careful observations as well as analysing the data.

The teachers were asked to predict what they thought would happen. The experiment was then performed followed by reality testing when the prediction was compared with the result. In this way they could learn to monitor and control their own attempt to perform an intellectually demanding task. This process involved developing metacognitive skills.

Their teaching skills were also developed by showing teachers how to apply this teaching strategy to teach for conceptual understanding and following it with a discussion of concepts often taught incorrectly.

By asking the teachers to draw a circuit diagram their reasoning and thinking skills were developed because they had to translate between a physical phenomenon and a specific representation.

6.5.2 Workshop

The workshops had several purposes, discussed in section 5.5.2. However, a science kit was included mainly aimed at developing conceptual understanding and experimental skills on waves and electric circuits. Twelve workshops were presented in the areas where the greatest number of students was concentrated. The duration of each workshop was two hours. They were conducted during the afternoons after school and on two occasions on Saturday mornings. They were held at the Giyani Science Centre in Limpopo, Thulemahashe Science Centre in Mpumalanga, at Unisa in Pretoria in Gauteng, at Unisa in Durban, and in Empangeni in KwaZulu Natal.

In the compilation of the material for the workshop on waves I used some materials of the Physics Education Group (Evans et al. 1984) at the University of Washington. Extracts of the notes follow:

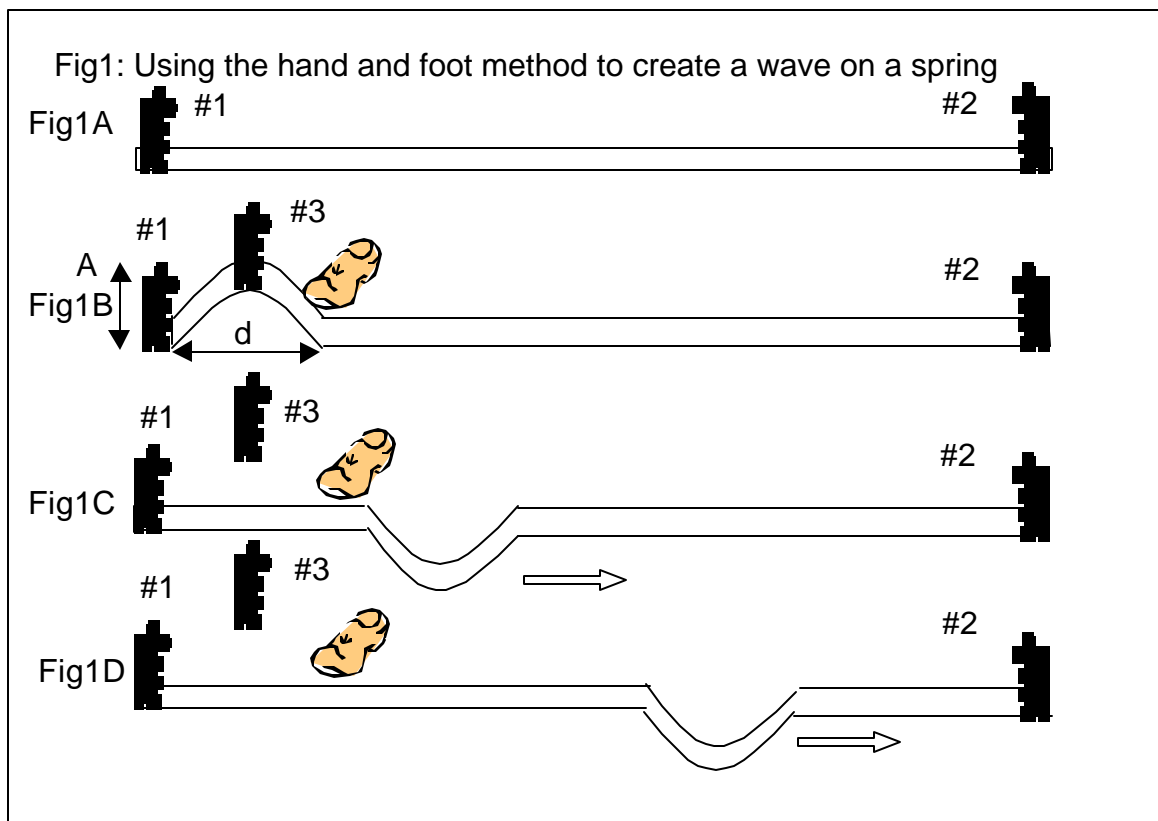
How to make waves: The hand foot method

You need 3 people and a string or slinky. Two people (labeled #1 and #2 in Fig.1A) stretch out a spring on the floor and hold its ends at rest.

A third person (labeled #3) uses one hand and one foot to create a wave as shown in Fig. 1 B. The foot should be placed so that the toe is up against the spring, just barely touching it. The hand then pulls the spring straight out along the floor. The distance d at which the foot is placed will determine the *length of the wave*. And the distance A through which the spring is stretched by the hand will determine the height or *amplitude* of the wave.

Sometimes it is important to produce waves of a particular amplitude and length. In such a case, marks can be placed on the floor showing the proper positions of the hands of persons #1 and #2, as well as the hand and foot of person #3. In this way, identical waves of any desired length and amplitude can be generated over and over again.

Person #3 releases the wave by letting go of the spring with his hand. (Fig. 1 C). The foot should remain in place. The wave will then flip over and travel down the spring as shown in Fig. 1D



Experiments were then given on determining the wave speed, establishing whether the wave speed depends on the amplitude, the wavelength or on the length of the stretched spring. The teachers had to do the experiments and had to collect and analyse their data. The material provided in the science kit was to be used for the experiments.

The material compiled for the workshop on electricity was taken from the Physics for Teachers II study guide. The teachers first had to predict the brightness of two identical bulbs in a series circuit and explain their reasoning. They then had to predict the brightness of one bulb in comparison with two bulbs in series in another circuit. This was followed by an investigation using their science kits to establish whether their prediction was correct. Later in the workshop they were asked to do the experiment which was described in section 6.5.1 involving parallel circuits.

6.5.3 Peer coaching pilot project

The peer coaching pilot project was introduced for several reasons namely to address the isolation of teachers and the need for peer support as well as to develop their teaching practices and start developing a professional community. This strategy could also provide an alternative to classroom observations by a programme designer.

Each teacher had to identify a peer. Both the teacher and his/her peer were expected to plan a lesson in writing. Presentations of the lessons had to be observed reciprocally. Both of them had to submit written answers to the following questions:

Self-report after lesson (This was done by the observed teacher first, followed by the peer after he/she had been observed):

How did you plan (before the lesson) to get the learners involved? (e.g. do experiment, ask questions, etc.)
Do you think you were successful? If yes, whyand if no, why not.....
Describe how you felt to be observed?
In what ways did it help you to have a peer?
In what ways didn't you like it to have a peer?
Will you use your peer in future? Why or Why not?
Write down what came out of the discussion with the peer after he/she observed your class (from your point of view)

Questions to be answered by peer after observing the teacher's lesson: (Then by teacher after he/she had observed the peer)

Were the objectives of this lesson met? How?

Was the teacher's teaching approach appropriate for this specific lesson? Why?

In what ways were the learners actively involved?

How did the teacher monitor the learner's progress or feedback?

How did the teacher help individual learners who did not understand? Explain.

What type of homework was given? Do you think it was adequate? Why?

Discuss the lesson with the teacher. Write down what came out of the discussion (from your viewpoint):

The teacher had to return all the forms to me for analysis.

6.5.4 Journals

The teachers were instructed to complete journal entries on a weekly basis in the books provided. All journals had to be submitted for analysis. The teachers' reflections on any change in their content knowledge, their teaching and their professional attitude were analysed.

6.6 Improvement of Teachers' Content Knowledge

6.6.1 Study material

The study material was developed by integrating content knowledge, pedagogy, pedagogical content knowledge and a variety of skills (see 5.2.4.1). The teachers generally thought that the study material did not only contribute to the development of their conceptual understanding, but also enhanced their confidence in their teaching which in turn, improved their professional attitude. The following paragraph quoted from a teacher's journal illustrates this view:

I have developed an understanding of the following concepts magnetic field, magnetic poles and I'm able to explain the difference between magnetic force and electric force. I have learned the hints when writing out an experiment. I have also learned that there are two sources of magnetic fields, i.e. permanent magnets and moving electric charges. Before I had no idea of connecting the magnetic field and electric field but after studying this study unit, I know the connection. I used to omit this section when teaching because I had not enough knowledge and understanding of it. Now I will treat it with confidence because of what I've learned from this study unit of magnetism.

The comments above show a positive change in the teacher's professional attitude, as a result of his improved content knowledge. He now teaches with confidence. The following two entries were taken from the journal of the same teacher; the first one was entered at the beginning and the second at the end of the course.

I feel proud about the information that I got from this guide. My learners and my knowledge had so improved from the information that I got from this guide. I have no problem now because I see that my knowledge is improved. I have no doubt that my learners will benefit to the information.

This course forces one to concentrate on the linkages between concepts in order to develop a reasonable knowledge. After studying one is more clearer than before coming across the material. The obvious benefit thereof is good classroom practice if not an excellent one.

These excerpts confirm that improved content knowledge increases teachers' confidence in their teaching ability.

Sometimes teachers do not realise that they have misconceptions. The study material helped them to become aware of misconceptions and suggested ways to correct them which in turn contributed to the development of their metacognitive skills.

Your study materials are just like walking Physics lecturers, they are excellent, they explain the concepts clearly. They correct our misconceptions in Physics. They also correct the misconceptions our learners have.

Development of content knowledge also influences professional attitudes as shown by the following:

The way you explained the concepts, and the misconceptions I had before are now clarified therefore my attitude is completely changed, it is positive I was negative before.

Excited about knowledge that I have gained hence because it will help me a lot and it will boost my confidence as a physics teacher.

The professional attitude questionnaire showed that initially teachers were reluctant to “walk the extra mile”. The excerpt below indicates a radical change of heart. Furthermore, one of the aims in designing the study material was to integrate an inquiry approach into science teaching. This teacher indicated that the study material contributed substantially towards achieving this goal.

The material in our guide moves one from confusion to clarity. The subject matter is very interesting and thought provoking in such a way that **one could hardly skip a day without studying**. Theory could immediately be put into practice and awareness of natural science is sharpened. The enquiring mind is also awakened. One also becomes considerate to the environment.

Capacity building is a critical issue which needed to be addressed. The following journal entry indicates that the study guide assisted this teacher in “getting developed”.

This part of my study guide was very much interesting and enjoyable to both my learners and me, since I am getting more and more developed while using my study guide. I have developed an understanding of concepts of sound waves e.g. frequency and pitch etc.

The study material focused, amongst other things, on the development of the teachers’ reasoning and thinking skills. This journal entry shows that a degree of success has been achieved.

I feel very much happy because I can easily translate scientific theories into practice by carefully following the procedures of the investigations and putting the information obtained from investigation graphically.

6.6.2 Assignments

The teachers’ opinions about the assignments were not discussed in previous chapters. The following quotation from a journal indicates that assignments were regarded as positive developmental experiences:

They serve as a wake up call to some of the things one took for granted. One realise the correct approach by practicing. Relevant experiments and exercise helps one to make sense of the questions. The questions are not at all easy even though they are for grade 12 question papers they demand a lot of reading and search for new knowledge.

The realisation by this teacher that he has to “search for new knowledge” suggests an awakening of his metacognitive awareness.

6.6.3 Workshops

The following paragraph illustrates how the use of the science kit during the workshops contributed towards the development of the teachers’ content knowledge. Data from pre- and post - tests were used. (These tests were identical but the teachers did not know that in advance).

The following questions were asked in the pre-and post test on waves.

1	Do the properties of a wave, namely, the length of a wave and its amplitude have an effect on the speed of a wave? Yes <input type="checkbox"/> No <input type="checkbox"/> Give a reason: _____
2	What will happen if 2 waves are created at two ends of a spring on the same side of the spring? _____
3	What will happen if 2 waves are created at two ends of a spring on different sides of the spring? _____

The five teachers who wrote this pre-test all answered the first question incorrectly. They all ticked the yes box, which was wrong. The answers to the first question in the pre and post-test are both given in order to illustrate how the content knowledge of three teachers developed during the workshop.

Question 1

Teacher	Pre-test	Post test
1	Yes. The shorter the distance between the waves the higher is the speed of the waves.	No. The only thing that can have an effect on the speed of a wave is the length of the spring and the type of the spring used
2	Yes. Higher the amplitude higher the frequency hence speed	No. Amplitude is independent on the speed of the waves
3	Yes. The smaller the length; the increase in speed. Increase in amplitude result in decrease in speed	Had to leave early
4	Yes. The speed and wavelength decrease and increase with same ratio when the waves change the media	No. No reason
5	Yes. If the length is big, then the speed will be slower	No. When doing the practical we observed that the length and the amplitude have no effect.

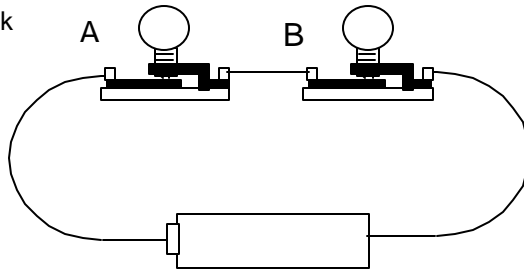
Questions 2 and 3 were answered satisfactorily before and after the workshop.

It can therefore be concluded that after the experiment was performed using the slinky from the science kit, all the teachers answered the first question regarding the properties of a wave correctly. By performing the experiment and analysing their observations they were in a position to determine the effect of the length of a wave and its amplitude on the speed of a wave.

The pre-test forced them to think, their experimental skills were developed by performing the experiment and the answering of the post-test forced them to explain their reasoning. The processes are similar to the development of metacognitive skills of prediction, checking and then reality testing.

The following questions were asked in the pre- and post test on electricity

1(a) For the circuit shown, predict how bright you think bulb A will be compared to bulb B. Explain how you get your answer.

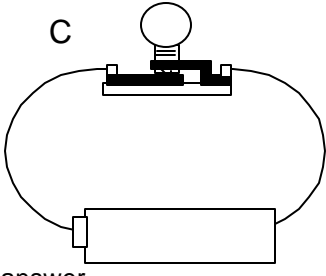
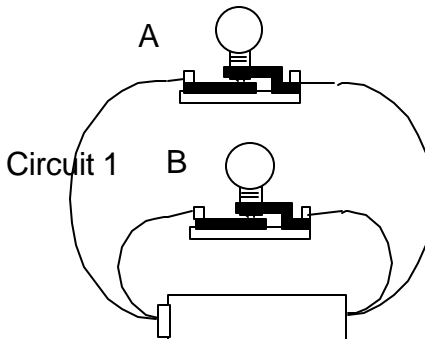
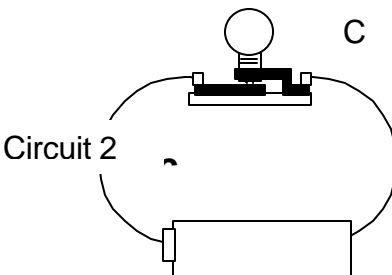


(b) How does the brightness of bulbs A and B in the circuit above compare to the brightness of the bulb C in the circuit below? Explain how you get your answer.

2(a) In circuit 1 below, predict how bright you think bulb A will be compared to bulb B. Explain how you get your answer.

