DESCRIPTION OF A HOLISTIC APPROACH TO PHYSICS TEACHER DEVELOPMENT

JEANNE KRIEK

Department of Mathematics, Science and Technology Education, University of South Africa, PO Box 392, Unisa,0003
South Africa

DIANE J. GRAYSON

Department of Physics, University of Pretoria,,0001
South Africa

A holistic professional development (HPD) model was developed and tested with 75 secondary school physics teachers over a period of four years. This HPD model was developed in three phases and provides for the simultaneous development of teachers along three dimensions namely content knowledge, teaching approaches and professional attitudes. The model comprises the following elements: a study guide that integrated the development of teachers' content knowledge, pedagogical content knowledge, cognitive skills and experimental skills; reflective journals; assignments; workshops; peer support; and science kits. A brief description will be given of the research that culminated in the HPD model, and then a description of each element of the model will follow. Evidence is then presented for the effectiveness of the model in helping teachers develop along the three desired dimensions.

1 Introduction

The Third International Mathematics and Science Study (TIMSS) provides an international benchmark against which the achievement of learners in mathematics and science can be tested. A number of developing and developed countries did not do well in the study over the past few years, and their governments expressed their concerns [1] and [2]. Various reasons for underachievement were given such as the qualification of teachers, traditional ways of teaching and teacher's lack of knowledge [1], [3] and [4]. Therefore, long-term, sustainable improvement of mathematics and science education must focus on strengthening teachers.

Science teacher professional development is no easy matter, and is a cause for concern internationally. According to Jane Butler Kahle [5], the problem often stems from the short-term, superficial nature of many professional development programs. Fullan [6] expressed his misgivings about the effectiveness of teacher development programs in the USA as follows:

> "*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*".

In developing our holistic model for physics teacher development we therefore determined that the intervention should be designed to take place over an extended period of time and to build explicit links between teachers' content knowledge and their classroom practice. Another issue that we felt needed to be addressed, particularly in developing countries, was the development of teachers' professional attitudes, by which we mean their understanding of their roles and responsibilities as teachers. In a study [7] involving 1200 South African mathematics and science teachers, it was found that attitudes which we considered unprofessional were widespread. The model we designed was therefore holistic in that it integrates the development of physics teachers' content knowledge, teaching approaches and professional attitudes.

In the sections that follow we briefly describe the research framework involved in developing the HPD model. We then describe the elements of the final version of the model, and present evidence for its effectiveness.

1.1. *Research framework and methods*

The development of the HPD model was carried out in three phases over a period of four years. In Phase I baseline data was obtained about teachers' content knowledge, teaching approaches and professional attitudes by conducting case studies with three senior secondary school Physics teachers. The results of the baseline study, together with information obtained about other professional development programs and models, were used to construct an initial version of the HPD.

In Phase II this initial version of the model was trialed. A one-year distance education course was designed for Grade 10 to12 Physical Science teachers, called Physics for Teachers I. It was followed the next year by a second course, Physics for Teachers II. The elements of the initial version of the model were: a study guide, workshops, assignments and reflective journals. A variety of qualitative data sources were used to obtain information about the effectiveness of the model, including teachers' assignments, examinations, journal entries and workshop evaluation forms, as well as transcripts from interviews conducted with selected teachers. On the basis of the data collected, the model was modified.

In Phase III the modified model was implemented and evaluated. Data was obtained from 38 teachers in rural and urban schools. New elements that were added were peer support and the provision of a science kit. Modifications to some of the existing elements were also made. The process of developing the HPD model was therefore iterative.

In developing the HDP model a design framework for professional development for mathematics and science education [8] was used. The framework is presented in Figure 1. At the centre of the framework is a generic planning sequence consisting of four elements - goal setting, planning, doing and reflecting. This is referred to as the implementation process and was applied in the three phases of the development of the HPD model. Figure 1 indicates multiple feedback loops from the "reflect" stage to illustrate how design continues to evolve as we learn from doing. Reflection can influence every input which, in turn, affects the creation of a new and better design of the model. A great deal of changing of the design and retrialling of the model took place after each phase.

