

Creating a holistic model for Physical Science teacher development: establishing a baseline

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Abstract

We are in the beginning stages of trying to develop a holistic model of teacher development that will integrate the development of teachers' content knowledge, pedagogical content knowledge and teaching approaches, and professional attitudes. As a first step in the process, baseline information on three Physical Science teachers were collected in each of these three dimensions using a variety of data collection methods. The data were combined to create case studies. The results indicate that there is a need for development in each of the three dimensions. Furthermore, the results show that there is a strong interaction between teacher's content knowledge and the focus of their lessons. An important implication is that teachers' content knowledge and teaching approach cannot be addressed in isolation from one another. In addition, teachers' attitudes towards their own professional development and time they are willing to spend on teaching-related activities play an important role in the quality of instruction they are able to provide.

Introduction

The performance of learners from previously disadvantaged schools in Physical Science is a cause of great concern. Statistics from the Department of Education (June 2001) show that not only is the number of Higher Grade passes in Grade 12 Physical Science not increasing, it is actually decreasing. This number has 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 have increased from 35200 (of 65200 enrolled) in 1997 to 55000 (of 125100 enrolled) in 2000. Evidently, more learners are being channeled into Standard Grade Physical Science, presumably in order to increase the pass rates. A similar trend was observed during classroom observations. Of the 45 Grade 12 learners who were observed in two Physical Science classes at two schools, only 4 learners were registered for Higher Grade. We thus see a situation where more learners are taking Physical Science but fewer at a level that could lead to tertiary level science studies. The problem is particularly acute in formerly disadvantaged schools. The Faculty of Science at Unisa

“has conducted research in a number of schools for mainly black learners in a single district. In these schools, the situation reached an all time low in 2000, when, out of 11 such schools, only 5 learners passed Higher Grade Physical Science in matric. This was compared to 16 self managed (previous ex model C or ex Transvaal Education Department) schools in the same district, which produced 337 Physical Science Higher Grade passes in the same year.” (Unisa News, 2001)

On the other hand, the schools whose learners passed shared certain characteristics:

“Observations of all of the district's senior schools show that the schools whose learners consistently passed the Physical Science examinations did the prescribed practical work, in well-equipped laboratories, with confident, well-trained educators who were supported by skilled and motivated technical staff. In addition, Science teaching and learning took place in a well-managed, safe school climate, with appropriate materials for learning support.” (Unisa News, 2001)

In order to try to improve these results, it is reasonable to look at the teachers. A large number of maths and science teachers are either unqualified or underqualified in these subjects (Arnott et al, 1997). In addition, a study of maths and science teachers' professional attitudes (Grayson et al, 2001) indicated that many teachers hold unprofessional attitudes, attitudes which must contribute to the poor performance of their learners. Furthermore, many classes are dominated by “teacher talk and low-level questions” (Taylor and Vinjevold, 1999, 143), an approach which is unlikely to develop the thinking skills needed to succeed in maths and science. Another major reason for the poor performance of these schools for black learners,

therefore could be that they rarely, if ever, do the required practical work. "Very few outcomes can be achieved without practical work in the teaching of Physical Science" (Wolmarans, 2001).

It is against this backdrop that we are in the process of trying to develop a model for the holistic development of practicing teachers. The function of the model is to propose a way to integrate the development of teachers' content knowledge, pedagogical content knowledge and teaching approaches, and professional attitudes.

Aim

The aim of the study reported in this paper is to obtain baseline information on teachers in each of the three dimensions that will form part of the model, namely content knowledge, teaching approaches and professional attitudes.

Method

A case study approach was used to obtain baseline data about Physical Science teachers' content knowledge, teaching approaches and professional attitudes. Three secondary Physical Science teachers were selected and will be referred to as Teacher A, B and C. They teach Grades 8-12 in different township schools around Pretoria. The number of learners in these schools varies from 525 to 1100. The Grade 12 Physical Science classes are relatively small. Teachers A and B are responsible for Grade 12 learners in Physical Science. The highest grade that teacher C teaches is Grade 10, but he has taught Grade 12 learners in the past. Of the 45 learners in the two Grade 12 Physical Science classes, only 4 were in the Higher Grade.

All three teachers were enrolled in a one-year GDE INSET programme and were asked if they would be willing to participate in the study. In order to assess the teachers' prior content knowledge the GDE INSET program included a pretest based on a test designed by the HSRC to test the knowledge and insight of potential Physical Science educators. The same test was written as a post test, although the participants did not know in advance that the same test would be given. The teachers also had to complete a test comprising items from the TIMMS (1995) test designed for Grade 12 learners.