(b) How does the brightness of bulbs A and B compare to the brightness of the bulb C in circuit 2? Explain how you get your answer.

(c) How does the amount of current through the battery in the first circuit compare to the current through the battery in the second circuit? Explain.

The following answers below were given by the teacher who demonstrated the greatest change in conceptual understanding.

Question 1

Pre-test

- (a) Their brightness will be the same since they are connected in series
- (b) It will be the same, because A & B are in series and connected to one cell as C.
Therefore the current through C is the same as the current through A and B.

Post-test

- (a) Their brightness will be the same since they are connected in series
- (b) Bulb C glows brighter than A & B. In C the resistance is less than the resistance in A and B.

Question 2

Pre-Test

- (a) I think B will be brighter than A, since there will be more resistance in conductor A than in conductor B
- (b) C will be brighter than A and B, because C will get all the current that A and B will be sharing.
- (c) The amount of current will be the same only that A and B will divide the total current while C gets all.

Post-Test: Question 2

- (a) Their brightness is the same, because they experience the same resistance, therefore each of the two gets equal current
- (b) Bulb C will be brighter than bulbs A and B.
- (c) The amount of current supplied is the same because they are both connected to one cell.

It can be concluded that there was a marked change in this teachers' conceptual understanding of the principles involved in series and parallel circuits. This could be attributed to practical investigation performed with their science kits. However, his answer to question 2(b and c) indicated that he had not mastered the concepts fully, which confirmed that development of conceptual understanding is not a quick and easy process (Grayson, 2004, p. 1132).

By using this apparatus to set up the circuits, making observations and analysing data, the teachers' experimental skills were enhanced. Their reasoning and thinking skills were also developed because they performed both proportional and hypothetico deductive reasoning.

6.6.4 Peer coaching pilot project

The peer coaching pilot project contributed to overcoming the problem of teacher isolation, to changing their classroom practices and to deepening their content knowledge. Although not specifically planned for and hence unexpectedly, it also contributed to the building of capacity and, to a certain extent, to the realisation of a professional community.

The teacher's reflection on his/her lesson was compared with the peer's reflection on the same lesson. The teacher's perception of how his/her peer interacted with him/her was analysed. This was also done when the teacher observed the peer's lesson.

The following responses by teachers on certain questions on the observation forms indicated a positive effect of the project on their content knowledge as well as improved metacognition.

When asked to describe her feelings on being observed, one teacher replied: Comfortable and happy because I will be able to know where I went wrong and rectify my mistakes.

This comment showed that the teacher felt positive about someone being available to help her in difficult situations due to her lack of content knowledge. There was someone she could go to when she had a problem. This also alleviated the problem of teacher isolation.

Two other teachers also commented that their peers helped them with improving their content knowledge: He taught me many things which I was not familiar to remarked one, while the other added that it helped her to have a peer for enriching my knowledge.

6.7 Improvement of Teachers' Teaching Approaches

6.7.1 Study material

The following excerpts from journal entries showed the effect of improved content knowledge on their classroom practice which teachers obtained from the study material.

There is a great improvement in my teaching methods since I studied this Physics for teachers.

I think it will have a great change in my teaching practice because now I have more knowledge

I think it will have a positive effect on my classroom activities because now I have more questions to ask my learners and I have more skills and method of answering questions.

Excited to learn the above things because it has armed me as physics teacher. I can teach physics with pride because I will be knowing more about physics.

From the beginning of this course a lot of things that I gained it from this course. My knowledge of teaching, skills on teach is also improved. Even the way of teaching is also improved

The study material was designed to be used by the teachers during their lessons. The following journal entries confirm that it actually happened:

The unit is well organized in the guide and easy to read and implement the suggested approaches. Most of the suggestions can be adapted to a poor environment where learners found themselves without proper support systems.

Unlike the school textbook approach, the approach in the unit is logical in such a way that the teacher can use the material directly in his classroom without making a lot of adjustment for learners to understand.

Following the tips in the guide and immediately implemented them in my classroom practice. I learned the hard way because learners are used to be given lifts rather than be led to discovery by step by step learning based on real understanding.

It was encouraging to note the change in teaching approach: instead of “giving lifts” conceptual development was promoted.

The study material and science kit also encouraged teachers to do practical work:

The effect of the study guides work on my classroom practice will be of great help because the learners will be fully involved in conducting the experiments because I have a science kit provided, it would be very easy to demonstrate the experiments.

The study material did not only promote investigations but encouraged a teacher to “combine them with other examples.” The fact that he realised that he needed additional support and obtained it, indicates development of his metacognitive skills.

I feel that it is very interesting and I think this part of sound waves is very enjoyable part if I can follow all my investigations that I found in my study guide, and also if I combine them with the other examples that I find in my text books that I use to teach my learners.

Teachers usually teach following the example of how they were taught. The best way to stimulate teachers to change their teaching is to convince them that the new way of teaching is better.

evidence suggested a strong influence between teachers’ beliefs about teaching and learning and how they taught science. In particular, their data and others suggested that a teacher incorporated his or her preferred learning style, based on learning history, into their approach to teaching (Eick & Reed 2002, p. 410).

The following journal entry shows that one teacher was brought to this conclusion:

I said to do this course it helps me a lot to some of the things that I have taught before but not in a good way. I think it because even our teachers were taught in that way. When I discover that to this course I gained it.

6.7.2 Science kit

The science kit was provided to be used by teachers to develop their own conceptual understanding and experimental skills. In addition the teachers could also use it in their own classrooms to develop the learners’ conceptual understanding.

Doing investigations with my learners. I instructed them to do investigations one to six as presented in physics for teachers 2. I provided them with the materials from our Physical science basic kit guided them and prepared worksheets for them which we use for continuous assessment. (CASS)

The experiment and question in this chapter helps me a lot. I am able to teach this chapter with experiment. The science kit helps me a lot. I am able to perform the experiment in a class of 87 students. ... I enjoy teaching this chapter.

The experiments used in this section are ideal to use in a class situation. I am very grateful for all these easy-to-use experiments. When I used them in my lesson which was observed by my peer, I could see that the students also understood the principles easily.

Keep on doing the easy and affordable practical work to clarify the physics concepts

I was not aware that the tuning fork was going to help me with a lot of work when it comes to sound waves. I find my science kit to be very useful to me when it comes to this module.

In the past, I taught sound as an abstract concept but now I am able to teach it using the apparatus. The tuning fork helps me a lot to demonstrate the propagation of sound. The slinky also helps me to explain sound as a longitudinal wave. The pupils are able to see that energy can be transported through the slinky. They are able to see the compressions and rarefactions.

The following journal entry demonstrated that use of the science kit effected profound change:

I was forced to do experiments with my learners while in the past I simply skipped them.

The change in this teacher's professional attitude is manifested in his enhanced conscientiousness.

The next journal entry showed that the teacher changed his teaching approach: he asked his learners questions which led to observations and conclusions.

I was also so excited when learning how charging by induction occurs during thunderstorms and the kids were also excited about that. The learners were able to follow the investigation I guided them through the investigations by asking them

carefully structured questions that lead them to make relevant observations and draw conclusions.

From the teachers' comments in their journals I can conclude that the science kit had a positive effect on their teaching, understanding of concepts and improvement of practical skills.

6.7.3 Peer coaching pilot project

6.7.3.1 Responses to questions in the observation forms

The effect of the peer coaching pilot project on the teachers' teaching was determined by analysing responses by teachers and their peers to certain questions on the observation forms.

Question: Do you think you were successful? If yes, why... and if no, why not.....

Responses:

- Yes, 80% completed the worksheet excellently
- Yes because 40% managed to get the answers correctly.
- Almost 95%, most learners showed much interest. Although this lesson was good and successful; it was also time consuming. Little work was done over a long period. At this pace exam time might come with the teacher having not completed the syllabus.

The first two reasons given here are acceptable if answers to the questions on the worksheet reflect the learners' conceptual understanding. However, often worksheets are constructed in such a way that it only requires basic recall of facts by the learner, often as single words or short sentences.

The last response shows that teachers are inclined to teach with examination results in mind. It would be preferable to focus teaching on conceptual understanding.

Question: In what ways did it help you to have a peer?

Responses:

- It help me....to be the best teacher I could.
- now it is easy for me to contact her, if I am faced with problem(s) during the time of doing assignments.
- Motivating, trying to impress both the peer and the learners to show learners that with cooperation the lessons can be interesting and captivating.
- We share a lot and gained a lot because our discussion was very fruitful, and aspects that I gained helped me with my learners in class.

As a result of the interaction, teachers change their teaching practice and the value attached to discussions and interchange of ideas between peers suggest the emergence of a professional community. It could also lead to an alleviation of the isolation problem identified by participant teachers while there is also evidence of capacity building - "it helped me... to be the best teacher"

It is often heard that teachers do not want other "people" in their classrooms. Within the framework of the Japanese-style research lesson this is in contrast with the common perception that teachers do not want other teachers in their classrooms.

One of the issues addressed in peer coaching is to support teachers to provide opportunities to focus on improved teaching practice (see 5.2.4.5). The following response by a teacher showed that not only was that achieved but that the teacher's professional attitude also improved: By preparing more than the way I used to and use different approaches.

The following comments on the teacher-peer interaction which followed the observation lesson indicated that both the teacher and his peer reviewed their classroom practice, which suggests they are starting to develop into reflective practitioners. In addition, it was exciting to note that this teacher's peer helped him to change his teaching approach.

My peer advised me to organise my lesson in such a way that it be pupil-centered and not teacher-centered. By this I mean that a teacher should do less and talk less and allow the learners to do more and talk more. In this way it will help the teacher to find out where the learners are lacking or need more emphasis. It will help the teacher to realise whether the objectives yet have been achieved and if not and how to improve on it.

This teacher did not only reflect on the behaviour of his learners. He also contemplated possible measures to rectify the situation due to the fact that later in the discussion they were reflecting on the standard of the lesson, and the way he presented it. In my class there are a group of learners who are too passive during the presentation. So I was busy thinking about those learners.

One of the teachers also reflected on the way the learners were doing an experiment and made the following exciting comment: ...it is better to teach for knowledge not for examination! This came from the same teacher that previously was worried about not finishing the syllabus before the examination.

6.7.3.2 *Journal entries regarding the peer coaching pilot project*

The following journal entries were analysed to determine the teachers' views on the peer coaching pilot project:

One teacher indicated that it had a positive effect on his teaching practice while another indicated that both the teacher and peer can learn from each other. Recognition of this fact would help teachers to overcome the feeling of isolation. Furthermore, colleagues helping each other could be the beginning of a professional community.

So the effect of this part of team teaching will make my classroom teaching to be successful for the things that I help or observed by my peer. I have already improved at where is good to me. I am so proud about it.

The visit by your peer it is a good advantage to you as an educator to see the learning of development which can make you to be good and also you can learn something from your colleague. And also you peer will learnt something to you too.

6.7.4 Keeping of Journals

The following quotations were taken from various journals to indicate what effect the keeping of a journal had on the teachers' classroom practice:

It opened my eyes on how I used to approach my teaching and how I should do it now and in the future.

It helps to improve our teaching methods and approaches it also helps us to be aware of our mistakes when teaching learners.

These can be regarded as signs of gradually developing reflective practitioners whose metacognitive skills are being enhanced.

The keeping of a journal not only had an influence on the teachers' classroom practice but also illustrates increased metacognition. This teacher realised he had to "read continuously in order to keep the pace".

It is taking time but worth every minute of doing it. It reminds one to read continuously in order to keep the pace. One is always ready to face the class and implement what one learned and share the experience of the correct scientific approach to issues, concepts and principles. For now this is the best approach to implement.

6.7.5 Conclusion

I am confident that there is sufficient evidence that this programme contributed to real changes in the teaching approaches of participant teachers. This is supported by the following journal entry:

It means when you want to teach you need to check the knowledge of the learners first and find the ways of thinking. After that develop the knowledge from the information for the learner she/he have. That can make the learning and teaching be so interesting. Even myself I gain a lot from the way we do that make us to be improved.

The acknowledgement by this teacher of the fact that you have to “check the knowledge of the learners first” represents a radical change in approach.

In the following journal entry, the teacher recognises that she had changed. She started to discuss her teaching with her colleagues which indicated the development of a professional community. Her improved knowledge impacted positively on her professional attitude which again confirmed the interconnectedness of content knowledge, teaching and professional attitude.

The way I prepared my lesson and planning my teaching it also show me that I changed I am not like before. Even some of educators they tried to find out about it and I told them. This means to use this study unit or to do this courses it help me a lot on it. So that is why I can say my knowledge is improved and also my attitude of teaching is also changed completely.

The teachers also realised that they should use more sources when preparing their lessons which was evidence of developing metacognitive skills. Through gradual empowerment the teachers became more willing to criticise sources and not accept them uncritically. This confirmed that capacity building had been taking place.

This approach is going to lead to a radical change in the way I present this topic due to the new focus such as demanding logic from my learners and pointing out the weaknesses of textbooks without rejecting them completely.

Capacity building is also perceived in the following: This teacher was going to change her way of teaching. She knew she was going to meet resistance from the learners. However she accepted the challenge because she felt convinced that this new approach would maximise learning.

I cannot wait to start implementing this, since this is the only correct approach. Obviously learners are going to be a bit impatient because they are used to short cuts where they are only given exam orientated information. The unit opened my eyes to seek the correctedness of issues to maximise learning

6.8 Improvement of Teachers' Professional Attitudes

6.8.1 Study material

Questions from the professional attitude questionnaire (Grayson et al. 2001) indicated that teachers were reluctant to go to class because of their tendency to be insufficiently prepared. In the following journal entry it is evident that change is taking place:

I'm so proud about the information that I study from this guide which is encourage me to ensure that I must be prepared for my lesson when I go to class.

Use of the study material helped teachers realise their lack of content knowledge, which is indicative of developing metacognition:

I thought I know more about electrostatics. Having read through study unit 4 pages 122 – 159 I realised the mistakes that I was making for a long time. Now I am becoming a better teacher through reading your study units.

Every subtopic in this chapter was new to me. I was embarrassed to learn that we have two types of friction. I used to tell my learners that the pulling force is the normal force of which is wrong.

Not only did the study material motivate the teachers, it enhanced their metagocnition. Contrary to the professional attitude study (Grayson et al. 2001 also found in section 4.9.2), which found that teachers do not want to study and take responsibility to master a topic with which they previously had problems with, signs were found of capacity building and building of a professional community as the following journal entries confirms:

I feel proud about this guide and the information about sound and also preparing the topic this make me be proud of my lesson and I see even my self it also developed me to do so.

When you prepared it make the educator to think more ahead and have a good thinking which can make the educator to express him/her self when he/she is in class.

I feel excited when I manage to make my learners to master this topic of sound waves, because it was my first time to be able to teach them this lesson since I used to ask one of my colleagues to do it for me.

I have gained a lot to have registered in this course because it has caused me to keep on studying and updating myself with recent discoveries and to keep myself busy with physics every time. It has also helped me in gaining more knowledge of physics because I had to read and study more books and consult my colleagues.

Reading the guide and writing the important points. I used to share what I learned with my colleagues and my learners.

This approach makes one like the subject more and more and therefore always to enjoy reading and searching for more knowledge to supplement the previous gathered knowledge.

