Professional development program for natural science teachers

Soane Joyce Mohapi
University of South Africa
mohapsj@unisa.ac.za

Abstract
The challenges facing the teaching of science in South African schools are considerable. The article describes the professional development program involving thirty natural sciences teachers (n = 30). Teachers were drawn from one provincial education district of South Africa. Qualitative method was used to collect data through questionnaires, focus group discussions and document analysis. Teachers were selected purposively for participation in the study. Of the thirty teachers, fifteen were qualified to teach life sciences in grade 10-12, five qualified to teach natural sciences in grade 4-9 and ten qualified in teaching subjects other than the sciences in grade 4-9. Teachers' views on natural science concepts and methods are used to draw conclusions for the study. The findings of the study revealed that teachers did not understand scientific methods and natural science concepts. Given the findings of this study it is possible to suggest steps to be followed when conducting professional teacher development workshops.

Keywords: Chemical reasoning, Continuous Professional Teacher Development, Science concepts, Scientific method.

Introduction

In the South African curriculum natural science is one of the learning areas in grade 4-9. As a learning area offered in junior classes it provides a basis upon which prospective physical science learners in grades 10, 11 and 12 are selected. South Africa has few science learners matriculating with good marks in science that qualify them for further study in and science, technology and engineering (STE) fields. Moreover, those who qualify perform poorly in their first year of university studies (Horak, 2003). This study is as the results of the problems associated with the teaching of natural science in grade 4-9. Problems such as insufficient content knowledge of the subject, subject specialisation displacement and those that are linked to teacher re-deployment have compelled provincial education departments to arrange development program for these teachers. The weak performance in mathematics and science by South African learners in international studies has pointed to serious problems in science and mathematics education (Fricke, Horak, Myer & van Lingen, 2008).

Many science teachers are not qualified to teach science either in terms of subject matter training or professional qualifications (Mji & Makgato, 2006). For example, many teachers who are trained in life science find themselves teaching physical science, a subject with a specialized content (Gauteng Department of Education Internal Moderators' Report, 2008). Thus there are more teachers who are trained for life science than those trained for physical science. Most of the participants in this study were affected by these, hence there was a need to arrange an intervention workshop to assist the teachers.

Teacher profile

In terms of the regulations promulgated in government notice R1676 of 1998, section 5(2) of the Act, the Ministry of Education (MEC) in the concerned province determines allocation of teaching posts to each school. In doing post establishment for schools the ministry must consider the following factors: (1) consult with teacher unions and School Governing Bodies (SGB), (2) consider provincial budget, (3) the need for redress in the implementation and promotion of curriculum policy, and, (4) schools' enrolment. Apart from the posts that are distributed to schools through a staffing model, provision should also be made for the ad hoc allocation of posts to schools where specific circumstances necessitate such additional allocations. A limited, but sufficient number of posts therefore need to be retained in a central pool for this purpose. Due to the unavailability of science and mathematics teachers in South Africa, these posts are eventually used to appoint foreign teachers in these subjects.

Initially it was a requirement for teachers to have a relative equivalent qualification value (REQV) of level 12 (REQV 12) in order to be appointed. An REQV is a rating system used by the National Department of Education to classify teachers in terms of their professional qualifications. For instance, a teacher with a matriculation certificate and three years of training (M+3 qualification) is classified as being at REQV 13 level, while a teacher with an M+4 qualification would be placed at REQV 14. In terms of occupational specific dispensation (OSD), a fully qualified teacher should have REQV 14 and duly registered with South Africa Council of Educators (SACE). However, some of the teachers with REQV 13 qualification are still in the system and have been advised to improve their qualification. Participants in the study were redeployed from Intermediate phase to General Education and Training (GET) schools to teach Natural Science, although they have teachers' qualification, they did not major in science at the training colleges. The department of education envisaged that the teachers might have challenges in facilitating the learning area and hence arranged professional developmental programs to assist the teachers in content and pedagogy.