In order to obtain baseline information on their professional attitudes, the teachers had to fill in two self-evaluation tests, one a personal evaluation (Prinsloo, 1987) and the other on what they perceived to be their effectiveness as a Physical Science educator (Trowbridge et al, 1981, 330 -1). They also had to fill in a questionnaire on Professional Attitudes (Grayson et al, 2001).

In order to obtain baseline information on their teaching approaches, classroom observations were carried out. In addition, the teachers were required to complete assignments and to compile a one-hour activity for Grade 11 learners, giving the intended outcomes of the activity, the teacher's preparation, the teacher's role, the learners' activities and assessment. In one assignment they had to give five reasons why it makes sense to use a variety of teaching methods when teaching Physical Science and in another assignment they had to compile a concept map. Qualitative data was obtained from pretests, assignments, examinations, researcher classroom observations and reflections. The data was collected and interpreted to generate case studies (Neuman, 1997, 344-380) for each of the teachers.

Results

The case studies reveal problems in each of the three areas referred to above, namely teachers' content knowledge, teaching approaches and professional attitudes.

In order to evaluate teachers' content knowledge two sources of information were taken into account. One source was the marks the teachers obtained in tests (discussed in the following paragraph). The second source was the understanding of the content that was revealed through lessons and lesson plans (see examples later.)

The marks obtained for the pretest and TIMMS test were: for Teacher A, 46% and 28%, Teacher B, 8% and 38% and Teacher C, 54% and 31%, respectively. When asked to evaluate their own effectiveness

(Trowbridge et al, 1981, 330-1) they all indicated that they had a thorough knowledge of Physical Science. Teacher A gave himself 4,2 out of 5, Teacher B, 4,75 out of 5 and Teacher C, 4 out of 5. These results suggests that in addition to needing to develop their content knowledge, these teachers also need to develop their metacognitive awareness, in particular, the ability to judge their own understanding (Flavell, 1979).

In the post test Teacher A, who attended the classes frequently on Saturdays got a mark of 65%. This teacher's matriculation results showed that he obtained an F symbol for Maths LG and had no Physical Science. He then went back to school the following year and repeated Maths and Science and obtained a D symbol for both. It could be concluded that he really wants to improve his content knowledge.

Teacher B stopped the course halfway through the year. When asked why he said he had, "too much to do at school," and, "everything is too much" for him.

Teacher C obtained a mark of 45% in the post test. Out of the 8 contact sessions in the second half of the year he only attended 3. He wants to leave Education. When asked why he said, "I have been temporary for 10 years. I have been to an interview for the post I am in, but 6 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."

Typical problems from the pre-tests were that not one of 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 maths 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." (Schoenfeld, 1991).

During classroom observations of Teacher A and from his assignments it was clear to the researchers that he experienced conceptual problems, such as not being able to distinguish between the concepts of distance and displacement. His lack of deep-level content knowledge also manifested itself in what he chose to focus on in his lessons (see later), choosing to focus on simple mathematical manipulations rather than on central physical concepts. In one assignment for the GDE Inset program the teachers had to write a one hour *activity for Grade 11* learners (see method). They had to choose any topic from the physics prescribed textbook. Teacher A's response was the following:

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

- (a) Calculate units of displacement (ie 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 reveals that he does not appreciate what is significant. He wants learners to calculate the units of displacement and misses the importance of physical quantities. A lack of depth of conceptual understanding is also evident in the following:

In the introduction to his activity he posed the following questions to learners:

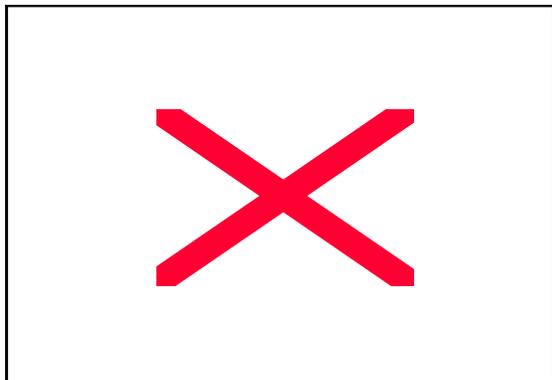
What are the units of velocity and of time? (The answer he expected was m/s and s)

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)

For Grade 11 learners we would expect more challenging questions. Another of his activities is given below.

