The structure and evaluation of a holistic professional development model for Physics teachers

Jeanne Kriek[1] and Diane Grayson[2]
[1]*Centre for Improvement of Mathematics, Science and Technology Education, University of South Africa, South Africa*
[2]*Department of Physics, University of Pretoria, South Africa*
kriekj@unisa.ac.za; graysdj@absamail.co.za

A holistic model for the development of South African secondary school physics teachers in a distance education context was constructed. The model was tested with 75 teachers over a period of four years. The model was developed in three phases and provides for the simultaneous development of teachers along the following dimensions: content knowledge, teaching approaches and professional attitudes. Results showed development of the teachers in these dimensions. In the development process some of the elements of the model were changed, some left unchanged and new ones added. The final model included 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. In this paper a brief description of the research that culminated in the Holistic Professional Development (HPD) model will be given as well as how the model was evaluated. Evidence will be presented for the effectiveness of the model in helping teachers develop along the three desired dimensions.

Introduction

Mathematics, Science and Technology Education have been a national priority for several years, as evidenced, for example, by the National Strategy for Mathematics, Science and Technology Education devised by the Department of Education (2001). Nonetheless, the number of learners who are obtaining a pass for Higher Grade (HG) Physical Science in the Senior Certificate examinations remains very small (Department of Education, 2004). International measures also indicate that South African learners are performing poorly in mathematics and science. Of the approximately 40 countries that participated in the last three Trends International Mathematics and Science Study (TIMSS) tests, amongst them some developing countries, South African Grade 8 learners have come last in Mathematics and Science during each study (Howie, 2001; Reddy, 2004).

American veteran educator Larry Cuban (2003) made the following comment:

> ". . I know from both experience and research that the teacher is at the heart of student learning and school improvement by virtue of being the classroom authority and gatekeeper for change. Thus the preparation, induction, and career development of teachers remain the Archimedian lever for both short- and long-term improvement of public schools."

Therefore, long-term, sustainable improvement of mathematics and science education must focus on strengthening teachers. South Africa unfortunately faces problem regarding its teachers; teachers lack subject content knowledge, qualifications, keep to traditional teaching approaches (Howie, 2001; Taylor & Vinjevold, 1999) and unprofessional attitudes are widespread (Grayson *et al*., 2001).

Kahle (1999) describes many teacher professional development programmes as being

> "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. …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."

In developing our model for physics teacher development we 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 in the South African context was the development of teachers' professional attitudes, by which we mean their understanding of their roles and responsibilities as teachers. A study done by the HSRC (Human Sciences Research Council) commissioned by the Education Labour Relations Council reveals that "teachers on average spend only 16 hours of their 35 hour working week actually teaching" Sunday Times (2005).

This brings us to the focus of our research, namely creating a model for the holistic development of teachers which integrates the following dimensions: content knowledge, teaching approaches and professional attitudes.

Research design and method

In creating a model for the professional development of science teachers that could be used in a developing country we studied existing programs and models from several different countries. These programs include: PEEL (Australia), Discovery (USA), Cognitively Guided Instruction (USA) and the Japanese approach to professional development. These programmes were selected because they have shown themselves to be sustainable over a long period of time. Two models for professional development were also studied, namely the models of Bell and Gilbert (New Zealand and the UK) and Loucks-Horsely *et al*. (USA).

In considering the above mentioned professional development models and projects, a great deal of consensus about what constitutes effective professional development was found. The following features have been found to be important and almost all were included in the development of the HPD model:

- reflection on teachers' own practice;
- development of teachers' content knowledge;
- supply of infrastructure to support teachers;
- collaboration with fellow teachers and researchers;
- provision of opportunities to try out and discuss new teaching strategies
- development of teachers as life-long learners

The study comprised three phases: phase I involved constructing a baseline of teachers' content knowledge, teaching approaches and professional attitudes, phase II creating the initial version of the HPD model taking the above mentioned features into consideration and phase III, refining the HPD model after reflection on phase II.

During the first phase, a case study approach (Neuman 1997, p. 344-380) was used. The data included 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 (Kriek & Grayson, 2002).