i) Challenges faced by natural science teachers

It has been highlighted that persistent inequalities remaining within the educational system and suggested further research on the quality of education in schools, especially in the former homelands (Statistic South Africa, 2005). The 2004 Systematic Evaluation Report on grade 6 pointed to low levels of performance in Language of Learning and Teaching (LoLT), mathematics and science. Also, Howie (2002) alluded to the influence that mathematics and science teachers' instruction have on the performance of learners. The quality of teacher's instruction can be influenced by several factors. For instance, participants in the study cited the following factors and claimed that they impact on their instruction: poor conditions of service, low salaries and poor benefits, inadequate incentives, arbitrary redeployments, unprofessional treatment, lack of development opportunities and insufficient support, inappropriate policy implementation and work overload. The introduction of the new curriculum, together with the system of continuous assessment that is recently introduced in schools, has also been identified as an additional work overload to teachers.

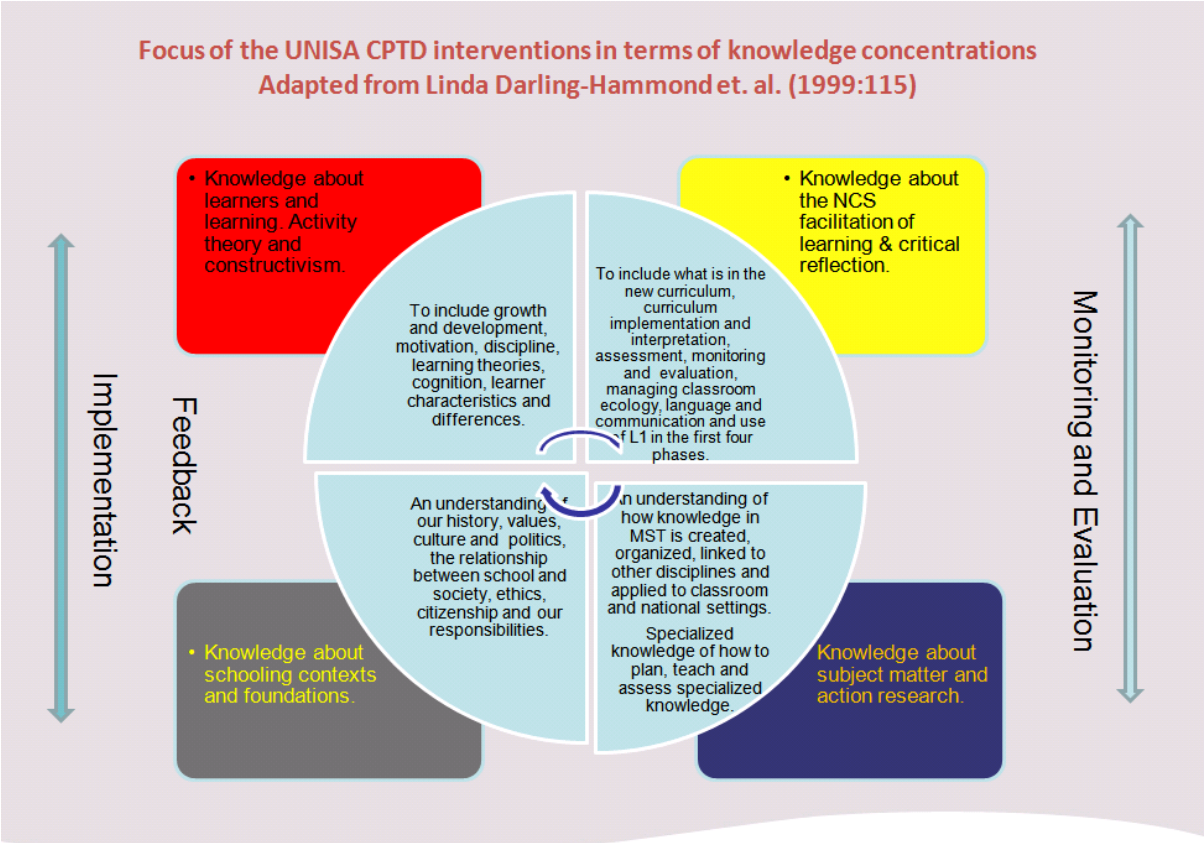
Kloot, Case and Marshall (2008) indicated that the unequal education provision is being felt throughout South Africa, and many learners are not adequately prepared to study science

