Are Grades 10-12 physical sciences teachers equipped to teach physics?

ILSA BASSON
University of South Africa

JEANNE KRIEK
University of South Africa

South African schools have been confronted with educational reform since the mid-nineties and the process is still continuing. The concomitant changes put a very high demand on physical sciences teachers and also have an impact on teacher behaviour. The purpose of this study was to probe whether teachers could be considered equipped to teach the physics part of the FET physical sciences curriculum. A revised framework on teacher behaviour, which includes three factors, namely teacher knowledge, teacher views and beliefs, and teacher attitudes, was used in conjunction with a questionnaire and a survey to analyse the data from individual and focus group interviews. A total of 68 FET physical sciences teachers from urban, township and rural schools participated in the research. Our findings indicate that teachers are positive about the curriculum. However, the problems identified with training, support and resources as well as the lack of teachers' subject content knowledge, particularly in rural and township schools, cannot be blamed on the curriculum and therefore cannot be fixed by curriculum changes.

Keywords: physical sciences teachers, physics, curriculum changes, teacher behaviour, teacher knowledge

Introduction

Planning and teaching any subject are complex cognitive activities and, in these processes, teachers must apply knowledge from various domains (Resnick, 1987; Leinhardt & Greeno, 1986; Wilson, Shulman & Richer, 1987). However, teachers' inadequate understanding of the knowledge structure of mathematics and science is problematic to the teaching and learning of these subjects (Taylor & Vinjevold, 1999). As Magnusson, Krajcik and Borko (1999:135) assert: "Effective science teachers know how to best design and guide learning experiences under particular conditions and constraints to help diverse groups of students develop scientific knowledge and an understanding of the scientific enterprise". Therefore, science teachers' knowledge and beliefs have a direct effect on all aspects of their teaching (Carlsen, 1993; Carlsen, 1999; Smith & Neale, 1991) as well as how and what their students learn (Magnusson *et al.*, 1994). Teachers' personal views about content influence what goals they set for their students as well as how they implement curriculum (Gess-Newsome, 1999).

Since 1994 the heart of school reform was the establishment of the comprehensive curriculum project called Curriculum 2005 (C2005) which was implemented in January 1998 (DOE, 1997). Deficiencies were identified and the National Curriculum Statement (NCS) was constituted with full implementation from January 2008 (Jansen & Taylor, 2003). The NCS Grades 10-12 (general) physical sciences (DOE, 2003) emphasises the legacy of poor quality and/or a lack of education in this area that resulted in limited access to scientific knowledge. Curriculum reform, as required by the implementation of the NCS, implies that teachers hold deep and highly structured content knowledge that can be altered efficiently for the purposes of instruction (Sternberg & Horvath, 1995; Talbert, McLaughlin & Rowan, 1993). Therefore, an essential component of any professional development programme should be to strengthen science teachers' content knowledge (Kriek & Grayson, 2009). In addition, educational reform needs "to focus the efforts of teachers towards increased student learning" (Mabogoane, 2006:127).

The implementation of the NCS physical sciences curriculum at the Further Education and Training (FET) level (Grades 10-12) started in 2006 with Grade 10. This paper focuses on some physical sciences teachers' readiness to teach the physics that forms part of the physical sciences curriculum. It is expressed by 1) their knowledge, 2) their views and beliefs, and 3) their attitudes and experiences during the implementation of the NCS.

Curriculum background

The NCS is modelled on an outcomes-based education (OBE) philosophy (DOE, 2003). The version of OBE chosen encourages a learner-centred and activity-based approach for the learning environment. At the core of this curriculum are three learning outcomes (LOs): 1) Practical scientific inquiry and problem solving skills, 2) Constructing and applying scientific knowledge, and 3) The nature of science and its relationships to technology, society and the environment (DOE, 2003). Another important aspect is the introduction of assessment standards (ASs) which describe the ways in which learners should demonstrate the achievement of the LOs. The thrusts of the ASs for each LO are listed in table 1.

Table 1: Assessment Standards (ASs) of each Learning Outcome (LO) of the NCS FET curriculum (DOE, 2006)

Learning outcome	Assessment standard	Description
LO1	AS1	Conducting an investigation
	AS2	Interpreting data to draw conclusions
	AS3	Solving problems
	AS4	Communicating and presenting information and scientific arguments
LO2	AS1	Recalling, stating and discussing specified concepts
	AS2	Indicating and explaining relationships
	AS3	Applying scientific knowledge
LO3	AS1	Evaluating knowledge claims
	AS2	Evaluating the impact of science on human development
	AS3	Evaluating the impact of science on the environment and sustainable development

In the meantime, an amended curriculum, the Curriculum and Assessment Policy Statement (CAPS) (DOE, 2010) has been announced and will be implemented in 2012 in Grade 10. This single comprehensive Curriculum and Assessment Policy document is now being developed for each subject to replace the NCS Grades 10-12 (2004), as well as the previous Subject Statement, Learning Programme Guidelines and Subject Assessment Guidelines in Grades R-12. The CAPS "promotes the idea of grounding knowledge in local contexts, while being sensitive to global imperatives" (DOE, 2010:3).