6.8.2 Science kit

The following journal entry indicates that the teacher's attitude was changed by doing the practical work in class.

My attitudes have changed a lot, particularly the practical part of it. I find it easy to teach physics using practical work. I was scared of practical because I was not exposed to them even at high school level our teacher did not do the practical work part. Now I have confidence in myself after completing this module of physics.

The above entry shows that this teacher was not used to do practical work at school. His example was one of no practical work. Therefore he was "scared of it". This confirms that usually one follows the example you had when in school (see section 6.7.1).

Not only did the following teacher's attitude change but his creativity was stimulated and he improvised an experiment to explain polarisation.

I feel excited because I learned that you don't have to use the sophisticated science kit in order to understand the physics concepts. Just use what is in front of you to explain any concept e.g. I used my spectacles to explain polarisation.

6.8.3 Keeping of journals

The journal entries below show a growing realisation among teachers that they have to control and monitor their attempts to perform intellectually. This can be regarded as evidence of developing metacognition. They have also grown sufficiently in confidence to criticise textbooks which in turn, may indicate that they are developing into reflective practitioners. It all adds up to capacity building being achieved.

I have found that many years I've been doing physics in a wrong way because of many mistakes in school books. I have gained a lot. In some section for the past years I discovered that I was not well in doing them. Now I feel like bringing those years back in order to rectify those mistakes done by following the schoolbooks that mislead many of us as teachers.

I am no longer a textbook slave. I am now more wide awake and open minded.

Responses to questions in the professional attitude questionnaire (Grayson et al. 2001) indicated that teachers showed a tendency not to prepare their lessons and therefore did not want to go to class. The teacher whose response is quoted below realised that her unpreparedness led to demotivation of her learners:

It is very much embarrassing if a teacher is lazy because physics can proof him/her laziness before the learners. And this will demotivate learners from continuing learning physics. When it comes from doing the experiment, it is very wise for a teacher to do those experiment alone or with his/her other colleagues before carrying the apparatus and stand in front of the learners trying to do the experiment for a very first time. When the experiment fails the learners will ask the teachers as what happened to the experiment and by so doing they will laugh at the teacher expressing the news that he or she is a failure teacher. This will cause learners to be highly demotivated because they won't see any necessity of learning physics any longer.

The cooperation between teachers referred to in the next journal entry can be regarded as the emergence of a professional community:

I have not any problem by help some of the teachers about this information some of my friend they have already tried it they said it work as if it work even to me so I can say learners will benefit to it so easy.

Furthermore, the building of capacity will cause sustainability as seen in the following entry: My confidence has been boosted in such a way that I can present this concept any time anywhere.

The following journal entries indicated that maintaining the journal enabled the teachers to become reflective practitioners:

Yes it is helpful because it keeps you focused to your work. The journal helps in the sense that as you read you also think how each statement made in the unit you going to reflect on.

I thought that filling in the journal book is a waist of time and energy but I discovered that it is fruitful because you cough out what is inside yourself.

Writing a journal is a good idea and helpful because we voice out the problems we encounter and our ideas are catered, but is time consuming when you are committed.

The remark in the last entry shows that the advisability of doing journal entries weekly should be reconsidered.

6.8.4 Peer coaching pilot project

The effect of the peer coaching pilot project on the teachers' professional attitude was determined by analysing the responses to the following question in the observation forms.

Describe how you felt to be observed.

- It helps me to be well prepared and organise my lessons. It would develop experience and friendship between us as they are our science teachers.
- Comfortable and happy because I will be able to know were I went wrong and rectify my mistakes.

The latter remark shows that the teacher was positive about someone being available to help her where she lacked content knowledge. This could be the first steps towards alleviation of the problem of teacher isolation. The fact that a friendship have developed could also indicate the building of a professional community. A peer or colleague is available on a fairly regular basis with whom classroom practice and teaching problems could be discussed.

The following reply to the question above and journal entry, both are very positive and encouraging

I thought he is going to look at my mistakes, whereas he helps me a lot.

It was quite interesting to learn that any object do bend when placed on another object (supporting). My peer did not believe me and I told her. We tried and proved that.

Both instances are indicative of a growing confidence and frankness developing between peers. In the first case there are clear signs of the inherent mistrust between teachers being broken down by a developing relationship and the realisation that reciprocal acceptance paves the way for reciprocal positive criticism and assistance. The second case shows that the increasing comfort experienced in a relationship between peers allows for healthy and stimulating interchange of ideas without fear of being belittled. These are all essential elements for the development of a closely knit professional community which is much needed.

6.8.5 Conclusion

The following journal entry summarises the change in the teachers' professional attitude as a result of the intervention program. These changes involve enhancement of the teachers' metacognition and capacity and development of a professional community.

When I register for this course I thought I would not have enough time for assignment because of commitment. I have and since physics is the most difficult subject therefore I had a negative attitude towards it since I had not do it at college level and even at

high school we did not do the practical work but because I'm about to complete this course now I have changed my attitude.

6.9 Interview with a Teacher

A second interview conducted with Teacher X (see 5.10) was used as an additional data source to reconfirm what has been found previously namely that it is necessary to develop the teachers' content knowledge, teaching approaches and professional attitudes simultaneously. This would lead to the building of capacity and metacognition as well as a professional community.

1 I: Do you think there were any changes in your confidence in your subject knowledge?

2 T: Yes, In the past when we were at school, we did not have much experiments and even
3 textbooks did not explain well some of the aspects but now when joining you, I discovered that
4 something what was missing in me which I was not confident about so I started to study with
5 Unisa and going through those books I started to have much more confidence and even the
6 assignment you give us – make me to work harder than I used to do. Those equipment for
7 electricity I use it very much I even give it to the learners themselves to have first hand
8 experience I use the long spring even I used what you have showed us.

9

10 I: Where did you find that you used the Study material of the Physics for
11 Teachers modules?

12 T: What I do is that when I prepare my lesson I also go through the material to enrich what I have
13 thought. Because the resources are so limited. So I use this information as an addition. I even
14 pick up some of the questions and even those that you used to give me, I give them [the learners]
15 those. So I even encourage them to work cooperatively. Then they do those problems. They
16 come with those problems and then they work, but how well did they do those problems and then
17 there after we do those corrections.

18

19 I: Give an example of something that has changed.

20 T: I can say the enrolment of the science classes. We used to have a few per grade but now the
21 science classes are overcrowded.

22

23 I: Is there anything that you previously didn't understand properly, but understand
24 now? Give an example

25 T: There was this question of acceleration. When the object goes up and down. Is the value of g
26 negative or when the object goes up. Acceleration is always down. Even if a object moves
27 upwards and then stops. Then what is the acceleration, zero? Huh – no – but then there is the
28 weight. So I started to be enlightened. Even myself I learned that the acceleration is not zero.
29 There is always g . And even this question about graphs. I have the workshop materials even now
30 with me. Even those displacement – time graphs, velocity acceleration, distance and speed. How
31 does this differ? I even use those materials. I keep it I even give the learners some copies. Do
32 help learners because if they see an object thrown upwards then you are given 5 different graphs.
33 If you draw a distance-time graphs – What is the shape? They were used to say no when you
34 throw a ball upward then it comes back then they mistake a displacement –time graphs to a
35 distance – time graph. Because if you say the height is 20 going up and coming down is also 20.

36 If it is distance it is 40. But then in displacement it is zero. It helped me, even in explaining to the
37 learners better using those graphs.

38

39 I: Did the program influence your way of teaching? And how?

40 T: Information that I got here that coupled with the information that I was receiving in the textbook
41 make me to be well equipped. Even when I go to class I don't have any problems.

42

43 I: Do you think that problems teachers experience in understanding Physics have
44 an effect on their teaching?

45 T: Yes, I remember at one stage we used to have these committees, maths, science and biology
46 with our neighboring schools. We don't have it any more because of the funds and resources.
47 What we used to do we come together say once a week. Then we discuss our problems,
48 because you find that one teacher is comfortable with this and that chapter but not comfortable
49 when it comes to this and that chapter. So we used to make arrangements on who feels that he is
50 very much okay in that chapter can visit your school then you ask him to help you. So we
51 discovered that no, many of us were honest enough to say, I am not good in that particular
52 section, so one can help me in that particular section. And even to make the learners to realise
53 that no, teaching is not about an individual, you don't have to be selfish to think there is one who
54 knows much better you, then for that single case you invite him/her to help you in class.

55

56 I: Do you think in future you would be the one that goes to the school to help the
57 others?

58 T: Ya I think so!

59

60 I: Do you feel you have more confidence now to handle situations in class than
61 previously?

62 T: For now I can say that. You know I could not treat these kids in a manner to help them
63 because I used to scold at them, you see. I know you won't pass – rather go and do history. But
64 then it helps them to realize their dreams – by encouraging them. But there are situations where
65 you find out that no this particular child they definitely cannot do it. But then I advise them politely,
66 that no may be they can be good at law – they can go for history.

67

68 I: Do you think that your teaching has changed? How?

69 T: It has boosted my confidence. By providing them information which is not in the textbook and it
70 surprises them, how/where did you get that information. They see you as a person who teaches

71 as a super class – somebody who is well informed and learners are people who are very much
72 observant. If they see that you are doubting they start doubting too. But then if you teach them
73 with confidence they also refer them to teaching that – they say that heah – that one is great. And
74 they start to have confidence.

75

76 I: What have you taught previously in a different way than you are doing now?

77 T: Also that question of cooperative learning – the one you have introduced to us. That
78 cooperative learning does not necessary mean the one does everything and the other sit – that
79 they need to share the information whatever work is given to them but not in the case of tests and
80 assignments.

81

82 I: What do you think the effect of the science kit was on your own understanding?

83 Give an example.

84 T: Yeah, normally it is boring to teach a subject like science, using a few words only. But when
85 you bring something like this tape-recorder [referring to the tape-recorder used for the interview],
86 now they want to know what is this? What is he going to do with that? We grab their attention by
87 bringing that particular thing, so by me taking that [referring to the science kit] they thought no – it
88 is a lunch box. Then I said – no I want to share the food inside here with you. So when I opened
89 it, the learners did not sense it. It is no lunch box. And even if you move with it, through these
90 blocks, even the other learners are wondering, what is this that he is carrying there. They also
91 have an interest. Okay what is that? You see, so that is something very, very great that you did.

92

93 I: Did the science kit, help you to see the value of experimental work? And your
94 learners?

95 T: Yes, even when one was talking about a light bulb, they did not know it before. So I make it a
96 point that they can touch it, and look at it. This is this, this is this and so on.

97

98 I: Has your view changed on how much effort a teacher has to put in every day?

99 T: A teacher must work harder and harder and harder. Because if one relaxes, the learners also
100 relaxes. For subjects such as these ones we need more and more practicals. Or practice not
101 necessary practicals. Because you have to work out a number of problems, so say that I finally
102 come to grips of what is going on here, because I usually give them this example you cannot ride
103 a bicycle by looking at someone riding a bicycle, you need to ride also. You fall then you start,
104 then there come a time that you can ride.

105

106 I: Do you see any changes in yourself? Give an example.

107 T: I was referring to the confidence now I am having. It is that I don't ever have a problem if I

108 maybe asked in another school One teacher can ask me to come and help him. Even himself with

109 some of the problems he is having. I feel great. Yah I feel great about it.

One of the issues that needed to be addressed was developing metacognitive skills. The teacher's realisation that "I discovered that something what was missing in me" (see lines 4 – 5), can be regarded as the first step in the development of metacognition. The second step would be to assess his own effectiveness and take positive steps to improve his performance if necessary. He realises that he needs enrichment and decides to use the study material (see lines 12 – 14).

The interview also provides evidence of positive trends in the development of the teacher's professional attitude. His attitude to his learners has certainly changed. Where previously he was often ready "to scold" them, he now "advises them politely" (see lines 63 – 66). He also approaches his work differently. He openly admits that previously he did not devote as much time to his work, but that he is now working harder than he used to (see line 6). His remarks in lines 99 to 109 are, in general, an acknowledgement that effective teaching requires continuous devotion and commitment. However, a slight discordant note is found in his remarks contained in lines 47 to 58. Although his acknowledgment of inadequacy of his content knowledge on certain topics can be appreciated as a sign of improving metacognition, his reluctance to take personal responsibility for the improvement thereof can still be regarded as a real weakness in his professional attitude by inviting someone to help in class (see line 50 – 54).

The inclusion of the science kit was positively accepted as demonstrated by his enthusiastic use of it during the lessons. He even allowed his learners to do experiments with it (lines 7 – 9). It helped the learners to actually handle a light bulb. In the rural parts of South Africa many of the learners do not have access to electricity in their homes, and they are not familiar with normal light bulbs (lines 95 – 96). Lines 87 – 95 illustrate the value of the "lunch box" science kit to stimulate curiosity not only amongst the science learners but also amongst other learners not taking science.

This teacher's frequent use of the study material and workshop materials in his preparation and during his lessons is an acknowledgement of its

usefulness and improvement of his classroom practice (lines 12 – 15 and lines 26 – 37). Not only did this teacher introduce a new teaching approach (lines 77 – 80) namely cooperative learning which he experienced during one of the workshops but he also uses additional resources to prepare his lesson (lines 40 – 41) because he realises the value of thorough preparation. This enables the teacher to be “a super class”: a confident educator who, in turn creates confidence in his learners. It will develop improved confidence in both teacher and learners (lines 72 – 74).

One of the problems raised in Chapter 1(1.3.2.1 and 1.3.2.2) was the decrease in the numbers of the learners who choose Physical Science as a subject. This situation is improving in his school (lines 20 – 21).

Furthermore, as a result of the program this teacher regards himself as a leader in his community of teachers (line 107 - 109). He has gained confidence which is a result of the building of his capacity and is even confident enough to express his willingness to help those colleagues who are experiencing teaching problems. This could possibly be regarded as an indication of a gradual development of a professional community.

From the analysis of the interview, it can be clearly seen that this teacher has experienced a development in his content knowledge, changes in his teaching practice as well as an improvement in his professional attitude. This confirms the interconnectedness of three dimensions; content knowledge, teaching approaches and professional attitudes. Furthermore, the intervention program addresses critical issues such as building professional capacity as well as a professional community which ensures sustainability. Metacognition as part of building capacity is one of the goals that was also addressed.

6.10 Improvement of learners as a result of the intervention

In order to illustrate that there was not only an improvement in the teachers but also in the learners several journal entries are given below:

My learners are becoming used to the development of information rather than take the shortcut of cramming to avoid setting aside sufficient time to learn and invest effort in their studies. It is tough to change old habits, they die hard.

This teacher prefers the strategy of conceptual development to spoon feeding information. However, he realises that change is not an easy process.

Due to increasing confidence, the teacher can give more relevant examples, answer “difficult” questions and experience the enjoyment of his learners. This can be seen in the responses of the teachers in answering the question on how I feel.....in the journal.

The programme was rewarding as it has given me more knowledge and courage and determination in departing the knowledge to learners as I am armed with more practical examples that are easier to follow than before thus I feel more determined than before.

Excited because all my learners paid attention on what I told them. They asked some relevant questions showing that they are well pleased of the way I taught them.

A lot more confident and my scope of making examples have been opened and I can easily give relevant examples in my lessons. I am also ready for questions from the enquiring minds of my learners and I am prepared to answer them satisfactory.

My learners are enjoying my lessons in Physical Science than in previous years because I was not so confident in what I was doing.