related subjects at tertiary level. Kopolo (2009) mentioned the following as challenges faced by science teachers: lack of well equipped laboratories and science equipments, low performance in science and mathematics and under-qualified teachers. According to Kopolo (2009) the study conducted by World Bank has also supported this claim, mentioning that 60% of the teachers are not trained in science, are inexperienced and have limited understanding of science. This goes to the teachers used in this study.

Conceptual framework

The study used the below-knowledge-concentrations as a framework to guide teachers' development program.

Figure 1: Conceptual framework to guide teacher development program



The framework suggests that teacher development programs should focus on four knowledge domains, namely, (1) knowledge of learners: the teacher must have knowledge of a socio–cultural background of the learners, (2) knowledge of National Curriculum Statement (NCS), the teacher to understand policies involved in teaching practices and use learner centred approaches to present subject content, moving from constructivist approach, the teacher should create a platform where learners create meaning of their own learning.

(3) Knowledge about subject matter and research procedures. In this domain teachers are expected to demonstrate competency in their respective subjects of specialisation. This has to be demonstrated in ways in which teachers handle their classroom lessons and learners' queries. They should also demonstrate knowledge of research techniques. Given that natural science is an inquiry-based subject, research forms a crucial component of the subject. In this regard a science teacher should be able to provide direction and clear

guidelines on how to conduct research activities, and, (4) Knowledge about schooling context and foundations. An experience teacher is an effective and productive educator. A science teacher should strive to acquire in-depth knowledge of the school and its context. The latter includes knowledge of school policies and those of the department to which the teacher is reporting. This aspect would also entail knowledge of subject policies such as those guiding the assessment techniques of the subjects.

Indeed, teachers who respond positively to these for domains of knowledge would be able to assist their learners to do well in their respective subjects. In designing the approach to provide developmental assistance to teachers who participated in this study this framework was closely considered. Teachers had to be assisted in line with the four suggested domains suggested in this framework.

Objectives of the study

The study will determine the effect of the development program in enhancing teachers' understanding of the knowledge of science concepts and methods in order to improve the teaching of natural science in grade 4-9. Furthermore, the current study aims to suggest steps to be followed when conducting teachers' professional development programs.

Research methodology

This study used both quantitative and qualitative approaches. Participants were surveyed through a variety of techniques. According to Merriam (1998), two aspects of qualitative research that distinguishes it from quantitative work are qualitative description and induction. During training University of South Africa (UNISA) specialists described scientific concepts and method to the trainees. The following techniques were used:

Pre- assessment questionnaire was administered prior to the commencement of the program. All thirty teachers responded to the questionnaire. The results from the pre-assessment informed the design of training manuals and workbooks. The first five-day development session was conducted during September 2009 schools' holiday, the second five-day session was during January 2010 holiday, the final session was during June-July 2010 school holiday. Teachers evaluated the program by completing evaluation forms at the end of the workshop. The results of the evaluation assisted in drawing conclusions and also in answering the research objectives. Summative assessment of teachers' knowledge took place on the last day of the third session. Teachers were observed while teaching their learners in August 2010 and were given subsequent feedback. Post-assessment questionnaires were used at the end of the program, where teachers described their views on natural science concepts and methods, their level of understanding scientific concepts and how they felt about the program.