In the second phase, the design framework developed by Loucks- Horsley *et al.* (1998) specifically aimed at the professional development of mathematics and science teachers was used as a guide for the design and research process. 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 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.

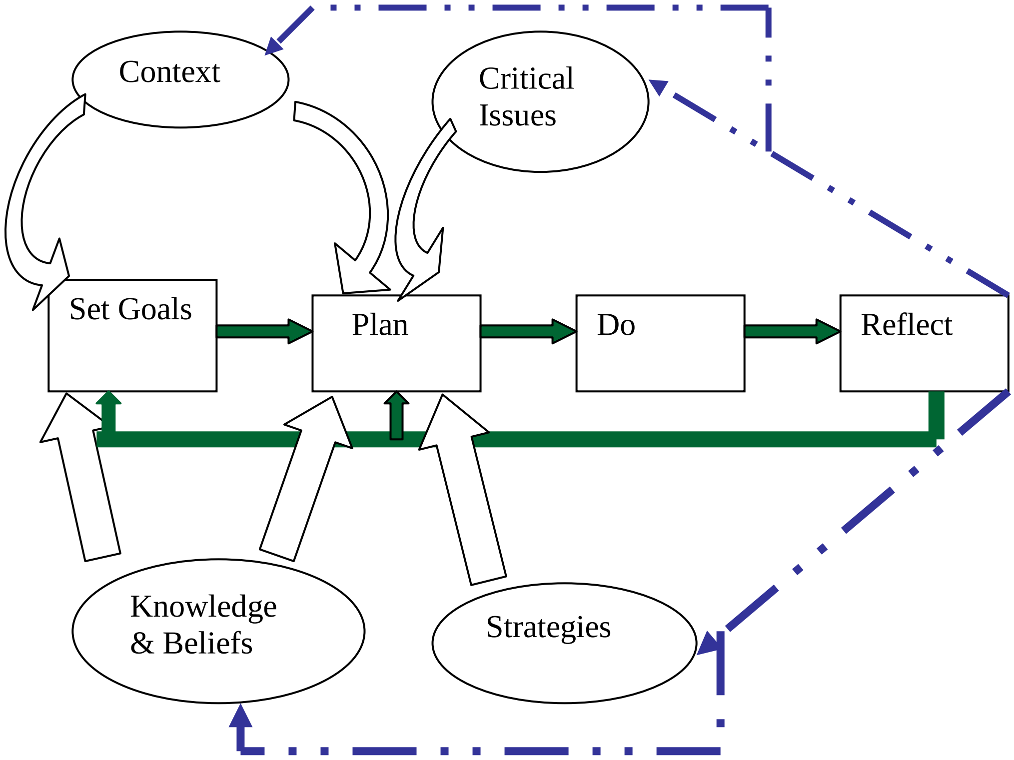

Figure 1. Framework for Designing Professional Development (Loucks-Horsley *et al.* 1998:17).

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 (Von Glasersfeld, 1992), and is influenced by what they already know (Ausubel, 1968), and that the greater the grasp of content a teacher has, the more open he/she is to innovative teaching approaches. Such teachers are more confident, eager to go to class, and to engage in a wider range of professional practices. The main strategy we adopted was to develop year-long courses, called Physics for Teachers I and II, that were offered via distance learning through a tertiary distance institution.

The elements of the initial version of the HPD model were study guides, assignments, reflective journals and workshops. The study material was designed to integrate teachers' content knowledge and pedagogical content knowledge (Shulman, 1986) as well as thinking and reasoning (Arons, 1979, 1984, 1990), experimental (Grayson, 1996), problem solving (Schultz & Lochhead, 1991), teaching and metacognitive skills (Nickerson, 1985). The four compulsory assignments were spread over the entire study period to keep the teachers on track through an extended period of time. The reflective journals were included to give the teachers the opportunity to reflect on their teaching and learning while the workshops were held to give opportunities to experience and try out new teaching strategies such as cooperative learning (Johnson, *et al*. (1986) and Johnson *et al*. (1994))

The setting of goals for and the planning of each new phase of the model were 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 model. Evaluating the additional forms of data collected e.g. interviews, workshop evaluations and journal entries influenced the new revised HPD model.