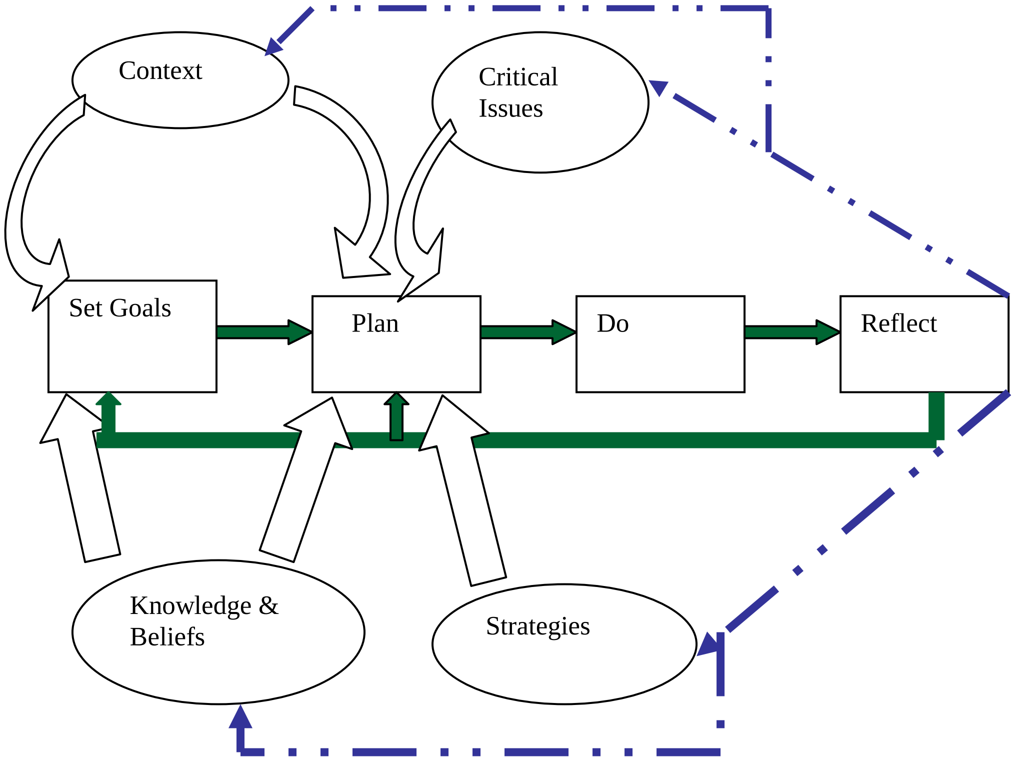

Figure 1. Framework for Designing Professional Development (Loucks-Horsley et al. 1998, p. 17).

The ovals in Figure 1 represent important factors that affect planning and goal setting, namely context, critical issues, knowledge and beliefs and strategies. The context within which this program was developed was for teachers in a developing country with a lack of content knowledge teaching at poorly resourced schools. The critical issues to be address were the promoting of equity and building of capacity for sustainable development and the development of a professional culture. The beliefs of the researchers are that knowledge is constructed by individual learners [9], and is influenced by what they already know [10] and 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. The main strategy we adopted was to develop a year-long course that was offered via distance learning.

1.2. *Features of the final HPD model*

The development of the HPD model involved three cycles of design and modification. The final version of the HPD model comprised the following elements: a study guide, assignments, workshops, reflective journals, peer support and a science kit. Each of these elements is discussed in the sections that follow.

Study guide
The study guide was designed to deepen teachers' content knowledge together with their pedagogical content knowledge. According to Shulman [11] pedagogical content knowledge (PCK) "goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching". Furthermore, teachers need to develop various thinking and reasoning skills [12], [13] and [14]; problem-solving skills [15]and experimental skills [16]. They also need to develop metacognitive skills [17] in order to monitor and manage their own learning processes, enabling them to continue to learn new physics after the end of the course. The study guide was therefore designed to integrate the development of all of these skills together with a sound understanding of physics concepts and principles.

Assignments
To help the students pace themselves and make sure they stay on task throughout the year, they were required to submit four compulsory assignments spaced out over the year. They were required to provide detailed solutions, outlining how they would explain their reasoning to learners as well as what they thought their learners' difficulties would be and how they would address them. In addition, they were asked to do a related experiment, which included taking measurements, analyzing results and drawing conclusions. They were also asked to compile and complete a worksheet for the experiment.

Workshops
The face-to-face workshops during the year were used to assist teachers with sections of the work they had difficulty with, which involved both addressing conceptual and cognitive difficulties and developing experimental skills. In addition, the workshops were used to allow the teachers to experience cooperative learning [18] and [19], which is a valuable teaching strategy when teachers have to cope with large classes. The workshops gave the teachers the opportunity to meet their fellow students, something which often does not happen in distance education and can lead to feelings of isolation.

Reflective journals
In order to encourage teachers to be reflective, they were required to write about their learning experiences on a weekly basis in a journal which was submitted four times a year, together with the other assignments. When teachers record what they have learnt, what they are still unsure of, how they are implementing different teaching strategies and how can they change their teaching practices in order to be more effective, their reflections become a tool for their own professional development.