One teacher stated that “learners have improved a lot since we have a science kit.”

Not only must the teachers feel more confident in the classroom, there must also be an improvement in the results of the learners. The following journal entry confirms that this is the case.

Effect on my classroom practice will be good in such a way that my results for Physics has even improved. It will even motivate my learners to take physics as a major subject in tertiary institution because they will love it.

A concrete example is the increase in the pass rate of the grade 12 Physical Science Higher grade learners of Teacher X's school from 43,2% in 2001 compared to 61,1% in 2002 and 84,4% in 2003. This change took place after Teacher X had enrolled for Physics for Teachers I (during 2002) and then for Physics for Teachers II (during 2003).

6.11 Reflection: Final model

Each of the elements of the model will be discussed individually to determine if the elements should be changed or not.

Study material

The development of the study material was aimed at developing teachers' conceptual understanding and integrating different skills, namely cognitive, experimental, teaching and metacognitive skills. Furthermore, an inquiry approach in science was followed to improve the teachers' content knowledge, pedagogy and pedagogical content knowledge.

From the journal entries of different teachers as well as the formal interview it can be concluded that the study material is effective and does not need major changes.

Workshops

The aims of the workshops were to develop teachers' conceptual understanding, and to provide them with opportunities to do practical work, experience different teaching approaches and meet fellow colleagues. It was shown how the teachers' conceptual understanding improved by comparing the answers to questions of the pre- and post-tests. From their reflections in the journals it can be seen that they felt more confident in their teaching as a result of what they learned in the workshop. In the interview, the teacher indicated that he was using the new teaching approach, which he experienced while attending a workshop. Therefore, it can be concluded that the workshops were effective.

The teachers expressed the need for more workshops in their feedback forms. However, this is not always possible due to lack of funds and time. The peer coaching pilot project could be regarded as an alternative and will be discussed under that heading.

Science kit

The science kit helped the teachers to be more confident in their teaching, to explain concepts to their learners and to develop their own experimental skills.

Unfortunately, only limited equipment was included in the science kit. The cost to compile a basic science kit was approximately R400, excluding postage. However, the value of the kit justifies the costs. Provision of the kits needs to be continued.

Keeping of journal and format of the journal

The keeping of a journal encouraged the teachers to think reflectively about change in their content knowledge, teaching practice and professional attitude. Participating teachers generally acknowledged the value of keeping a journal but differed on the time to be devoted to it, as reflected in the excerpts from the journals of two teachers given below.

Teacher 1:

It was helpful but strenuous. I would prefer to write a journal once and not have to write it on weekly basis.

Teacher 2:

In grade 12 we are forced to rush our presentations in order to cover the syllabus for preparatory exams which comes during mid-year. So one sometimes forgets to complete it weekly as required to do, in the rush. The space for week ending should be included to remind us

Although two different views regarding the frequency of journal recordings prevailed, it is decided that the frequency of the entries be reduced from once a week to one entry after completion of every study unit. On this basis, entries are now made approximately once a month.

Peer coaching pilot project

It was initially envisaged that each enrolled teacher should choose a peer who was also enrolled for the programme. This peer could be from another school or could be a Physical Science teacher from the same school. This was not always feasible because some schools had only one Physical Science teacher. Consequently, a peer teaching either Mathematics or Biology was chosen. Although I introduced the three teachers enrolled for the same module to each other during my classroom observations, they preferred to choose peers from their own schools. However, as it turned out, having a peer from the same school had certain advantages. Even if that person was not enrolled for the module they could use time during breaks or after school to discuss difficulties encountered in the classroom.

Although it was not possible for the teachers to develop the observation lessons together, opportunities were available for teacher - peer discussions after presentation of the lessons. These discussions focused on both good and bad points, what did and what did not go according to plan, and what could be improved.

Although this approach appeared to have the development of quality lessons as its primary purpose, the process actually addressed several other issues/problems simultaneously. Teachers worked collaboratively, which alleviated the problem of teacher isolation. It also focused the observations on the teaching and not the teacher. Through participation in the process, teachers deepened their own content knowledge, adopted effective teaching strategies and became reflective practitioners. In addition the process contributed continuously to the building of professional community and capacity. For these reasons, peer coaching was regarded as a promising approach to teacher professional development. If implemented correctly, it can be an in-house system for promoting teacher growth and improving teacher quality. Furthermore, to a certain extent it can also address the need for more workshops, which was identified by the teachers.

One teacher was so excited about peer coaching that he proposed that it must be continued:

We decided that from next year, we must implement it and involve all natural science teachers from all grades as long as they are willing to work with us and interested in peer observation.

Another teacher commented:

I am happy and I was suggesting that we can do this once in a quarter next year as it is helpful and will enable us to get better results and be excellent in all topics and feel positive when teaching every topic.

Concerns about peer coaching

The following concerns were recorded in the observation forms completed by the teachers:

In what ways didn't you like to have a peer?

- The learners were unhappy, because the classes are too formal. Some of the learners are afraid to say anything, they prefer to be quiet.
- Learners stare at the new extra person in class, you have to work extra hard to capture their attention.

Will you use a peer in future? Why or why not?

The teachers were generally positive about future involvement of peers, self motivation being an important reason. Some mentioned that although the learners were afraid the first time when the peer visited the class, next time they will get used to them and would be actively involved.

In order to determine the effect of peer support, more teachers must get involved, and the teacher - peer observations should not be an additional activity, but should be part of their assignment. The forms therefore need to be amended.

Assignment

The assignment consisted of Grade 12 problems as well an outline of how the teachers would explain them to their learners. Teachers also had to compile a worksheet, after doing practical work. The following comments from journal entries regarding the assignment are worth noting:

It forced me to revisit my casual approach to the teaching of science. It forced me to consult a number of material which I went through in a casual manner and forced me to do the experiment. My practical skills have improved.

The assignment measures my ability very well because it wanted me to make an application of what I learned. I think it's a good idea and good approach of measuring my ability.

Pre-test as part of the first assignment

As part of the first assignment the teachers had to complete the pre-test given in Chapter 4. They were allowed to fill it in at home. Unfortunately some teachers did not complete it at all while some only completed certain sections. Although the importance of the test was stressed in the tutorial letter, they did not seem to regard it as necessary to complete.

If sufficient time is available the pre-test should in future be written during the first workshop.

6.12 Conclusion

The revised model was tested and after the analysis of the effectiveness of the intervention programme, it was found that only one major change was necessary, namely the inclusion of observation forms of peer coaching in an assignment. Further slight amendments were made such as changing the format of the journals and by including multi-choice problems in one of the assignments.

My own experience has shown that teachers have difficulty with the answering of multiple choice questions. Therefore such questions should also be

included in the assignment. The teachers should choose the correct answer, A, B, C or D and should explain how they would correct the learners if the learners choose the incorrect answer.

A new group of 39 teachers started in January 2004 and I applied the revised model which incorporated these new elements with the new group. The following remarks on their assignments were taken from the journal entries from the new group of teachers:

The assignment fully measured the new difference that I am itching to make to my teaching. The misconcepts that I like to do away with. I really measure the challenges that I am faced with and really opened the way for improvements and quality delivery. It measured my ability fully.

Assignment is helpful to me like this one for lesson observation it make me to improve my lesson on planning. I do like it because by using the information that I got from those assignment I see the change of doing my things and teaching strategies.

The first and second comments were recorded after the teachers had completed all the assignments and the observation forms included with the assignment. Therefore the involvement of all the enrolled teachers and not only a selected group proved to be successful in peer coaching.

Compared to the marks of the other assignments, the class average of the assignment in which the teachers had to answer multiple choice questions, was very low. They experienced problems firstly with finding the correct answer and then explaining the incorrect answers to their learners. The difficulty they are experiencing with the answering of multiple questions is a major problem and needs to be addressed in future.

The weekly journal entries were also changed in 2004 to only completing the journals after each study unit. However, weekly entries will be reinstated as valuable information was lost due to the longer intervals between entries.

The final HPD model is described in Chapter 7. An evaluation of the HPD model will be given using Professional Development Standards set by the USA and by eminent researchers in the field. Recommendations for future research are made in Chapter 8.

Chapter 7 HPD Model: Structure and evaluation

7.1 Introduction and Overview

In the first phase of the study, baseline information was obtained on physics teachers' content knowledge, professional attitudes and teaching approaches. The reflection stage clearly showed deficiencies in all three dimensions that needed to be addressed (see Chapter 4).

In the second phase an initial version of the HPD model was developed. Various data sources (assignments, pre- and post-tests, journal entries, workshop feedback forms and interview) indicated a positive change in the teachers' content knowledge, teaching approaches and professional attitude. This could be ascribed to the intervention programme associated with the initial development of the HPD model. In particular, the effectiveness of the study material, workshops, assignments and the keeping of reflective journals was confirmed (see Chapter 5).

In the third phase, effective elements of the initial HPD model were identified, less effective elements were adjusted and new elements were tested to develop the revised HPD model. In the reflection stage a number of recommendations were discussed and tested (see Chapter 6).

In this chapter the overall structure of the programme and its elements associated with the HPD model are discussed (see 7.2). The HPD model is then evaluated against requirements for successful professional development (7.3) and Standards for Professional Development set by the USA (7.4). Finally the HPD model is compared with the South African vision for teacher development (7.6).

7.2 Structure of the Programme

A number of general concerns were identified about typical professional development programmes (see 2.5.1). They were criticised as being short-term (Kahle, 1999, p. 1) or not resulting in improved content knowledge for teachers or changed teaching practices which enhances student learning. Fullan (1991, p. 315) stated

Nothing has promised so much and has been so frustratingly wasteful as the thousands of workshops and conferences that led to no significant change in practice when the teachers returned to their classroom.

To address this issue of short-term professional development programmes, it is essential that teachers be engaged throughout the year. “Dead periods” during which they are not actively involved, should be avoided. The fact that the HPD model is a distance education course has a clear advantage. The enrolled teachers receive their study material and tutorial letter at the beginning of the programme and can work throughout the year. They know exactly what is expected from them from the start. The assignments and journals are structured in such a way that the teachers have to complete their journal books weekly or every second week, which ensures that no dead periods occur.

Another advantage of distance education is that the teachers can study in their own time and do not have to be taken out of their classrooms. This makes the model acceptable for the Department of Education because they have no need to employ substitute teachers.

In the following sections, each of the elements of the HPD model will be discussed individually.

7.2.1 Study material

The distance education study material designed for this course is unique in a number of respects.

Integrating Content knowledge, pedagogy and PCK

Shulman (1986, p. 9) defines content knowledge as

the amount and organisation of knowledge per se in the mind of the teacher

and pedagogical content knowledge as

a second kind of content knowledge which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching

Mason's (1988) research showed that beginning and prospective teachers who were considered to have good knowledge of their content area were not necessarily able to apply this content information to teaching methodologies.

They had difficulty in conceptually organizing their knowledge of science and the relationships of major concepts and consequently experienced difficulties in implementing their knowledge together with effective teaching strategies.

He concluded that there was a real need to guide teachers to apply information covered in educational courses to their content area in other words to merge content and pedagogy (cited in Tobin et al. 1994, p. 66).

When the baseline data was obtained, the GDE Inset programme I was involved with offered content knowledge and teaching method as two different modules. It was considered to be more effective to integrate the teaching of content knowledge, pedagogy and pedagogical content knowledge. In view of the concerns outlined above, it is accepted that content knowledge and PCK are interconnected. Consequently, an integrated approach was followed in the compilation of the study material for the HPD model.

Furthermore a variety of teaching skills, strategies and approaches were illustrated in the study material. Efforts were made in Physics for Teachers I to

simulate interaction between lecturer and students by including provocative questions in the study material as suggested by Thacker (2003, p. 1841):

At certain points in the material, the students discuss with an instructor, often this discussion takes the form of a “Socratic dialogue” between the instructor and the students, with the instructor probing questions, in order to challenge the students and determine if they have developed a correct understanding up to that point.

Developing conceptual understanding

Because of the teachers’ own lack of conceptual understanding they do not focus on developing their students’ understanding. As a result the situation described by Thacker (2003, p. 1842) is common:

There is evidence that many students taught traditionally can solve “textbook problems” but lack a solid conceptual understanding of physics.

The study material for the HPD model was compiled with this in mind. Approaches used to help teachers develop good conceptual understanding of physics included probing questions, creating and correcting controlled confusion and requiring predictions of the outcome of experiments and testing their predictions against experimental results (see 6.5.1).

Using multiple representations

The modules of the HPD model encouraged teachers to use multiple representations in solving physics problems, as a means to enhance their understanding of physics concepts. Graphical, mathematical/symbolic and pictorial representations which can be used to solve physics problems were included in the study material.

Developing different skills

The teachers’ metacognitive and cognitive skills, i.e. their reasoning and thinking as well as problem solving skills, were developed (see section 5.2.4.1.) This was done to enable the teachers to monitor and control their attempts to perform intellectually. Metacognition implies that “learners have an informed and self-directed approach to recognise, evaluate and decide

whether or not to reconstruct” knowledge (Gunstone & Northfield 1994, p. 526).

Inquiry approach

According to Eick and Reed (2002, p. 401), one of the goals of science teacher education is

to teach science as inquiry supported by constructivist learning theory .

An inquiry approach to science requires situations where students’ attention is caught and questions are raised which draw them into the world of scientific investigation. This initial stage provides the motivation needed for the challenge of doing science (Layman 1996, p. 21).

According to the National Science Education Standards cited in Layman, (1996, p. 25) a variety of skills associated with the process of scientific inquiry are relevant in practicing science, including:

- Describing objects and events
- Asking questions
- Constructing explanations
- Testing explanations against current scientific knowledge
- Communicating ideas to others

The study material was structured to promote an inquiry approach. By posing probing questions in the study material teaching were challenged to think creatively in order to answer the questions, giving scientifically correct explanations for their answers. The teachers were encouraged to follow the same approaches in their classrooms.

Presentation of the various sections in the study material is discussed in Chapters 5 and 6, which show that the study material was developed in an unique way.

7.2.2 Science kit

Laboratory activities offer important experiences in the learning of science. They promote intellectual development as well as the development of observational and manipulative skills. In this regard Tobin et al. (1994, p. 81) states that

...the laboratory is the essence of science, a metonymy (or central defining attribute of a concept) that can be used to make sense of experience in the context of science teaching. From a constructivist perspective, laboratory activities can be seen as a means of allowing learners to pursue learning autonomously, having varied multi-sensory experiences.

In the same vein, Lunetta (1998, p. 250) elaborates that

Laboratory experiences promote central science education goals including: understanding of scientific concepts, the development of scientific practical skills and problem – solving abilities and interest and motivation.

Although doing practical work is seen as central to science education, developing countries do not have the infrastructure such as laboratories or equipment, due to financial constraints.

The financial constraints on investment in science education determine the range of options that exist to provide learning materials, physical infrastructure and equipment and consumable materials (Lewin 2000, p. 8)

Muwanga-Zake (2002, p. 2) carried out a survey during 1998 in rural Grade 7 – 12 schools in the Eastern Cape. He reports that a deficiency in practical skills and a deficient understanding of the relevant science concepts are the main reasons why teachers do not use practical approaches.

The inclusion of a science kit as a component in the HPD model was regarded as a means through which some of these problems could be alleviated. The equipment in the science kit was used during the workshops to explain

concepts and develop teachers' practical skills. It also enhanced learning with understanding.