During the third phase, a number of effective elements from phase two were identified and incorporated into 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 peer support). This version of the HPD model was implemented with a new group of teachers and a final version of the model was produced.

The science kit was included to develop teachers' conceptual understanding and experimental skills. It contains basic physics equipment such as bulbs, batteries, magnets and fits into a "lunch box". The peer support component is a hybrid of a Japanese practice known as lesson study (Lewis, 2002) and a practice promoted in the USA called peer coaching (Loucks-Horsely *et al*, 1998). Enrolled teachers had to find a peer in their school, attend one another's classes, and discuss the lessons afterwards. This component was included to encourage collaboration with fellow teachers, give opportunities to discuss and try out new teaching strategies as well as address isolation, one of the problems of distance education.

The final HPD model was evaluated against the Standards for Professional Development of the National Research Council of the USA. (National Science Education Standards, 1996) and requirements for successful professional development as formulated by Jane Butler Kahle (1999). In a three-year longitudinal study in 10 district and 5 states in the USA, Desimone et al., (2002) identified a number of features of professional development activities which had significant positive effects on the teachers' increase in knowledge and consequent changes in their classroom practice. These features were also addressed in the HPD model.

Results

The effect of the different versions of the HPD model was tested on 75 Science Teachers who were teaching Grade 10 – 12 over a period of four years. The final model consists of study guides, assignments, workshops, peer support, reflective journals and a science kit. In this section we present examples of some of the data to illustrate changes in their content knowledge, teaching approaches and professional attitudes are given:

Changes in teachers' content knowledge

After analysing the data from the pre-and post tests, reflective journals, interviews, evaluation forms after the workshops and observation forms, it was found that the study material, workshops, science kits and peer support had an influence on the teachers' content knowledge.

The following journal entry illustrates how the study guide helped teachers improve their content knowledge and start critiquing their textbooks:

> By studying this unit, it made me aware that in many Grade 12 school textbooks, they talk of e.g. isolated system, and tends to explain the term "isolated" only taking it for granted that most learners and some educators understand what a "system" is. The unit clearly showed that to understand concepts such as Work, Potential Energy, etc. you must first understand the concept system, and in situations such as experiment one, one should distinguish the role players, be able to identify the system, etc. In brief one should be able to identify the system, effect of the action on the system, internal and external quantities and state of the system.

Data from pre- and post – tests collected before and after the workshops showed that the use of the science kit during the workshops on waves (first part) and electricity (second part of workshop) contributed to the development of the teachers' content knowledge. For example during the second part of the workshop on electricity, a marked improvement in the teachers' conceptual understanding of the principles involved in series and parallel circuits were noticed. This could be attributed to practical investigation performed with their science kits. However, some data from their post-test indicated that they had not mastered the concepts fully, which is not surprising, given that development of conceptual understanding is not a quick and easy process (Grayson, 2004, p. 1132).

Furthermore, the teachers wrote a pre-test during the first workshop with a class average of 22 %. During the last workshop time did not permit a post-test, however, the examination average at the end of the intervention was 45%. This also indicated an improvement in their content knowledge.

Changes in teachers' teaching approaches

The following changes in the teaching approaches were recorded by a teacher in his journal as a result of the study material:

> The PCK [pedagogical content knowledge] 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.

The following are examples of responses from a teacher during a formal interview to determine the effect of the intervention on his teaching approaches as a result of the course. This teacher obtained a mark of 8% in his pre-test even though he had been teaching Physics to Grade 12 learners in a rural school for the past 12 years.

> *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 [referring to cooperative learning] in the past but now I have introduced it.

Not only did the teachers use the newly introduced teaching approaches but they also used the workshop materials in their classroom, as illustrated by the following journal entry:

> 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.

Changes in teachers' professional attitudes

In the following journal entry one of the other teachers illustrates the interrelatedness of professional attitude and teaching. Since her learners are more positive she is more motivated.

> … 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.

From the presented data, changes could be seen in the teachers' content knowledge, teaching approaches and professional attitudes.