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



He said he would ask one of the learners to calculate the area of the triangle and a square formed in the graph and add them together. He then concludes “the answer is in metres and metres are the units of distance and displacement.” The conclusion from the answer above is that, as far as he is concerned, the area under a velocity versus time graph gives us **distance or displacement.**” It appears that he does not appreciate the distinction between these two concepts.

In response to the same assignment Teacher B chose a topic which did not reveal an obvious lack of conceptual understanding, while Teacher C wrote the following:

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.

Again the stated outcomes of his lesson reveal that he does not appreciate what is significant since he has chosen to focus on “dividing the graph into sections”. Instead of focusing on salient physical concepts, he has focused on mathematical manipulation. Further on in the assignment he writes:

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)

B Linking the pre-knowledge with new knowledge

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



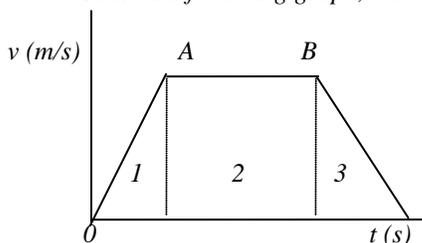
Answer: Area = $l \times b$

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 $s = (l \times b)$ as in 2

units: s metres

*proof: $s = vt$
 $= m/s \times s^{-1}$
 $= \text{metre}$*

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).

From the example given it can be concluded that Teacher C has a lack of conceptual understanding. He has an inappropriate focus and misses the point. He muddles the quantities and their units. He concludes that because the units are meters the quantity involved must be displacement. This is however an invalid conclusion as there are numerous examples of different quantities that have the same units, such as density and concentration or work done and kinetic energy.

Some results on baseline Professional Attitudes were very interesting. In response to a question in the Professional Attitudes questionnaire (Grayson et al, 2001) where the respondents had to indicate whether they think it is a reasonable thing to expect from 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 said “rarely” or “never”, viewing these periods as time to be spent with family. This is in sharp contrast to the practices common at ex-Model C schools, where spending time in the evenings and over weekends on marking and preparation is the norm rather than the exception. Thus there is a need for a change in attitude from seeing the work of a teacher as something that ends when classes end to something that extends well beyond the confines of the formal school day.

In another question in the questionnaire asking teachers the extent to which they agreed or disagreed (using a 5-point Likert scale) 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,” Teacher C selected neither agree nor disagree (3) but suggested that someone must give the lecture on his behalf. This indicates that he feels that the responsibility lies somewhere else. As part of professional development, it would be important for the teacher to undergo a change of attitude in order to take ownership of his own content knowledge and be willing to study on his own so that he can teach all sections of the curriculum.

One of the questions on teacher conduct in the questionnaire was “how often have you heard of teachers coming late to class.” All three teachers’ response was “often”. This was clearly seen during classroom observations when some teachers only returned to their classes 20 minutes after break. Furthermore, it was observed that Teacher C left his class before the end of period. When asked why he replied, “I usually leave a few minutes before the class ends to prepare for the following class.”

During classroom observations it was apparent that the only teaching approach used was the “question and answer” mode by all three teachers. The teachers asked questions and the learners were expected to answer in a chorus. Learners do not bring textbooks to class. At two schools the learners had to share textbooks. The teachers did not use the textbook as a teaching aid. Only Teacher A gave homework out of the textbook. Of the 5 school observations that were done, not once did any of the teachers check whether their learners had done their homework.

When asked to show what physics apparatus was available, Teacher A showed a drawer in a cupboard in his class with some loose electricity apparatus. It seemed clear that it was not used at all. Teachers B and C showed a van der Graaff generator without a belt and covered with dust. The three teachers do not do physics practical work. The reasons they gave were that they were not equipped with physics apparatus or

that they did not know how to do it. Teacher C had to borrow trolleys from nearby schools to do the experiment for the Grade 12 portfolios. Teacher A got his physics apparatus from the Medunsa bus. The bus visits selected schools once a month. The teachers must let them know beforehand what apparatus they must bring along. The Medunsa advisor does the demonstrations. The learners do not handle the apparatus. By contrast, the schools visited all seem to be well equipped with Chemistry apparatus, mostly micro chemistry kits.

Implications

The results presented in this paper give us insights into problems experienced by Physical Science teachers in the areas of content knowledge and metacognition, professional attitudes and the use of limited teaching approaches.

The results suggest 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 be different.

From the classroom observations, it is clear that there is considerable room for growth in the use 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 indicate that there is a need for the teachers to be prepared to spend more time on school-related work, including improving their own content knowledge.

Future research will concentrate on trying to find ways to help the teachers develop simultaneously in all three dimensions.

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