White and Gunstone report on the importance of laboratory work to develop conceptual understanding as well as practical skills.

Learning of science can be promoted when laboratory experience are integrated with other metacognitive learning experiences such as "predict-explain-observe" demonstrations and when they incorporate the manipulation of ideas instead of simply materials and procedures (cited in Lunetta 1998, p. 251).

The effects of the science kit on the improvement of the teachers' content knowledge and skills are illustrated in section 6.6.3.

Unfortunately, the science kit provided contained only very basic scientific equipment, cost being a limiting factor, and hence could be used for only relatively simple Grade 10 – 12 experiments. Not only is the cost involved in distributing a better equipped science kit prohibitive, but also more workshop time would have to be devoted to familiarise the teachers with the extra apparatus.

7.2.3 Peer coaching

Lesson study and peer coaching were combined in the HPD model. This aspect of the model is discussed in section 6.2.4.5. This combination seemed to be more feasible than either component on its own.

Apart from the production of quality lessons it also allowed the teachers to work collaboratively, which alleviated the problem of teacher isolation. Participating in the process of lesson study and peer coaching deepened the subject knowledge of the teachers, allowed them to adopt effective teaching strategies and stimulated them to become reflective practitioners. It also helped them begin to establish a professional community.

7.2.4 Assignments

The completion dates for the four compulsory assignments were carefully chosen to ensure that the teachers work throughout the year. The assignments comprised a combination of typical grade 12 problems and descriptions of how the teachers would explain the solution of the problems to their learners. A number of multiple choice questions were also included which the teachers had to answer. In addition, the teachers had to explain why each wrong option was unacceptable. In this way they would gain experience in correcting their learners' thinking.

The teachers also had to perform an experiment which was prescribed in the study material. They had to take and record measurements accurately, make careful observations and analyse and display the data appropriately. They were required to compile a worksheet for the experiment. This component was introduced in the assignment to encourage the teachers to do practical work by experiencing first hand the value of developing conceptual understanding.

In one of the assignments it was explained what was expected of the teachers regarding peer coaching. The various observation and report forms, which had to be submitted after completion, were included in the tutorial letter.

The teachers had to evaluate the assignments as measuring tools for their ability and had to record their comments in their journal books. The majority of teachers were satisfied and reported that their wrestling with the assignments changed their way of teaching, improved their practical skills and forced them to use alternative resources to answer some of the questions.

7.2.5 Workshops

The workshops were held in areas where the teachers were concentrated and were presented at the beginning and towards the end of the programme. The first workshop provided the very important opportunity for the enrolled teachers to become acquainted with one another. Some of them became

good friends during the programme. This contributed towards the alleviation of the problem of isolation which some of the teachers identified. Many now had someone whom they could contact whenever they experienced problems.

The teachers had to use their science kits to do experiments. The workshops provided the ideal opportunity for development of the teachers' practical skills, which they were lacking. While performing some of the experiments teachers had to predict what they expected to happen and after execution of the experiments, they had to explain their observations which contributed towards development of their metacognitive skills.

According to Eick and Reed many researchers recognise (see section 6.7.1)

a strong influence between teachers' beliefs about teaching and learning and how they taught science. In particular, their data and others suggested that a teacher incorporated his or her preferred learning style, based on learning history, into their approach to teaching (Eick & Reed 2002, p. 410).

Therefore, the workshops were structured to introduce the teachers to teaching approaches which differed from those they had been exposed to in the past. Previously, data was given and they had to draw graphs, using the concrete values blindly without understanding. During the workshops I changed the structure. I confronted them with a real life situation and they had to draw graphs without any concrete values. Cooperative learning was also introduced as a new teaching approach.

After each workshop the teachers completed an evaluation form anonymously. All the teachers asked for more workshops and indicated that the workshops helped them tremendously.

One of the constraints of distance education courses is the difficulty in providing contact sessions. Therefore workshops have to be presented. These are usually held at locations where students are concentrated.

However, due to the remoteness of many rural schools and due to time and financial limitations this is not always possible.

7.2.6 Reflective journals

The keeping of journals was introduced to encourage the teachers to become reflective practitioners and to develop their metacognitive skills.

Gunstone (1994, p. 135) describes a

metacognitive learner as one who undertakes the task of monitoring, integrating and extending their own learning. Monitoring involves an informed awareness of both progress through task and progress towards achievement of learning goals.

In addition Baird, Fensham, Gunstone and White (1991, p.165) emphasises the link between teacher and learner metacognition as follows:

Changes in the metacognition of students could occur only after changes in the teachers' attitudes, perceptions, conceptions and abilities, that is, development of teachers' metacognition must precede that of their students.

Therefore it is desirable to develop the teachers' metacognitive skills first. This would result in teachers becoming reflective practitioners regarding their own learning and teaching practices. In achieving these outcomes the programme will be sustainable, because it will ensure lifelong learning.

7.3 *Kahle's requirements for successful Professional Development*

Several professional development models, programmes and projects are reviewed (see 2.3.1 – 2.3.3). This review showed that there is general consensus among researchers regarding the type of professional development that should be encouraged. In this section I will compare the HPD model with requirements for successful professional development, as

formulated by Jane Butler Kahle (1999, p. 4) one of the prominent workers in this field.

It must be sustained, content-based and use new teaching methods

The sustainability of the model was ensured by building the teachers' capacity. The development of the teachers' content knowledge was effected mainly through their use of the study material and some workshop materials. New teaching methods were described in the study material and some were practised during the workshops (see 5.6, 5.7, 6.6, 6.7 and 6.8).

It must provide for follow up experiences so that teachers have opportunities to test, discuss and analyse new teaching strategies

This was done during the peer coaching component of the model. The post observation lesson discussions between teachers and peers created the opportunity for an exchange of ideas on the effectiveness of teaching approaches and the adoption of new teaching strategies. Peer coaching paved the way for teacher cooperation on a more permanent basis. The teachers also had the opportunity to reflect on their new teaching strategies in their journals (see 6.6.4 and 6.7.3).

It should include leadership opportunities and model strategies that teachers will use with their students

The opportunities provided for teacher-peer discussions on classroom practices stimulated the gradual development of a professional teacher community. Development of content knowledge led to growth in confidence, to such an extent that participating teachers started to emerge as leaders in local teacher communities (see 6.9 lines 107 – 109).

Different teaching strategies were presented in the study guides and some were modelled during workshops. After analysing the teachers' journal entries it was evident that they used the strategies with their students.

It should provide time for teachers to reflect on and practice what has been learned

Through use of the study material, different teaching skills were acquired and applied by the teachers. Amongst others, teaching approaches that were inquiry based and learner centred were introduced. Recording their thoughts and views on their newly required skills and new practices obliged them to reflect on what was learned and could be seen in the teachers' journals.

It must include ongoing assessments that provide information to revise and redesign the professional development experiences

The HPD model is structured in such a way that the development of content knowledge, teaching approaches and professional attitudes is effected simultaneously. Experience gained with the implementation of the model, however, can lead to revision or changing of certain elements from year to year.

It should provide incentives (graduate credit) and be tied to career goals, including differential staffing and teacher career ladders;

The programmes Physics for Teachers I and II are certificate courses. At this stage they do not lead to any academic qualification and completion of the courses is for the benefit of the teachers' own professional development. Ways should be sought to accredit the modules.

In the discussion document on Continuing Professional Teacher Development (CPTD), Morrow (2004) explained how registered and approved activities of continuing professional development will be assigned professional development (PD) points in future. Teachers will then have the opportunity to earn a certain number of points in each three-year cycle.

It should be accountable, including research to assess changes in teaching practices and in student learning.

Triangulation of various data sources was applied to ensure that the data was reliable. However, I had to rely on what the teachers' perceptions of

their change in teaching practice were. In view of the Physical Science results of the Grade 12 learners of a participating school which showed an increase in the pass rate from 43,2 % to 84,4%, the contribution of the model can be regarded as significant.

In view of the above I am convinced that the HPD model satisfies the requirements for successful professional development formulated by an eminent researcher in this field.

7.4 National Research Council's Standards for Professional Development

In order to further evaluate the HPD model I decided to use an international benchmark. The National Research Council of the USA determines Standards for Professional Development (National Science Education Standards, 1996) for the Science and Education faculties of colleges and universities. These institutions are primarily responsible for the initial preparation of teachers of science; for the training of teachers who select and design activities for personal professional development; and for the preparation of all others who design and lead professional development activities. These standards also serve as criteria for state and national policy makers who determine important policies and practices, such as requirements for teacher certification and the budget for professional development.

A respected international benchmark is needed to evaluate the HPD model because a substantive change in the teaching of science and in professional development practices at all levels is required in South Africa. Previously professional development involved traditional lectures to convey science content and emphasised technical training about teaching. Presently professional development must create opportunities to engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability.

The Standards for Professional Development are classified in four Standards, A, B, C and D (see Appendix E). The first three of the Professional Development Standards address the learning of science, the learning to teach science and learning to learn. The characteristics of quality professional development programmes at all levels are evaluated in the last standard.

Professional Development Standards A and B have different learning experiences which are numbered (see Appendix E). Only the numbers of the experiences which are achieved in the HPD model are given in Table 7.1. The activities included in Standard C are also numbered. Again only the numbers of those activities which have been achieved are given in Table 7.1. Standard D will be discussed in a separate paragraph (see 7.4.3).

Table 7.1: Elements of the HPD model and the Professional Development Standards A, B and C

Elements of HPD model	Professional Development Standards			
	A	B	C	D
Study material	2; 4	1; 3; 4	5	Discussed in paragraph
Assignments	1; 4; 5; 6	1; 3; 4	2; 3;	
Workshops		1; 3;		
Reflective journals	5	4	1; 2; 3;	
Science kit	1	4		
Peer coaching	6		1; 2; 3;	

7.4.1 Comments on Standards A, B and C

Each of the elements of the HPD model were compared to each of the required learning experiences of Standards A, B and C. In the following sections the degree to which the elements of the model meet the requirements of specific learning experiences of some of the standards, is described.

7.4.1.1 Study material

Professional Development Standard A 2:

The following two examples are taken from the study material Physics for Teachers I: Study Unit 3 p 13

Science and technology

Many developments in physics (and science in general) have stimulated applications in technology. Mechanics stimulated better designs for mechanical apparatus. Heat and temperature had a huge impact on the design of steam engines which in turn started the industrial revolution using coal as a fuel to drive engines in factories and in steam trains. Electricity and magnetism made it possible to bring electricity to the homes and factories and stimulated the development of radios, TV and electric motors. Quantum mechanics gave insight into the behaviour of atoms and stimulated the development of your pocket calculator and computers. We should also mention here that many developments in physics stimulated the productions of weapons like canons, jetfighters and sophisticated bombs. The latest major development in this regard was the production of the atomic bomb and, a bit later, the production of the hydrogen bomb. Many technological developments have been a blessing for mankind but they also pose a serious treat for the existence of mankind like the greenhouse effect, the depletion of the ozone layer and weapons of mass destruction.

This extract contains a brief overview of prominent technological developments which have their origin in physics research. It serves as an example of how a topic of significance in science is addressed.

Study Unit 14 p 20: Describes the causes of the greenhouse effect which currently is a matter of global concern. It illustrates how an issue of great concern for mankind has been addressed.

Finally, the greenhouse effect – A major concern for mankind

The Sun emits electromagnetic waves mostly in the form of visible light and these waves travel quite easily through the atmosphere. The waves are absorbed by the surface of the Earth thereby increasing the temperature of the surface. The surface, at a higher temperature now, starts to emit electromagnetic waves but entirely in the form of infrared waves.

If the temperature of the Earth is to remain the same (that is what we want) the amount of energy received by the Earth from the Sun in the form of light should balance the amount of energy lost by the Earth to space in the form of infrared waves.

It is found that with the increase of CO₂ in the atmosphere due to industrial activities (especially electric power stations and traffic) infrared waves can pass less easily through the atmosphere into space. The CO₂ in the atmosphere acts like a filter, it allows light waves to come in, it hinders infrared waves from going out.

Careful measurements have shown that as a result of the filter working of CO₂ the average temperature of the Earth has gone up by several degrees over the last century. This is a major concern as any change in the temperature is bound to have an impact on the climate. Much discussion is going on what these effects will be; some predict a much dryer climate in large parts of Africa.

Industrialised countries are asked to reduce their emission of CO₂ but this requires a political will and changes in the economy. Some countries are willing to strive for change, others, notoriously the United States of America, far less so.

South Africa does not show a good picture either; the amount of CO₂ produced, given the size of the population, is very high. Power stations and traffic produce a lot of CO₂. Perhaps consider using a bicycle when you go to work, or, do not turn on the heater but put on a jersey when feeling cold.

Professional Development Standard A 4:

An example of how this learning experience has been addressed is taken from Study Unit 4 p 14



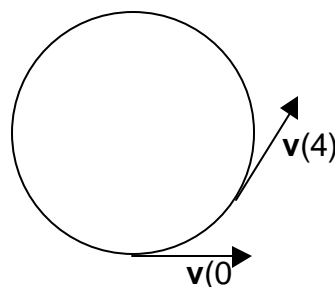
For reading only

The need to consider the vector nature of the acceleration for non-rectilinear motions – An example

In dealing with acceleration for rectilinear motions we might opt to ignore the vector characteristics of the acceleration (as is done in most Matric textbooks).

In the example below we will show that for non-rectilinear motion we **must** consider the vector characteristics of the acceleration.

Consider an object moving with a constant speed following a circular path, for example a car driving with a constant speed of 20 m/s over a circular road. What is the acceleration?



Suppose we would ignore the fact that we are dealing with vectors then we would say:

$$a = (20 - 20) / 4 = 0/4 = 0 \text{ m/s}^2.$$

The conclusion would be that there is no acceleration. But this defies common sense; we all know that when we sit in a car that goes through a curve in the road something is happening, we can actually feel a force on our bodies. In other words the calculation above is wrong, we must consider the directions; the vector nature of the quantities must be taken into account.

Note 1: It can be shown that the acceleration in the above example is actually directed towards the centre of circle.

Note 2: In this module we will only teach rectilinear motions.

This section explains the vector nature of the acceleration for non-rectilinear motion. To master this concept, a thorough understanding of the vector nature of the acceleration for rectilinear motion is essential. It serves to illustrate how new knowledge is built on the teacher's current science understanding.

Professional Development Standard B 1, 3 and 4

The study material was developed with a view to integrating physics content knowledge, pedagogy and pedagogical content knowledge. The study material also provided for the development of cognitive, metacognitive,

teaching and experimental skills. The effect of the integration was investigated and found to be successful.

Professional Development Standard C 5

Recent information from current research on teaching methods in physics is included in the study material. This includes the latest approaches to learning, for example, through creation of confusion or probing questions to develop conceptual understanding.

7.4.1.2 Assignments

Professional Development Standard A 1, 4, 5 and 6; B 1, 3 and 4; C 2 and 3

The assignments were structured in such a way that all the above mentioned learning experiences are addressed. This was confirmed by analysis of participating teachers' journal entries.

7.4.1.3 Workshops

Professional Development Standard B 1 and 3

During the workshops teachers' conceptual understanding was developed and different teaching approaches were experienced (see 6.6.3 and 5.7.2).