Not only did the model deepen the teachers' content knowledge, change their teaching approaches and positively affect their professional attitudes, but there is also some evidence that the Grade 12 learners' examination results improved. For example the pass rate of one of the teacher's Grade 12 Physical Science Higher Grade learners improved from 43,2% (before intervention started) to 61,1% the following year and 84,4% two years later.

Evaluation of the model

After trialling and re-trialling the HPD model we also compared our model to the six factors the American Institute for Research, (Buchanan, 2002) identified as critical in making professional development the most effective. They are form, duration, collective participation, content, active learning and coherence. All of these factors have been addressed in the HPD model.

The duration and form of the intervention is that the intervention programme runs for an entire academic year with face–to–face workshops, four assignments and reflective journals the teachers have to reflect in weekly. Longer, sustained and intensive professional development programmes are more likely to have an impact than a half-day event or a few of after-school sessions spread throughout the school year. Collective participation is addressed when activities are designed in a way that teachers in the same school grade or subject work together while active learning is fostered through observing and being observed. This has been addressed in the uniqueness of the peer support in the HPD model, combining peer coaching and research lessons. The content factor was explicitly addressed in the study guides and workshops that focussed on both substance and subject matter as well as how to teach the content. The coherence factor was addressed when teachers perceived themselves to be part of a coherent and cohesive program of teacher learning and to support other teachers. This was not envisaged from the start of the intervention programme, however, data from teachers indicated that because their content knowledge improved, they had more confidence in their teaching which lead to act more professional. This empowered them to assist teachers from other schools who needed help in their subject matter and teaching.

The seven principles for professional development initiatives to be effective identified in the Professional Development Project of the National Institute for Science Education in the USA (Loucks-Horsley, Stiles & Hewson 1996) were also addressed.

In addition 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. Almost all the standards were achieved except the introduction of media and technological resources, providing places where effective science teaching can be illustrated and modelled and the explicit teaching of research skills. This connects to the feature of supplying infrastructure to support teachers that were identified as important when professional development models and programs were studied. This aspect was also not addressed in the study. However, it should be looked at in future.

Implications

The development of the HPD model was an iterative process comprising a continuous cycle of feedback and reflection leading to change. Through constant reflection and feedback, limitations were identified which were rectified through changes in the model. Thus, the cycle was continuous leading to continuous improvement.

In future ways must be found to introduce media and technological resources, as well as to provide places where effective science teaching can be illustrated and modelled. Furthermore, ways to explicitly teach research skills has to be found.

References:

Arons, A.B. (1979) Some thoughts on reasoning capacities implicitly expected of college students. In J Lochead and J Clement (eds), Cognitive Process Instruction: Research on Teaching Thinking Skills (Philadelphia; Franklin Institute).

Arons, A.B. (1984) Students' patterns of thinking and reasoning, Physics Teacher. Part 2 (January), 21 – 26, Part 3 (February), 88 – 93.

Arons, A.B. (1990) A guide to Introductory Physics Teaching (New York: Wiley)

Ausubel, D.P. (1968). Educational psychology: A cognitive view. New York: Holt, Rinehart and Winston.

Buchanan, M (2002) Making Mathematics Professional development helpful for teachers. Accessed 2003-11-04 http://www.nrich.maths.org.uk/mathsf/journalf/jul02/amarticle/

Cuban, L. (2003). "Why Is It So Hard To Get Good Schools?" Teachers College Press.

Department of Education (2001). National Strategy for Mathematics, Science and Technology Education in General and Further Education and Training. Pretoria: Department of Education

Department of Education (2004). Subject statistics for the 2001 - 2004 senior certificate examinations Retrieved, May 31, 2005 from http://nikita/index.asp?src=dvie&xsrc=594..

Desimone, L.M., Porter, A.C., Garret, M.S, Yoon, K. S. & Birman, B.F. (2002) Effects of Professional Development on Teachers' Instruction: Results from a Three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24(2),* 81 – 112.