Peer support
The peer support component is a hybrid of a Japanese practice known as lesson study [20] and a practice promoted in the USA called peer coaching [8]. In the HPD model, each teacher enrolled in the course is asked to select another teacher at the same school or a neighboring school to act as a peer. Both the teacher and the peer are asked to attend one another's classes and discuss the lessons together afterwards. Teachers in the course then

submit their comments about both their own and their peer's lessons, together with the peer's comments about the teacher's lessons.

Science kit
A science kit is provided so that the teacher can carry out some of the experiments that are part of the course. The kit was designed to fit into a "lunch box" and contains basic physics equipment, such as bulbs, batteries, magnets, iron fillings, a slinky and a tuning fork. When teachers use the kit to perform experiments, both their conceptual understanding and experimental skills are developed. In addition, when they use the science kit in their classrooms which we found happened to demonstrate phenomena and explain concepts to their learners, both their teaching skills and their learners' understanding are improved.

1.3. *Effects of the HPD model*

Data were obtained from the teachers' reflective journals, peer coaching forms and pre- and post-tests administered during workshops. Information was also obtained from two formal interviews with one teacher and several informal interviews with teachers attending workshops. Analysis of the data indicated an improvement along the three desired dimensions, namely, teachers' content knowledge, teaching approaches and professional attitudes. Furthermore, the three dimensions have a strong influence on one another, as the sections that follow will show.

Teachers' content knowledge
The teachers indicated that the study material contributed to the development of their conceptual understanding, which, in turn, enhanced their confidence in their teaching and lead to improved professional attitudes. 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".*

Teachers' teaching approaches
Marked changes in the teachers' teaching approaches were recorded. The following journal entry given below from one of the teachers illustrate the positive effects participation in the programme had on his ability to manage classroom discussions. From a one-way teacher dominated "chalk and talk" teaching approach, so common in South African classrooms [21], the approach was transformed into animated teacher-learner and learner-learner interaction, which contributed to an improvement of both the teacher's and learners' content knowledge.

> *"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"*.

Teachers' Professional attitudes
Bearing in mind the general reluctance to "walk the extra mile" amongst many teachers, the following question was asked during the formal interview: "Has your view changed on how much effort a teacher has to put in every day?" The teacher replied as follows:

> *"A teacher must work harder and harder and harder. Because if one relaxes, the learners also relaxes. For subjects such as these ones we need more and more practicals. Or practice not necessary practicals. Because you have to work out a number of problems, so say that I finally come to grips of what is going on here, because I usually give them this example you cannot ride a bicycle by looking at someone riding a bicycle, you need to ride also. You fall then you start, then there come a time that you can ride"*.

This teacher experienced a striking increase in the pass rate of his Grade 12 Physical Science Higher Grade learners from 43,2% in 2001 (before he took the course) to 61,1% in 2002 and 84,4% in 2003. This change took place after this teacher enrolled for Physics for Teachers I (during 2002) and Physics for Teachers II (during 2003). Given that he teaches in a deep rural school with very few facilities, these results are especially impressive.

1.4. *Conclusion*

For physics teacher development in the South African context to be effective and sustainable, we propose that teachers need holistic development that integrates content knowledge, teaching approaches and professional attitudes. The Holistic Professional Development model was designed to facilitate such development. The following elements formed part of the final HPD model: a study guide that integrated the deepening of teachers' understanding of physics concepts and principles and pedagogical content knowledge with the development of a range of skills, assignments, reflective journals, peer support and a science kit. Although all of the elements of the model are important, peer support played an important affective role in that it did much to alleviate the problem of teacher isolation. Also, although not specifically planned for, it contributed to the gradual establishment of a professional community of teachers.

The development of the HPD model was an iterative process comprising a continuous cycle of design, implementation, feedback, reflection and modification. During this cycle, weaknesses were identified and addressed, leading to changes in the model. Thus, the cycle leads to continuous improvement.

Our results have shown that the application of the HPD model has the potential to extricate teachers from a vicious cycle where poor content knowledge leads to lack of confidence and enjoyment, resulting in an unwillingness to spend time on task and use innovative teaching approaches. Instead, teachers can become part of a virtuous circle where improved content knowledge leads to increased confidence, enjoyment and a willingness to spend more time on task and use more learner-centred teaching approaches. Examination results improve, teacher morale goes up, a professional community begins to develop, and the system as a whole starts to improve.

Acknowledgements

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