7.4.1.4 Reflective journals

Professional Development Standard A 5; B 4; C 1, 2 and 3

Ongoing reflection was implemented by requiring teachers to reflect on their own learning and teaching in their journals.

7.4.1.5 Science kit

Professional Development Standard A 1:

The inclusion of the science kit as a component of the study material involved the teachers in experimental investigations. It also allowed them the opportunity to interpret their results and to give scientific explanations for their findings (refer 6.6.3).

Professional Development Standard B 4:

Using the science kit allowed the teachers to experience an inquiry approach to science and to improve their cognitive and experimental skills.

7.4.1.6 Peer coaching

Professional Development Standard A 6; C 1, 2 and 3

This learning experience was addressed in peer coaching where the teachers were encouraged to collaborate with each other.

7.4.2 Comments on learning experiences referred to in Standards A, B and C but not addressed by the HPD model

Professional Development Standard A 3:

This learning experience was not achieved in this study. A possible way of addressing this learning experience in future is to include a compact disc with the study material introducing websites such as “the physics classroom”. A booklet will have to be compiled to guide the teachers on basic computer use. The majority of the teachers enrolled for the program did not have access to internet, email had not been exposed to a computer at all. Inclusion of a compact disc with useful information could be a way to introduce teachers to scientific literature, media and technological resources that expand their science knowledge and their ability to access further knowledge. This will become more feasible as more schools acquire computers.

Professional Development Standard B 2

Unfortunately, this learning experience was not achieved in this study. It was impractical to remove teachers for extended periods from their classrooms to allow them to experience modelled effective science teaching at a variety of places.

Professional Development Standard C 4

This professional development standard was not deliberately targeted when the model was designed. However it emerged as an unexpected outcome. Some teachers indicated that they now have more confidence in their

teaching as a result of improved content knowledge and regard themselves as suitably equipped to act as mentors, coaches or resource teachers in their various districts. Future support for the sharing of teacher expertise needs to be considered in more detail.

Professional Development Standard C 6

Opportunities to learn and use the skills of research to generate new knowledge about science and the teaching and learning of science were not addressed in the model and should be investigated in future.

7.4.3 Comments on Standard D

Professional development for teachers of science must be coherent and integrated. Quality pre-service and in-service programmes are characterised by:

Clear, shared goals based on a vision of science learning, teaching, and teacher development congruent with the National Science Education Standards.

The HPD model was based on the policy documents of the Department of Education as well as the “old” National curriculum which is currently (2004) being used. The HPD model also shares the goals expressed in the *Norms and Standards for Educators* (National Education Policy Act 1996).

Integration and coordination of the programme components so that understanding and ability can be built over time, reinforced continuously, and practiced in a variety of situations.

The modules Physics for Teachers I and II were year long modules. The teachers enrolled for the modules constantly had to apply what they had learnt through the assignments, to their classroom practices. In addition they had to reflect about their learning and teaching in their modules.

The following is an additional example of how the teachers have to take more initiative in learning a new topic. The module Physics for Teachers II was developed, amongst others, to give the teachers the opportunity to

gradually work on their own. This was a slow process building towards the last study unit in the module on magnetism. It was done in the form of a table with two columns. In the first column different outcomes were given of what was expected of the teachers. In the second column, information was given on how each corresponding outcome could be achieved. The teachers could use any additional source. A list of books was provided to guide them to achieve these outcomes.

The following example is taken from Physics for Teachers II as illustration:

What you should know:	What you should be able to do:
When a current flows through a coil or a solenoid it acts like a bar magnet. The shape of a magnetic field of a solenoid is like that of a bar magnet.	Carry out an experiment to observe the magnetic field of a current-carrying solenoid. Determine the direction of this field. State the rule that is used to determine the direction of the magnetic field in this instance. Compare the magnetic field of a solenoid with the magnetic field of a bar magnet.

Options that recognise the developmental nature of teacher professional growth and individual and group interests, as well as the needs of teachers who have varying degrees of experience, professional expertise, and proficiency.

One of the advantages of distance education is that the student determines his own pace which address the fact that teacher have varying degrees of experience, professional expertise, and proficiency. However, the programme was structured in such a way that the participants were encouraged to work continuously. Teachers were under no obligation to take part in the programme, they decided on their own professional growth.

Collaboration among the people involved in programmes, including teachers, teacher educators, teacher unions, scientists, administrators, policy makers, members of professional and scientific organisations, parents, and business people, with clear respect for the perspectives and expertise of each.

This was not achieved through the HPD model and needs to be addressed in future research.

Recognition of the history, culture, and organisation of the school environment.

Some of the teachers enrolled for the programme were on the staff of ineffective schools situated within poor communities in rural areas. Hence, those teachers did not have access to appropriate resources or laboratories. To a certain extent the science kits provided, overcame the lack of laboratories and equipment while the study material guided the teachers to do practical work with simple equipment. The study material also provided a resource especially for teachers who did not have textbooks.

The teachers were following a teacher-centred approach (see 1.3.1.1) and by being exposed to other teaching approaches through peer coaching, workshops and the use of the study material, some of the teachers changed their teaching approaches. This was shown by an analysis of their journals.

Continuous programme assessment that captures the perspectives of all those involved, uses a variety of strategies, focuses on the process and effects of the programme, and feeds directly into programme improvement and evaluation.

Continuous programme assessment was achieved through the requirement that teachers continuously record their reflections on their learning and teaching in their journals. They were expected to reflect on what they liked or disliked in each the study unit, what they thought about the level of difficulty of the study material and on how the modules could be improved. They also had to reflect on how it felt to be a distance learner, on writing a journal and on the assignments they had to complete.

In addition, they had to complete evaluation forms after every workshop. The questions included in the forms pertained to what they learned, in what ways the workshop could be improved, what remained unclear after the workshop and what they would like to learn in the following workshop. The forms were completed anonymously and the views expressed were used in the planning of future workshops.

Information obtained from the teachers was used to revise and improve the HPD model.

7.5 Professional Development Activities by Desimone et al.

Desimone et al. (2002, p. 83) (see section 2.6) indicated in their research that the following features of professional development activities have significant positive effects on the teachers' knowledge and consequent changes in their classroom practice

- Content
- Active learning
- Coherence with other learning activities.
- Type of activity
- Collective participation of teachers from the same school, grade or subject
- Duration of the activity.

Each of these features has been discussed in detail in Section 2.6. All these features have been compared to Kahle's requirements for successful Professional Development (section 7.3) and the National Research Council's Standards for Professional Development outlined in Section 7.4. All of them have been addressed in the HPD model. Detailed discussion is therefore not necessary.

7.6 South African Vision

The HPD model must be in line with the South African vision for teacher development. In this regard the South African Department of Education (2001a, p. 19) proposed the following:

[Higher education institutions] should develop rigorous new programmes for educator preparation, strengthening both subject matter expertise and pedagogical mastery. The

quality and relevance of the training programmes should be reviewed to ensure that when trainees complete, they are competent in both subject content knowledge and teaching skills and strategies (pedagogic content knowledge) – that is, knowing how to teach specific scientific, mathematical and technological concepts and principles to young people at different stages of development.

Being a lecturer at a higher education institution, and being responsible for the structuring of a professional development model for physics teachers, I had to make sure that implementation of the model would bring about strengthening of the teachers' content knowledge as well as their pedagogical content knowledge. This was achieved by designing the model in such a way that simultaneous development of the three professional development dimensions namely content knowledge and PCK, teaching approaches and professional attitudes was attained. The research on the effectiveness of the model showed that the teachers improved their content knowledge as well as their teaching approaches. There was also a change in their willingness to spend more time on task, they became more confident and experienced more enjoyment in their teaching.

7.7 Summary of Chapter

The structure of the programme and the different elements of the final HPD model were discussed. Further recommendations to the model will be made in Chapter 8.

The HPD model had to be evaluated and therefore I used the following benchmarks: Professional Development Standards of the National Research Council of the USA (National Science Education Standards, 1996) and Jane Butler Kahle's (1999:4) requirements for professional development programmes as well as against features of professional development activities according to Desimone et al. (2002, p. 83).

A comparison of the HPD model with the vision of the South African Department of Education on professional development indicated that the model is in line with one of their goals.

In Chapter 8 constraints encountered during the development of the HPD model as well as recommendations and possibilities for future research will be discussed.

Chapter 8 Conclusion

8.1 Overview of the Study

The quality of Mathematics and Science education is a source of concern for education authorities in both developed and developing countries (see Chapter 1). Due to problems peculiar to itself, the situation in developing countries is worse. South Africa, being part of the developing world and having experienced circumstances over the past fifty years which impacted negatively on its education system, now has to cope with a situation in mathematics and science education which is highly unsatisfactory. This was confirmed by the latest TIMSS results which were released in December 2004. As previously in the TIMSS and TIMSS-R, South African learners were again outperformed by the learners of all other participating countries (Reddy, 2004).

A variety of professional development approaches were reviewed to determine the strengths and limitations of current approaches to professional development for mathematics and science teachers. This review revealed a general consensus among researchers regarding the type of professional development that should be encouraged (Kahle 1999, p. 4).

In Chapter 3 the research framework was discussed. I decided to use the professional development design framework for mathematics and science education reform as described by Loucks-Horsley et al. (1998, p. 16 – 24) as a guideline for my work for the following reason: according to these authors “it is important to draw upon practitioner wisdom when developing a model for professional development” (p 16). Hence the design of their professional development framework emerged after thorough discussions with prominent professional designers on programmes for both mathematics and science teachers.

Unique circumstances pertaining to mathematics and science education exist in South Africa. These circumstances need to be carefully considered and any model for the professional development of South African teachers in these subjects will have to be carefully moulded to meet the specific South African needs. I am convinced that a model aimed at the simultaneous development of teachers' content knowledge, teaching approaches and professional attitudes will be the best suited for the South African situation.

Figure 3.1 illustrates the framework used to design the HPD model. Features such as context, knowledge and beliefs, strategies and critical issues influence the implementation process. The setting of goals for and the planning of each phase of the model was preceded by feedback and reflection on the previous phase. Therefore the development of the HPD model was an iterative process, comprising continuous changing in order to construct the most suitable HPD model.

The study comprised three phases. The first phase was a baseline study. Data was obtained to determine the problems experienced regarding the teachers' physics content knowledge, their teaching approaches and their professional attitudes. In the reflection stage deficiencies in all three dimensions were identified which needed to be addressed (see Chapter 4).

The second phase comprised the initial development of the HPD model. The different data sources (assignments, pre- and post tests, journal entries, workshop feedback forms and interview) indicated a positive change in the teachers' content knowledge, teaching approaches and professional attitude. The effectiveness of the study material, workshops, assignments and the keeping of reflective journals was also confirmed (see Chapter 5).

During the third phase (see Chapter 6), a number of effective elements were identified. In the revised HPD model some elements were left unchanged (study material and workshops), while others were modified (journals and assignments). In addition new elements were introduced (science kits and the

peer coaching pilot project). Several further modifications were considered and implemented with a new group of teachers.

In addition, the HPD model was evaluated against the Standards for Professional Development of the National Research Council of the USA. (National Research Council, 1996) and requirements for successful professional development as formulated by Jane Butler Kahle (1999, p. 4). Furthermore, all the features of professional development activities which had significant positive effects on the teachers' increase in knowledge and consequent changes in their classroom practice (Desimone et al. 2002, p. 83) were addressed in the HPD model.

In this chapter constraints encountered during the development of the HPD model as well as recommendations and possibilities for future research are discussed.

8.2 Limitations of the Study

My study was hampered to a certain extent by several limitations. Firstly time and financial constraints prohibited extensive classroom observations. Therefore I had to rely largely on the teachers' and peers' self reports and observation forms as well as on the teachers' entries in their journals. These could unfortunately not always be verified by my classroom observations.

Secondly the teachers' replies in the confidence and professional attitudes questionnaires are self-reported data. However, the marks they obtained in related sections of their assignments allowed me to conclude that they were lacking in metacognition. At the outset of the programme, they were generally over confident and could not assess their ability objectively. I also did not observe some of the practices to which the teachers referred in the professional attitude questionnaires. However, I did unfortunately observe a serious lack of punctuality amongst them.

According to Simon (2000, p. 356) all qualitative researchers have to have “competencies in observation, questioning, data management and data analysis”. He states further that

in all qualitative research the quality of research depends directly on the knowledge, skills and interactive abilities of the researcher involved, because the researcher is the “instrument”.

Although I am actively involved in qualitative research, my abilities to observe, to question and to manage and analyse data, could have been a limiting factor in this study.

8.3 Constraints of the Study

Several constraints were experienced during the study. Firstly the sample size was very small. Only seventy five teachers were reached during the first three phases. However, the small sample size could be justified due to the fact that the data was triangulated to ensure reliability and in view of Desimone et al.’s (2002, p. 101) remarks that it might be necessary to

focus professional development on fewer teachers in order to provide the type of high quality activities that are effective in changing teaching practice

The development of the HPD model was an iterative process. After completion of each phase, the model was changed. After the third phase, the model had been changed substantively, and was trialled with a new set of teachers but only the effect of the changes was reported (see 6.11).

Secondly, the model comprised one year modules and data was obtained from the teachers enrolled for the modules. This ensured a continuous process as the participants were actively involved for the whole year with their journals and assignments. However, as the final effect of the intervention could only be assessed after the teachers have completed the modules, therefore a long period lapsed before new data could be obtained.

Thirdly despite numerous efforts, I was unable to have these modules, Physics for Teachers I and II, accredited towards a degree. The fact that it was not accredited could have had an effect on the enrolment of the teachers due to the fact that the students cannot use it as part of further studies. It could also place a restriction to those teachers who want to obtain a formal qualification. However implementation of the new Professional Development Strategy for Teachers in South Africa (see 3.3.4.4), in terms of which teachers would be allowed to earn professional development points, may create new opportunities in this regard.

Lastly, a distance education environment creates advantages but unfortunately also has specific constraints. The advantages of distance education for students are that they can study at any suitable time, in any suitable place and that they can determine their own work pace. At face-to-face institutions, non attendance of classes implies loss of work. With distance education the study material is available to every student for the entire duration of the study period. Distance education allows students to continue with their occupation, does not necessitate long periods of study leave, allows students to maintain family commitments, is not hampered by geographic location of students and is generally cheaper than education at face-to-face institutions.

The constraints of studying in a distance education environment are:

- Lack of face-to-face contact

Students expressed the need for contact time with lecturers. Due to financial implications for both students and institution this will always be a challenge in distance education.

- Geographical spread of students

The fact that the students are spread countrywide and are not normally concentrated in one area poses certain problems. It is difficult to get the students together or for the students to reach the lecturer. This influences the

selection of localities for workshops and also hampers the interaction between partners in the peer coaching component of the programme.

- Limited amount of support

The teachers were mainly supported through written material, a science kit, tutorial letters and memorandums which were provided after each assignment had been submitted. The teachers could also buy a textbook at a subsidised price. Unfortunately no videos, tapes or compact disks could be provided for additional support.

- High level of ability to learn from text

Student support was mainly in the form of written material. This implied that the students have to have adequate ability to learn from texts as no fellow students or lecturers were within easy reach nearby to explain difficult sections in the text.

English is the language of instruction. In most cases English is the teachers' second or third language. This poses problems such as lack of understanding.