Although the CAPS will replace the NCS curriculum for the physical sciences at the FET level, knowledge in the physical sciences is still organised around six core knowledge areas with the following foci:

1. Two with a chemistry focus – chemical systems; chemical change (18.75% each)
2. Three with a physics focus – mechanics; waves, sound and light; electricity and magnetism (12.50% each)
3. One with an integrated focus – matter and materials (25.00%).

The percentages indicated in brackets represent the proposed time distribution between the knowledge areas per year. New topics have been included, such as the Doppler Effect, superposition and alternating current in physics, chemical systems in chemistry, and macromolecules in matter and materials (DOE, 2006).

The NCS was designed to encourage educators to use a spiral approach for the knowledge areas (Wilson *et al.*, 1987). A concept is introduced in one grade and revisited in later grades. Grade 10 learners are, for example, introduced to the concept of weight. In grade 10 they learn only that the Earth exerts a force on any object and that this force is referred to as the weight of the object. With this, learners are introduced to motion in one dimension only. The fact that it is mentioned only as a one-way force might lead to alternative conceptions about forces since Newton's third law is dealt with only in Grade 11. In Grade 11 learners study forces in more detail and learn that weight is a special kind of non-contact force. They also learn that, not only the Earth, but all objects with mass exert forces on each other. In Grade 12 learners revisit motion and freefall and then learn about projectile motion in one dimension and the work done by a force. These examples underpin the principles of conceptual progression and coherence. In the past the physics part of physical sciences at secondary school level was presented as consisting of many unrelated topics. Complex concepts such as velocity, force, acceleration and momentum were all introduced at the beginning of Grade 11 in one chapter under the heading 'vectors' (Basson, 2002).

Purpose

All the changes mentioned above put a very high demand on physical sciences teachers. To be able to deal with the requirements of the NCS and OBE, they not only ought to be equipped with pedagogical skills, but especially with appropriate content knowledge as well as pedagogical content knowledge (PCK) (Shulman, 1986). At the heart of PCK is the manner in which subject content knowledge is transformed for teaching. Shulman (1987) identified seven knowledge bases for teaching, namely subject content knowledge, pedagogical content knowledge, pedagogical knowledge, curricular knowledge, knowledge of students, knowledge of context and knowledge of educational goals. Rather than viewing teacher education from the perspective of content or pedagogy, Shulman (1986) believed that these two knowledge bases should be combined to more effectively prepare teachers.

The purpose of this study was to probe whether teachers could be considered equipped to teach the physics part of the FET physical sciences curriculum with regard to teacher knowledge, teacher views and beliefs, and teacher attitudes.

Framework

Educational reform is, in part, implemented by changing teacher instructional behaviour and we therefore relied for the work presented here on a revised research framework on teacher behaviour (Van der Sandt, 2007). The original framework was developed by Koehler and Grouws (1992). An outline of the framework is summarised in table 2. The framework includes three factors, namely teacher knowledge, teacher views and beliefs, and teacher attitudes. Four components have been indentified for teacher knowledge; those of student learning, curriculum knowledge, subject content knowledge and PCK. Teacher views and beliefs deal with the teaching, learning and nature of the subject, as well as the students as learners. The third factor of teacher attitude is focussed on the attitude toward the subject itself, the teaching of the subject and the attitude toward the students.

Table 2: Revised research framework on teacher behaviour (Van der Sandt, 2007)

Teacher behaviour		
1. Teacher knowledge	2. Teacher views and beliefs	3. Teacher attitude
1.1 Curriculum knowledge	2.1 Teaching of subject	3.1 Subject
1.2 Subject content knowledge	2.2 Learning of subject	3.2 Students
1.3 Pedagogical content knowledge	2.3 Nature of subject	3.3 Teaching of subject
1.4 Student learning	2.4 Students as learners	

Participants

A convenience sampling method was used due to the availability and accessibility of FET teachers at the time. The research was conducted with a total of 68 FET physical sciences teachers at meetings of five clusters; three clusters of the Tshwane North District in Gauteng, one cluster in the North West Province and one in the Western Cape. The five clusters represented urban, township and rural schools (table 3). A cluster is an initiative of the Provincial Departments of Education for subject teachers to meet at least once in a school term to discuss subject-related issues. The regions were selected as shown in table 3, since we anticipated different responses from teachers working in a rural environment as compared to those working in either township or urban environments. Although a convenience sampling method was used for all the teachers, we purposefully selected teachers from North West Province and the Western Cape to take part in the content survey. The first author was invited by these Provincial Departments of Education to conduct workshops with the focus of developing teachers' subject content knowledge and permission was granted for and by the teachers to write content tests.