Sample and sampling techniques

According to Ary et al. (1996, p. 437), the main consideration when deciding on sample size is the degree of accuracy one wants to achieve in the estimation of the population values. Thirty teachers (n = 30) were selected purposively for participation in the study. Of the thirty teachers, fifteen were qualified to teach life sciences in grade 10-12, five qualified to teach natural sciences in grade 4-9 and ten qualified in teaching subjects other than the sciences

in grade 4-9. Participants were selected by the Free State Department of Education after having identified those that needed the development the most. These included teachers who taught life science and other learning areas but currently redeployed to teach natural science in grade 4-9. Those that were qualified to teach natural science needed further development in subject content, while those qualified to teach life science and other subjects needed development to teach natural science. Those qualified to teach other learning areas needed development as they lacked content knowledge including carrying out of practical work (experiments) as well as presentation (scientific method) of scientific lesson. This was mentioned by Free State education officials in their request for the workshop. The request was also based on low performance of grade 10 learners in physical science during the final 2009 examination. In this request it was also mentioned that teachers were in possession of both Advanced Certificate in Education (ACE) and Diploma in Education, however, the performance of learners in natural science was low.

Instruments

During development program for this group in 2009-2010, three natural science specialists facilitated the program. Questionnaires were used to elicit information that could not be observed directly. Pre- and Post-assessment questionnaires were given to teachers to determine the level of their understanding of scientific method and concepts. Teachers were also involved in group discussions. Observation is the systematic process of recording the behavioural patterns of people (Mouton & Marais, 1990, p. 15-157). Teachers were observed while teaching natural science lessons. The researcher observed how learners and teachers behaved during these lessons. What the researcher observed and found in teachers 'summative assessment results and the responses from teachers during the course of the program were used to triangulate pre-assessment results on teachers' understanding of scientific concepts and methods.

Data collection and procedure

Natural sciences study material and workbook activities on scientific method and concepts that included carrying out experiments were part of the documents used during the development program and each participant received a copy. Three natural science specialists from UNISA facilitated the program and the researcher was one of the specialists. During the program the participants were divided into groups to allow active participation and were observed especially when doing practical experiments. Summative assessment based on the workbook was given to the participants at the end of the program. Teachers' assessments sheets were marked and interpreted.

Results and analysis

i) **Pre- assessment questionnaire**

Pre-assessment results revealed that fifteen teachers were qualified to teach life science, while ten were qualified to teach their subjects other sciences and only five were qualified to teach natural science. Prior to the development program, teachers were unable to

indicate characteristics of natural science lesson. Teachers' knowledge of interpreting scientific concepts and methodology in presenting certain Science experiment was insufficient. Below are other specific findings from pre-assessment:

- Twenty out of thirty teachers thought mixing flour and dry yeast is a chemical reaction, an atom is the size of a dot, stirring is taken to be a catalyst whilst yeast is also taken as a catalyst in the baking of bread, dissolution is thought to be a chemical reaction while sugar changes to liquid when it dissolves (confusing dissolution with melting), sugar is non-polar but dissolves in water because of heat, magnets are not made from metals, reaction between $AgNO_3$ and NaCl is a mixture (physical change) as it results in a white precipitate which looks like a homogenous mixture (this is an additive view and not a chemical process view).

- Twenty teachers were unable to identify chemical reactions and associated them with magic. Burning of candle in a closed system revealed a huge misunderstanding, as some participants thought that excess of smoke gets (smoke eats the oxygen) rid of the oxygen thereby extinguishing the candle light. Some did not come to terms with the boiling points like (-183^0C) as they could not comprehend negative temperature values and appeared more comfortable with positive temperature values (e.g 100^0C). Some did not understand principles

- Twenty teachers did not take into consideration the idea of different boiling points when dealing with fractional distillation and some did not know that the principle of solubility applies during filtration.

- Twenty two teachers did not know the difference between mass and weight. This confusion probably originated from everyday use of the word 'weight' in shops.

- Calculations involving converting measurement units (e.g converting metres to millimetres) were not apparent to twenty teachers.