- Needs higher level of self motivation

In cases of ample contact time, fellow students and lecturers can motivate discouraged students. In distance education fellow students see each other only occasionally or never. Therefore a high level of self motivation and the ability to work independently are prerequisites.

- Limited opportunities for interaction with teachers

Only limited interaction with fellow teachers who were also enrolled for the modules was possible. This could be attributed either to a lack of time or the remoteness of rural areas in South Africa.

- Rural conditions

Most teachers in the rural areas do not have cars and have to depend on unreliable public transport to move from one place to another. Furthermore,

although teachers on the same post level all get the same remuneration, the rural communities are poor and rural teachers are additionally burdened by the responsibility to support extended families. They therefore often do not have the money to pay for transport or study material.

- Isolation

One of the main constraints of distance education was the teachers' experience of isolation. This was partly alleviated by the introduction of the peer coaching component of the programme.

8.4 Significance and Application of the HPD model

The effect of the HPD model was tested on Science Teachers currently teaching Grade 10 – 12. Remarkable changes were noticed. Not only did the model deepen the teachers' content knowledge, change their teaching approaches and positively affect their professional attitudes, but also the Grade 12 learners' examination results improved markedly.

Therefore the positive effect of the HPD model on science teachers should be communicated to the nine Provincial Education Departments. Due to the fact that it is a distance education model, teachers will not have to be taken out of their classrooms and the costs involved for professional development of these teachers are much lower than for face-to-face professional development.

8.5 Possibilities for Future Research

The development of the HPD model was an iterative process comprising a continuous cycle of feedback and reflection leading to change. As a consequence, the programme is dynamic: through constant reflection and feedback, deficiencies are identified which are rectified through changes in the model. Thus, the cycle is continuous leading to continuous improvement. Such a cyclic approach implies a constant need for new knowledge, hence continuous focused research is essential.

I have identified the following possibilities:

Access to further science knowledge

Some of the teachers need to expand their science knowledge and their ability to access further knowledge. The information in the study material helped the teachers to develop their conceptual understanding of physics but did not introduce the teachers to scientific literature, media, and technological resources. Ways of how these problems could be addressed are suggested in section 7.4.2. However research is necessary to develop means through which science knowledge can be made accessible to the teachers in future.

Development of research skills

As yet, the teachers participating in the programme have not been exposed to research and the development of research skills. Although the study material provided knowledge about the teaching and learning of science, opportunities were not provided to learn and apply research skills to generate new knowledge about science and the teaching and learning of science. Ways of developing research skills in a distance education mode must be found.

Implementation of a hybrid of research lessons and peer coaching

The implementation of research lesson and peer coaching in the South African context can be a subject for future research. However this will require major changes in the attitudes of teaching and district personnel. Education officials will have to be convinced of the value of research lessons and peer coaching for teachers and their learners. They will also have to be convinced that it will result in high quality student learning and other benefits such as a deepening of content knowledge and a change of teaching practices. The financial implications will also have to be taken into consideration. To design possible approaches to tackling this problem, thorough research is necessary.

Collaboration amongst external parties and the teachers

As an outsider to the Education Department and the various teaching communities it was not easy to accomplish collaboration amongst the teachers, teacher unions, scientists, administrators, policy makers, members

of professional and scientific organisations, parents and the business community.

Parents and business people are usually part of a community and different communities have different “rules”. To impose suggestions from outside on a community does not work. The natural distrust of communities for outsiders needs to be overcome and bona fides need to be established.

According to Desimone et al. (2002, p. 101–102), education authorities must focus on

setting priorities for professional development activities over time, given limited resources; acquire knowledge about the features of effective professional development; and build the infrastructure to design and implement the types of activities that teachers need to improve student learning.

Therefore ways must be found to promote collaboration between the education authorities and the universities. The education authorities have a need for professional teacher development to improve student learning, while universities are in a position to provide valuable assistance to meet those needs. Effective channels of communication between the designers of professional development programmes situated at universities and the education policy makers, still need to be developed.

Social issues

The first interview (see 5.10) showed that the problems experienced by teachers are much deeper than lack of content knowledge or deficient teaching approaches. Social issues such as drinking and debts impact negatively on the professional attitude of teachers. These issues need to be addressed in future as they no doubt will jeopardise the success of any future professional development activities.

8.6 Conclusion

The HPD model can be explained by means of Figure 8.1. The three professional development dimensions influence one another and have to be developed simultaneously. The elements of the intervention programme were generated by using grounded theory as well as the iterative cycle of feedback and reflection. During the analysis of the various data sources the degree to which the professional development dimensions had an effect on the intervention programme was demonstrated.

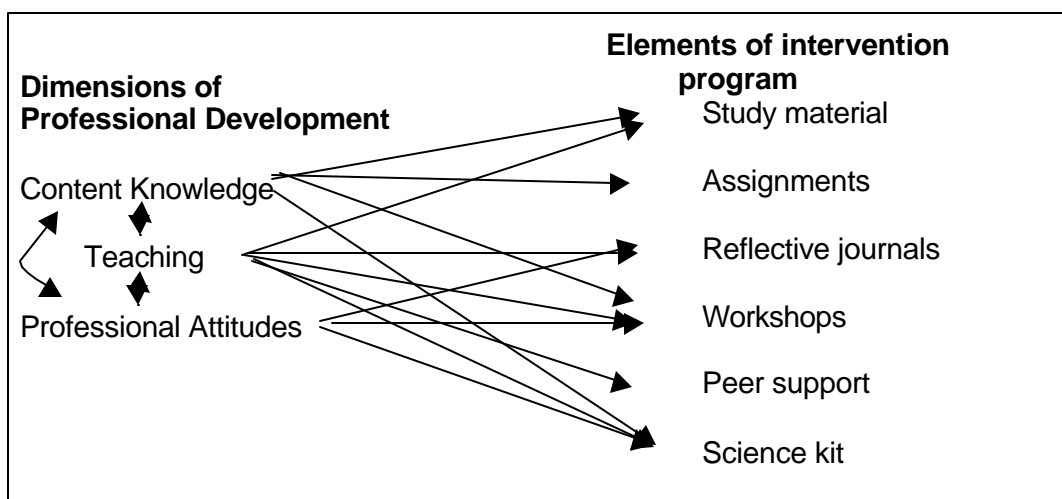


Figure 8.1: The relationship between professional development dimensions and elements of the intervention program

Analysis of the data showed that the teachers were extricated from a vicious cycle where poor content knowledge lead to lack of confidence and enjoyment which caused unwillingness to spend time on task (poor professional attitudes, ineffective teaching approaches). Instead they became part of a virtuous circle where improved content knowledge, leads to increased confidence, enjoyment and a willingness to spend more time on task (better professional attitudes and effective teaching approaches). It can be illustrated with the following:

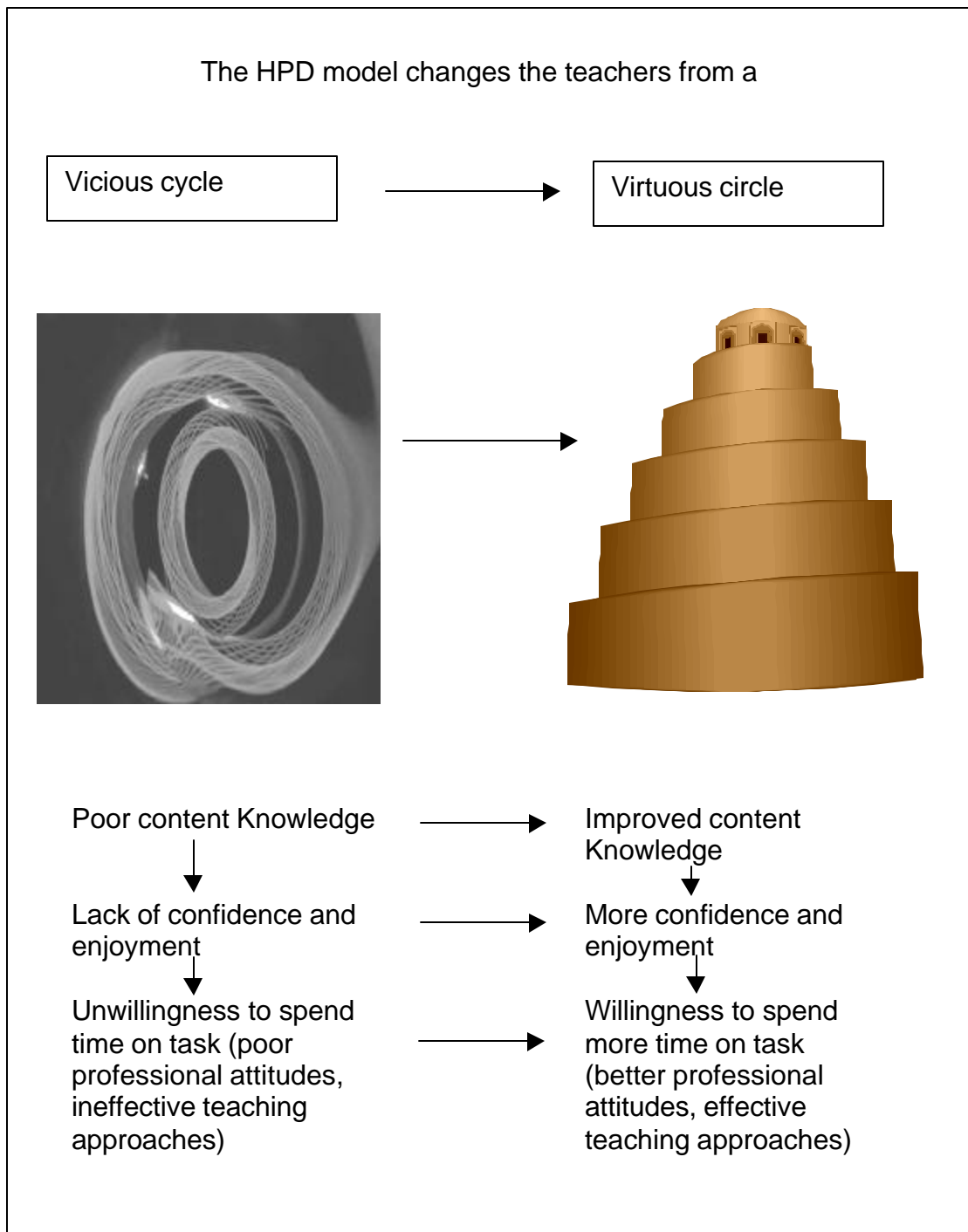


Figure 8.2: Change from vicious cycle to virtuous circle

Improving teachers' content knowledge builds their confidence in teaching their subject. This, in turn, motivates teachers to perform better in their jobs: they come to class better prepared, eager to do a job they know they are good at, no more coming late, no more plodding through uninspiring one-way lessons. They are turned into better professionals with a positive work ethic.

Their improved classroom practices lead to higher enrolments of science learners and improved learner achievement, the crown of successful science teaching.

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Appendix A: Study Unit 1 p 8

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The development of this material began in 1982 at the University of Botswana where I became aware of difficulties students experience in mastering the core concepts in physics. New ways to teach physics in a meaningful way with a focus on understanding rather than on a meaningless manipulation of formulas were developed. This happened in cooperation with the Vrije Universiteit Amsterdam and my colleague and friend Peter Dekkers. The material was developed further at UNIFY at the University of the North. In developing the material we drew on the educational literature on misconceptions in physics and on teaching strategies to overcome these misconceptions. I also incorporated ideas developed by other foundation year programmes like the SFP at the University of Natal. Much of the pedagogical content knowledge was developed at the teacher college MASTEC in Pietersburg. The development of the present course has taken place over many years and I wish to thank all my colleagues who have contributed by sharing their ideas and criticism.

To make the material suitable for distance training the material was extended and answers were included. Mrs Jeanne Kriek of UNISA thoroughly checked the material and all answers for which I am very grateful.

Ubbo Smith
January 2002

Study Unit 1 p 8

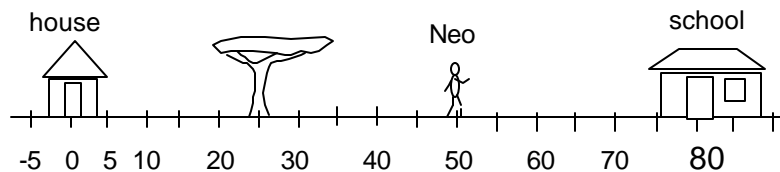
Motions along a straight line or rectilinear motions

Displacement

After the above study about position it is easy now to define a new quantity that deals with *change in position*.

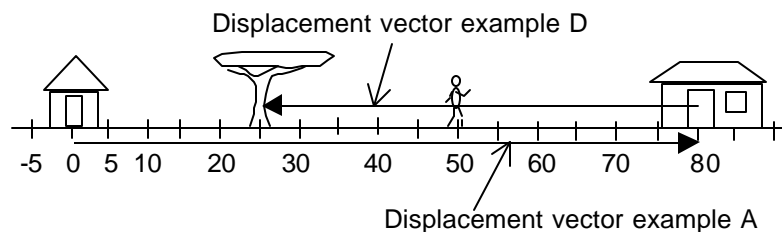
Displacement = change in position = position (t_2) — position (t_1)
whereby t_2 is a certain time later than t_1 .

Let us try to understand this rather abstract looking definition by applying it in the situation below. The diagram shows Neo walking from home to school. The diagram shows also that we took the origin O to be at his house and to the right is positive.



	Motion	$x(t_2)$ (m)	$x(t_1)$ (m)	Displacement (m)
A	Neo walks from his house to school	80	0	$80 - 0 = 80$
B	Neo walks from the tree to school	80	25	$80 - 25 = 55$
C	Neo walks from position $x = 50$ to school	80	50	$80 - 50 = 30$
D	Neo walks from school to the tree	25	80	$25 - 80 = -55$
E	Neo walks from position $x = 50$ to the tree	25	50	$25 - 50 = -25$

Notice that *displacement is a vector* because it has *direction*. The displacement in examples (a), (b), and (c) is to the right, in examples (d) and (e) it is to the left. In the diagram below the displacement vector is drawn for the examples (a) and (d).



You will have noticed that in the above we did not consider time. Displacement only deals with change in position regardless of the time taken. Below we will take time into consideration, which will lead us to a new quantity, namely velocity.



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Directed numbers in mathematics and the direction of vectors

Notice in the above that in giving the direction of the displacement we have used directed numbers. As the name 'directed numbers' implies already directed numbers can be used to describe direction.

*Directed numbers must be used correctly. Many pupils (and teachers) would say that the displacement in example D above is **minus** twenty five metres. This is incorrect, we should say: the displacement is **negative** twenty five metres.*

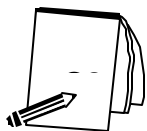
*Recall that in mathematics the word minus represents a subtraction, like 8 minus 4, just like the words plus represents an addition, like 8 plus 7. If we have a calculation like $11 - 20 = -9$ then the result is a directed number and we should read this as: Eleven minus twenty equals **negative** nine.*

Appendix B: Study Unit 1 p 9

Making a start with the quantity velocity

As the title indicates, in this section we will make a start with the quantity velocity. Later in the course we will encounter several different types of velocities. To keep matters simple for a start the present study unit only deals with motions with constant velocities.