Eick, C.J. & Reed, C.J. (2002). What makes an Inquiry-Oriented Science Teacher? The influence of learning histories on student teacher role identity and practice. In Deborah Trumbull (ed) *Science Teacher Education* 401 – 416.

Grayson, D.J. (2004). Concept substitution: A teaching strategy for helping students to disentangle related physics concepts. *American Journal of Physics* 72(8) 1126–1133.

Grayson, D., Ono, Y., Ngoepe, G., Kita, M. (2001). A comparison of mathematics and science high school teachers' attitudes in Japan and South Africa. Paper presented at the *9th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education*, 17-20 January 2001, Maputo, Mozambique. 119 – 129.

Grayson, D.J. (1996). A holistic approach to preparing disadvantaged students to succeed in tertiary science studies. Part I. Design of the Science Foundation program (SFP). *International Journal of Science Education*, *18(8),* 993 - 1013.

Howie, S.J. (2001). *Mathematics and Science performance in Grade 8 in South Africa 1998/1999. TIMSS-R 1999 South Africa.* Pretoria: Human Sciences Research Council.

Johnson, D.W., Johnson R., Roy, P. & Zaidman, B. (1986). Oral interaction in cooperative learning groups: Speaking, listening and the nature of statements made by high-medium, and low achieving students. *Journal of Psychology*, *119*, 303-321.

Johnson, D.W., Johnson, R.T. & Holubec, E.J. (1994). The new circles of learning. Cooperative learning in the classroom. ASCD

Kahle, J. B. (1999). *Teacher professional development: Department of Educations it make a difference in student learning?* Testimony to the US House of Representatives Committee on Science, Washington DC, 1999. Retrieved November 7, 2002 from http://gos.sbc.edu/k/kahle.html

Kriek, J. & Grayson, D.J. (2002). Creating a holistic model for Physical Science teacher development: establishing a baseline. Paper presented at the *10th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education*, 22-26 January 2002, Durban, KwaZulu Natal. 188 – 193.

Lewis C. (2002). In Japan: Everywhere I looked - levers and pendulums. *Journal of Staff Development*, (23) 3. Retrieved August 17 2003 from http://www.nsdc.org/library/jsd/lweis233.html

Loucks-Horsely, S, Hewson, P.W., Love, N. & Stiles, K.E. (1998). *Designing Professional Development for Teachers of Science and Mathematics*. Corwin Press, Inc. A Sage publications company Thousand Oaks, California.

Loucks-Horsley, S, Stiles, K. E. & Hewson, P.W.(1996) Principles of effective professional development for Mathematics and Science education: *A Synthesis of Standards*. NISE Brief.

1(1). Retrieved September 20, 2003 from http://www.wcer.wisc.edu/nise/Publications/Briefs/NISE_brief_Vol_1_No_1.pdf

National Science Education Standards (1996) Center for Science, Mathematics, and Engineering Education (CSMEE), National Academy of sciences: Washington, D.C.. Retrieved August, 1, 2003, from (http://books.nap.edu/html/nses/pdf/chap8.pdf),

Neuman, W.L. (1997). *Social Research Methods. Qualitative and Quantitative Approaches*. Boston: Allyn and Bacon

Nickerson, R.S, Perkins, D.N. & Smith, E.E. (1985). The teaching of thinking. Lawrence Erlbaum Associates, USA. 101 – 110.

Reddy, V. (2004). Press release at the Human Sciences Research Council. November 2004.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher* 4 – 14.

Schultz, K & Lochhead, J (1991). A view from Physics. In Smith M.U. *Toward a unified theory of problem solving. Views from the content domains*. Edited by Erlbaum Associates., Inc., Publishers. Hillsdale: New Jersey.

Sunday Times (2005) SA teachers teach only half the time, 8, 23 October 2005.

Taylor, N. & Vinjevold, P. (Eds) (1999). *Getting Learning Right*. The Joint Education Trust, Wits.

Von Glasersfeld, E. (1992). A constructivist view of Learning and Teaching. In Duit, R., Goldberg, E. & Niedderer, H (Eds). *Research in physics learning: theoretical issues and empirical studies. (*pp 29 -29). Kiel: IPN Institute for science education.