- It is clear from the alternative frameworks that emerged that the teachers did not have clear chemical reasoning about some chemical concepts. This may have been due to lack of content knowledge or incorrect everyday usage of scientific terms. Some teachers did not have a clear understanding of differences between chemical and physical changes.

ii) Focus group discussions

The discussion during development program focused on challenges faced by teachers in schools and the way they felt about the content intervention program that they attended. After ten days of the program it appeared that some participants were now very confident to go and present topics about matter and materials in their respective schools. One participant commented on calculations about density:

> *"I think I have gained something from this program as I now feel very confident to go and teach the topic of density to my learners. I used to skip the density topic"*

Furthermore, participants revealed that they had no proper laboratories and equipment in their schools. This was evident during the three sessions as they were not very confident when performing experiments. They insisted on laid down procedures and acted more like their learners (too excited to carry out experiments). However, they found it difficult to plan an activity given a set of apparatus. When asked why planning an activity could be difficult one participant responded:

> *"I was not trained as a natural scientist, I was trained to teach geography and history"*

Another participant responded:

> *"I was not trained as a natural scientist, I was trained to teach economics, accounting and technology"*

The fact that some teachers were not trained in the area of natural science poses a serious challenge in the teaching of science.

iii) Scientific method and document analysis

Some participants found the tasks of formulating the investigative question and hypothesis very difficult. For instance, the aim of an investigation was mistaken for the hypothesis. Document analysis carried out was in the form learners' class workbooks, lesson plans and portfolio of evidence (written test) given to teachers as summative evaluation after the teacher- intervention program. What emerged from the learners' class workbooks revealed that some teachers were not very confident on how to determine in learners' workbooks the content they had imparted to learners. Some ideas in the learners' class workbooks prior the intervention program reflected the same lack of understanding that teachers showed during the sessions. This was not a surprise at all. An assignment about lesson planning involving an experimental activity given to participants at the beginning of the program revealed good lesson planning format (good pedagogical content) but lacked proper sequencing (bad pedagogical content) of what the activity required. In some cases, important content information was completely absent indicating lack of content knowledge in the natural science teachers. There seems to be a missing link between pedagogical content and the actual subject content knowledge in the natural science teachers and this could have negative effects on the acquisition of content knowledge by our learners in GET schools. Participants did fairly well in the summative assessment, indicating that conceptual change had occurred to most of them. The performance by participants ranged between 49% and 89% with an average of about 69%. The results of the summative assessment also revealed that some participants still had challenges in some areas of the content taught to them. Fifteen of the teachers still did not understand the purpose of the Liebig condenser in the fractional distillation apparatus. This indicated the need for further development program for natural science teachers in the content for better science teaching.

iv) Classroom observations

Observation during classroom practice followed after the document analysis. Participants were followed up in order to observe if there had been any impact due to the development program carried out in three successive sessions. Those teachers who were observed teaching natural science lessons in their classrooms, showed a lot of confidence in their

presentations. They appeared to have been motivated to a considerable extent. Their learners also appeared to be highly motivated. Further document analysis on lesson planning showed a remarkable improvement. For example, the sequencing of events in an activity showed concept development and the teaching and learning process were very evident. Comments by both learners and teachers after the lessons spoke volumes of the impact of the program.

v) Post-assessment questionnaire

Teachers' responses in this questionnaire revealed that teachers were now confident to present natural science lessons, one teacher commented on the teaching of calculations about density and said:

> "*I think I have gained something from this program. I am now confident to teach topic on density to my learners"*

Twenty five teachers indicated that they need continuous professional development not only in natural science but in subjects, with more emphasis on mathematics, science and accounting.

The post-assessment results revealed that the time allocated to the program was little. In this regard one teacher said:

> *"Teachers should be development continuously, at least 5 days in each month"*

Discussions, implication of the study and suggestions

There is general observation from this study, that professional development of natural science teacher is needed. The objectives of the program were, (1) to improve the teaching of natural science in grade 4-9, (2) to promote understanding of scientific concepts, and method, and, (3) to suggest steps to be followed when conducting development program for teachers. The results of pre-assessment intervention revealed problems in the teaching and learning of natural sciences in grade 4-9 classes. It also surfaced that some teachers are not qualified to teach natural science and did not understand scientific concepts and method. During the first five days teachers found the tasks of formulating the investigative questions very difficult. However, as the program progressed, teachers started to understand and participated effectively during group discussions. When they were supposed to give a report back, they provided better responses to those they provided at the start of the program.