Question 8. Frame of reference



- What is your velocity when you sit on your chair?
- What is the velocity of the chair?
- The chair stands on the floor, what is the velocity of the floor?
- The floor is fixed to the earth, what is the velocity of the earth?
- Did you encounter a problem in question (d)? What is the problem?
- To talk about velocity in a meaningful way what is needed?

Before you continue consult the answers given on the last pages of this study unit.

Answers given at the end of the study unit:

Answer to Question 8

First answers given by pupils NOT physicists:

Answers given by pupils - PCK

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- When I sit in a chair my velocity is 0 m/s.
- The velocity of the chair is also 0 m/s
- The velocity of the floor is also 0 m/s.
- The velocity of the earth? Well, uhhh, it must be 0 m/s because the velocity of the floor is 0 m/s and the floor is fixed to the earth. But this is very strange, because I know that the earth is actually moving. Something is wrong!

Remark: Use incorrect answers given by pupils to develop an understanding of the thinking of pupils

Most teachers just ignore pupils' incorrect answer by saying: "You are wrong". But teachers should try to understand incorrect answers; incorrect answers provide information about what pupils think. Once we know what pupils think we can think of examples that stimulate pupils to rethink their answers, or perhaps we can do experiments that challenge the incorrect thinking. What definitely does not work is saying: Your answer is wrong, the correct answer is Very little learning takes place if we do that, but ask yourself how often you do just that.

*So knowing pupils answers is important and that is why their answers are given above. These answers are given because pupils are not used to defining a frame of reference first. They regard **velocity as a property of an object**, just like the colour of the object or its mass. They do not understand that **velocity is a relational quantity**; it relates the motion of one object to another object, whereby the latter is called the frame of reference.*

Answers given by physicists

The reason that something is wrong is that we cannot ask: What is the velocity of an object? We always have to ask: What is the velocity of an object A with respect to another object B? We need a frame of reference.

So because no frame of reference was given in question (a) we cannot answer question (a). When you sit still on a chair your velocity *with respect to the chair* or earth is 0 m/s but your velocity *with respect to the Sun* is very, very large and definitely not 0 m/s! When we talk about velocity we need to give a frame of reference. This applies also to the other questions, in none of the questions a frame of reference is given, in none of the questions an answer can be given.

Teaching strategy – Confusion first, then solving the problem

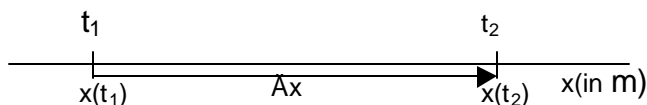
*Have you noticed that we did not start telling you that we need a frame of reference in order to talk about velocity in a meaningful way? Instead we presented you with a problem that resulted in confusion. In teaching in school we must do the same. If we really want pupils to understand something we should not start by giving the solution but rather by presenting the problem which at times could create confusion. This is good because **confusion makes pupils think**. After they have thought about it for some time you can give some hints, some guidance here and there such that they can solve the confusion. **Confusion when handled well can be an important instrument in engaging pupils intellectually.***

Note that many pupils (and people in general) are lazy; they prefer others to give the solutions. If your aim as a teacher is to develop real understanding then you must challenge the pupils, you have to force them to think. If you present solutions before allowing them to think about the problem they will learn NOTHING and you and the pupils can just as well go home.

*Please note: The kind of confusion meant above is not the kind of confusion that results when the teacher does not understand the material him/her self. The confusion that is referred to here is a **controlled confusion**.*

Question 8 shows that we need to define a frame of reference first before we can answer a question about the velocity of an object. This becomes clearer if we look at how we should define velocity properly as we will do now.

Consider an object moving along a straight line. Let the position at t_1 be $x(t_1)$ and the position at t_2 be $x(t_2)$.



But what was needed to determine these positions? Exactly; we can only define these positions after we have chosen an origin and a positive direction. In other words, we have selected a frame of reference (in this example the road).

Now we are ready to define velocity:

velocity = displacement / time required for the displacement

Or:

$$\vec{v} = \frac{\vec{x}(t_2) - \vec{x}(t_1)}{t_2 - t_1} = \frac{\Delta \vec{x}}{\Delta t}$$

Remarks

1. Velocity is defined by using displacement, displacement is defined using position, and position is defined using a frame of reference.
2. Displacement is a vector, hence velocity which is displacement divided by time is also a vector; velocity has direction.
3. The symbol Δ (pronounced as *delta*) is used in physics to represent change. Thus for example Δt is the change in time which is found by calculating $t_2 - t_1$.

The quantity speed can now be defined easily:

$\text{Speed} = \text{distance} / \text{time required to cover the distance}$

Remarks

1. Speed is the magnitude of the velocity vector.
2. Speed is a scalar quantity (just a number) and not a vector quantity, as it has no direction.

Velocity is a far more precise quantity than the quantity speed and hence more useful to describe motions.

Appendix C: Study Unit 1 p 7

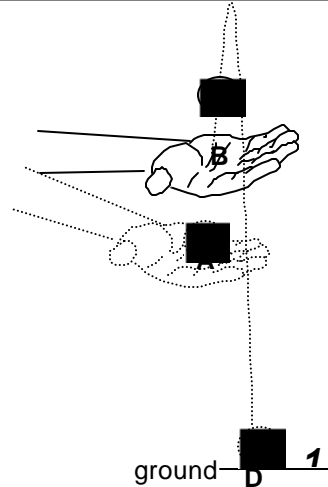


Question 6

In throwing a ball upward, letting it fly through the air and allowing it to drop to the ground there are actually three different motions.

(Note: the trajectory (path) of the ball is drawn as a parabola to show the up and down motion more clearly. If we throw the ball vertically upwards the trajectory is actually a straight line)

- (a) Identify the three different motions (realise that flying through the air is just one motion)
 (b) State for each of these motions whether the initial velocity is 0 m/s or not and o the same for the final velocity.



Motion	From A to B	From B to C	From C to D
v_{initial}			
v_{final}			

- (c) What do you think students will answer when they are asked: What is the initial velocity of the ball and what is the final velocity?
 (d) Explain in what way the teacher contributes to students getting confused.

The three motions are:

A – B: Pushing force by the hand

B – C: Flying by itself through the air

C – D: The force exerted by the ground reduces the velocity to 0 m/s. Note that this takes a bit of time.

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- (a) Initial and final velocities of the three motions

Motion	From A to B	From B to C	From C to D
v_{initial}	0	Not 0	Not 0
v_{final}	Not 0	Not 0	0

PCK

- (b) Pupils consider the three motions as just one motion, they will say that the initial velocity is 0 m/s (ball in the hand) and the final velocity is also 0 m/s (ball on the ground).

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- (c) The teacher wants to keep it simple and talks about the motion BC but he/she does not make that clear to the pupils. Pupils see the three motions as just one motion. When the teacher talks about initial and final velocity he/she talks about motion BC while pupils talk about the motion AD. The answers given by the pupils in (c) above are **correct** for motion AD but the teacher tells them that they are wrong only because he/she wants them to talk about motion BC.

Appendix D: Study Unit 6 p 10

1.4 Superficial understanding and real understanding

The problem of the heavy ball colliding with the stationary light ball was given to year 1 science students (good students) and 84% answered that the force exerted by the heavy moving ball on the light stationary ball is greater than the force exerted by the light stationary ball on the heavy moving ball. This was after they had correctly quoted the 3rd law.



PCK

It shows again a very superficial level of understanding. We must realize that learners will not develop an understanding beyond quoting facts if they are not stimulated (forced) to do so. From primary school onwards most teaching focuses on the learners' ability to regurgitate facts. If teachers are happy with this the learners are even happier.

In our teaching we have to set questions that force the learners to think, we have to allow them to struggle and not give away answers after 1 minute or so. Difficult questions must be part of tests and exams, and we should not be scared to get low marks initially. We need to focus on the long-term goal, that is, to develop a real deep understanding.



worksheet

Experiment 3. People know the 3rd law of Newton; however unconsciously

Introduction

Because people have to deal with forces all the time we have developed an intuitive understanding about forces. This intuitive understanding is sometimes right, sometimes wrong, sometimes partly right and partly wrong. The aim of the experiment below is to show that most people have an intuitive understanding about the 3rd law that is partly right and partly wrong.

In this unit you have learnt a lot about the 3rd law so your answers to the questions raised below might already be in agreement with physics. It is crucial that you also allow yourself to give intuitive (quick) answers. By comparing your intuitive answers and the correct answers you will learn where your intuitive understanding was wrong and thus develop a deeper understanding.

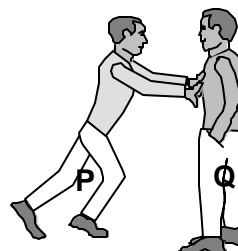
Instructions

The diagram on the right shows two pupils P and Q. In experiment A pupil P gives pupil Q a push as shown. Pupil Q must be relaxed pretending that he Department of Educations not know that pupil P is going to push him.

In experiment B pupil P pushes

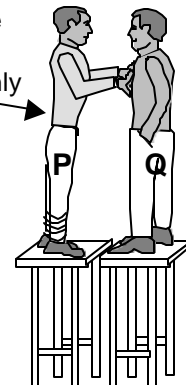
pupil Q but now both stand on two stools and the legs of pupil P are tied together. In experiment A pupil Q should not bend his body but just stand straight, in experiment B both pupils should **stand straight**.

Experiment A



Experiment B

Do not move body, push with arms only



Warning: In experiment B some fellow pupils must be ready to catch pupils P and Q. Note: Experiment B can also be done on the floor; doing it on two stools makes the experiment more dramatic but the physics involved in the pushing remains the same.

Observations

Answer the questions.

Questions

1. What happened to Q in experiment A?

2. Not knowing the 3rd law what would say in experiment A about the force P exerts on Q if compared to the force Q exerts on P?

3. What happened to P and Q in experiment B and what would you say about the force P on Q if compared to the force Q on P?

4. Was there any volunteer in your class to be pupil P in experiment A? And was there any volunteer to be pupil P in experiment B?

5. There was probably no volunteer to be pupil P in experiment B. Even people who have never heard about the 3rd law will not be prepared to be pupil P in experiment B. What Department of Educations this imply about the intuitive understanding of people about the 3rd law?

Conclusion

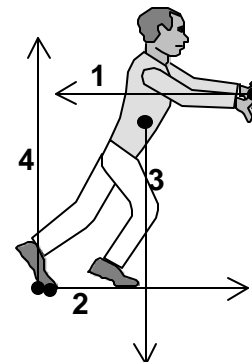
The fact that there was no volunteer to be pupil P in experiment B shows that people do have a good intuitive understanding about the 3rd law. Everybody knows that when you push against something while you cannot move your feet or body you will fall backwards. Also pupil P in experiment A has this correct intuitive understanding and that is why he automatically leans forward and keeps one leg firmly against the ground to balance the effect of the force that pupil Q exerts on him as he pushes pupil Q. Let us discuss the force on pupil P in detail.

The forces on pupil P in experiment A

Force 1 in the diagram is the force exerted by Q on P (as P exerts a force on Q). Force 1 is equal in magnitude to the force exerted by P on Q.

Force 2 is the force by the floor on P; as P pushes with his foot against the floor backward the floor exerts a force on the foot forward.

Force 1 and 2 balance each other and prevent A from moving horizontally.



Two more forces on pupil P (this section is for reading only)

Note that force 1 and 2 would cause the body of A to rotate anti-clockwise. To avoid this rotational motion A leans forward. As a result of positioning his body in this way the force of gravity (force 3 in the diagram) and the supporting force by the floor (force 4 in the diagram) create a rotational motion in a clockwise direction. Also the rotation caused by the forces 1 and 2 and the rotation caused by the forces 3 and 4 balance each other so that there is no net rotation. In other words pupil A has also a correct intuitive understanding about the rotational effects of forces.

Note that the rotational effects caused by forces (moments) is not included in this module.



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Remarks about experiment 3

Pupils find it hard to believe that the force P on Q is equal in magnitude to the force Q on P because pupil Q falls and pupil P does not. We can tell them that these forces are really equal but a much stronger learning effect is achieved when we ask them to do experiment B. Experiment B shows that when P pushes Q, Q also exerts a force on P. In fact in the situation of experiment B it does not matter who is pushing; both fall backwards regardless who is pushing. After pupils have discovered this for themselves by doing the experiments we have to explain why pupil P Department of Educations not fall in experiment A and then we have to discuss how pupil P prepares himself unconsciously to balance the force exerted by Q when he pushes Q. Here we need to discuss the effect of his rear foot pushing against the ground.

Appendix E: Professional Development Standards A, B, C and D of the National Research Council of New York

Professional Development Standard A

Professional development for teachers of science requires learning essential science content through the perspectives and methods of inquiry.

Science learning experiences for teachers must

1. Involve teachers in actively investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding.
2. Address issues, events, problems, or topics significant in science and of interest to participants.
3. Introduce teachers to scientific literature, media, and technological resources that expand their science knowledge and their ability to access further knowledge.
4. Build on the teacher's current science understanding, ability, and attitudes.
5. Incorporate ongoing reflection on the process and outcomes of understanding science through inquiry.
6. Encourage and support teachers in efforts to collaborate.

Professional Development Standard B

Professional development for teachers of science requires integrating knowledge of science, learning, pedagogy, and students; it also requires applying that knowledge to science teaching.

Learning experiences for teachers of science must

1. Connect and integrate all pertinent aspects of science and science education.
2. Occur in a variety of places where effective science teaching can be illustrated and modeled, permitting teachers to struggle with real situations and expand their knowledge and skills in appropriate contexts.
3. Address teachers' needs as learners and build on their current knowledge of science content, teaching, and learning.
4. Use inquiry, reflection, interpretation of research, modeling, and guided practice to build understanding and skill in science teaching.

Professional Development Standard C

Professional development for teachers of science requires building understanding and ability for lifelong learning. Professional development activities must

1. Provide regular, frequent opportunities for individual and collegial examination and reflection on classroom and institutional practice.

2. Provide opportunities for teachers to receive feedback about their teaching and to understand, analyze, and apply that feedback to improve their practice.
3. Provide opportunities for teachers to learn and use various tools and techniques for self-reflection and collegial reflection, such as peer coaching, portfolios, and journals.
4. Support the sharing of teacher expertise by preparing and using mentors, teacher advisers, coaches, lead teachers, and resource teachers to provide professional development opportunities.
5. Provide opportunities to know and have access to existing research and experiential knowledge.
6. Provide opportunities to learn and use the skills of research to generate new knowledge about science and the teaching and learning of science.

Professional Development Standard D

Professional development for teachers of science must be coherent and integrated. Quality preservice and inservice programs are characterized by

1. Clear, shared goals based on a vision of science learning, teaching, and teacher development congruent with the *National Science Education Standards*.
 2. Integration and coordination of the program components so that understanding and ability can be built over time, reinforced continuously, and practiced in a variety of situations.
 3. Options that recognize the developmental nature of teacher professional growth and individual and group interests, as well as the needs of teachers who have varying degrees of experience, professional expertise, and proficiency.
 4. Collaboration among the people involved in programs, including teachers, teacher educators, teacher unions, scientists, administrators, policy makers, members of professional and scientific organizations, parents, and business people, with clear respect for the perspectives and expertise of each.
 5. Recognition of the history, culture, and organization of the school environment.
 6. Continuous program assessment that captures the perspectives of all those involved, uses a variety of strategies, focuses on the process and effects of the program, and feeds directly into program improvement and evaluation.
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