The results of post-assessment verified that the program had positive impact on teachers' understanding of science method and concepts. The summative assessment results yielded impressive results. Teachers obtained an average score of 69%. The assessment results were testimony that such teacher development program was necessary.

It was evident that thirty natural science teachers who participated in the program did not make meaningful progress to teach their subject content effectively. These observations suggest that UNISA should conduct this kind of program continuously to assist teachers who are lagging behind in terms of their teaching duties. Furthermore, to successfully conduct workshops to assist teachers with problems the following steps are suggested (figure 2 below):

Figure 2: Suggested steps for professional development of teachers

In terms of this model of teacher developmental program the researcher has suggested three steps that should characterise intervention. In the *first step*, it is imperative to assess the knowledge status of the teachers ahead of intervention. This process entails collection of data that relates to teachers' classroom practice. This data should assist the service provider to design appropriate material that will address teachers' needs. At this point facilitators are able to position themselves properly in order to render effective service to the trainees. The *second step* is concerned with on-site interaction. Because the material for the workshop is prepared facilitators are able to interact with the trainees effectively. Discussions takes and problem solving tasks are executed by both the facilitators and trainees. In our study this aspect is highlighted when teachers are arranged in working groups to generate solutions and new ideas. The final stage, *step three*, is all about evaluating the success of the program. A post-assessment evaluation is carried. In our study teachers were given a post-intervention questionnaire to assess the status of content knowledge. Interviews were also conducted with some of the teachers who acceded to the view that the program was effective. Also important was the analysis of data to generate new suggestions and recommendations for future programmes.

Given that this study was conducted in one province with only thirty teachers, it is not possible to use its findings to generate a plausible generalisation. However, results obtained from this study are useful in highlighting some of the critical challenges experienced by natural science teachers as a result of re-deployment of their services and inadequate subject knowledge. Results obtained from this study could be used to map out intervention strategies to deal with similar challenges in other provinces and schools.

References

Ary, D. Jacobs, L.C., & Razavier, A. (1996). *Introduction to Research in Education* (5th ed.). Florida: Harcourt Brace College.

Department of Education. (1995). White Paper on Education and Training in South Africa; First steps to develop a new system (White Paper One). Pretoria: Department of Education

Fricke, I. Horak, E., & Meyer, L., & Van Lingen, N. (2008). Lessons from a Mathematics and science Intervention Programme in Tshwane township schools. *South Africa Journal of Higher Education, 22 (12).*

Gauteng Department of Education. (2008). Internal Moderators' Reports: National Senior Certificate Examination Mechanical Technology–Xitsonga. Available at www.gov.za.

Horak, E. (2003). Developing the small school pool for engineering in South Africa. Proceedings of the 7th Baltic Region Seminar on Engineering Education. UICEE series with UNESCO support. St. Petersburg. Russia, 4-6 September.

Howie, S. (1999). Report on science and Technology centres in South Africa. Human Sciences Research Council, Pretoria, South Africa.

Kloot, B., Case, J. M., & Marshall, D. (2008). A critical Revision of the educational Philosophies underpinning Science and engineering Foundation programmes. *South Africa Journal for Higher Education, 22(4).*

Kopolo, L. (2009). Assessing the impact of qualified Mathematics and Science Teachers in the Buffalo City area: Nelson Mandela Metropolitan: Submitted in partially fulfillment of the requirements for the degree of Masters in Business Administration: Nelson Mandela Metropolitan University.

Macmillan, J. H., & Schumacher, S. (1997). Research in Education: A conceptual Introduction (4th ed.). New York: Harper Collins.

Merriam, S. B. (1998). *Qualitative Research and Case Study: Applications in Education*. New York: Longman.

Mji, A., & Makgato, M. (2006). Factors associated with high school learners' poor performance: a spotlight on mathematics and physical science. *South African Journal of Education, 26(2),253-266*.

Mouton, J., & Marais, H. C. (1990). Basic Concepts in the Methodology of the Social Sciences. Pretoria: Human Sciences Research Council.

Statistic South Africa.(2005). Annual Report. Statistic South Africa