Table 3: Distribution of teachers in the five clusters visited

Cluster no.	Province	Region	No. of teachers
1	Gauteng North	Urban & township	9
2	Gauteng North	Urban & township	19
3	Gauteng North	Urban & township	14
4	North West	Rural	19
5	Western Cape	Township	7
Total			68

Methodology

A cross-sectional survey design was used, whereby a sample was drawn from a population at a particular time (Cohen, Manion & Marrison, 2007:213). This study was conducted after teachers implemented the first year of the NCS.

Individual and focus group interviews (Tustin, Ligthelm, Martins & Van Wyk, 2005), as well as a questionnaire, supplied information about the views of teachers. The purpose of these discussions was to generate an understanding of participants' experiences and beliefs. The questions posed to the discussion groups were put to the teachers in the sequence: positive unguided questions, positive guided questions, followed by negative unguided and negative guided questions as described elsewhere (Kriek & Basson, 2008). The interviews were transcribed, analysed and mapped onto the research framework with regard to the three factors, namely teacher knowledge, teacher views and beliefs, and teacher attitudes.

The first part of the questionnaire was used to obtain some basic biographical and teaching information about the teachers. We anticipated that some biographic features might have an influence on their responses. The main part of the questionnaire contained eight questions probing their views. The questions addressed issues such as the teachers' most positive experiences teaching physical sciences, the main problems they experienced, their views about the subject matter in the curriculum, the response of learners to their teaching and what aspects of implementing the curriculum influenced their teaching. They were also asked to indicate things they would have changed about their teaching of physical sciences had they been in a position to do so, as well as what they would need to be a successful physical sciences teacher. The questionnaire provided an opportunity for teachers to elaborate on issues already discussed or to share ideas that they did not want to mention in the presence of colleagues during the focus group interviews. The responses of the teachers to these questions were analysed and classified according to the framework.

The results of the transcriptions of the first three cluster meetings indicated serious concerns about the physical sciences subject matter prescribed by the NCS. It prompted us at the time to conduct a limited subject content knowledge survey with the teachers. The only opportunities for this were during the last two cluster meetings in the North West Province and Western Cape. The survey contained conceptual questions taken from research-based surveys provided as part of the 'Teaching Physics with the Physics Suite' publication (Redish, 2003). The collection of instruments in this suite is used internationally by physicists to determine the effectiveness of physics learning. The questions selected were on basic mechanics, electricity and magnetism because these knowledge areas comprise 50% of the physics part of the physical sciences syllabus. The survey focused on the subject matter that respondents were supposed to know since it had also been part of the previous syllabus. The nature of 12 of the 13 multiple choice questions were conceptual instead of numerical. A fourteenth item was added to test unit conversion skills because of the significance thereof in scientific calculations.

Results and discussion

Biographic details

The biographic profile of the teachers showed 60% male and 90% in the age group 30-50 years. The average age was 38 years. The home language distribution was 29% Afrikaans, 11% English and 58% African languages, of which Northern Sotho and Tswana were the most common. The teaching language used was 15% Afrikaans, 72% English and 13% both Afrikaans and English. All African-language speakers used their mother tongue to explain concepts to their learners.

The teachers held various qualifications. Forty percent held degrees and the rest a variety of teaching diplomas. Only half of the degrees were Bachelor of Science (BSc) or Bachelor of Science Education (BSc Ed) degrees. Of these teachers, 80% taught FET physical sciences without a qualification in the natural sciences (physics and/or chemistry). Twelve teachers held postgraduate qualifications, six of them Bachelor of Science Education Honours (BEd Hons) degrees. (In South Africa, all degrees after a first bachelor's degree are considered as postgraduate qualifications.) At the time of the survey, 24% were involved in some form of formal studies, with just more than half working on postgraduate qualifications and the rest on educational diplomas.

Teaching experience

The participants were all FET physical sciences teachers. The majority (73%) had five or more years' experience in teaching physical sciences (figure 1). A third had experience in teaching physical sciences at a lower level. The teachers are experienced in life and in their careers. This holds an advantage for the implementation of the curriculum, since it should be possible to rely on the general life and work experience of these teachers. There is also a disadvantage in that it might be harder for people who are used to a particular system and way of working to change their practices.

Teachers' responses to the questionnaire, interviews and survey

Six components of the research framework (table 2) emerged during the data analysis. Under the first factor of teacher knowledge, teachers elaborated on the curriculum (1.1) and subject content knowledge (1.2). With regard to views and beliefs, they indicated issues related to the teaching of the subject (2.1) and the students as learners (2.4). The third factor of attitude revealed information about their learners (3.2) and again the teaching of the subject (3.3).

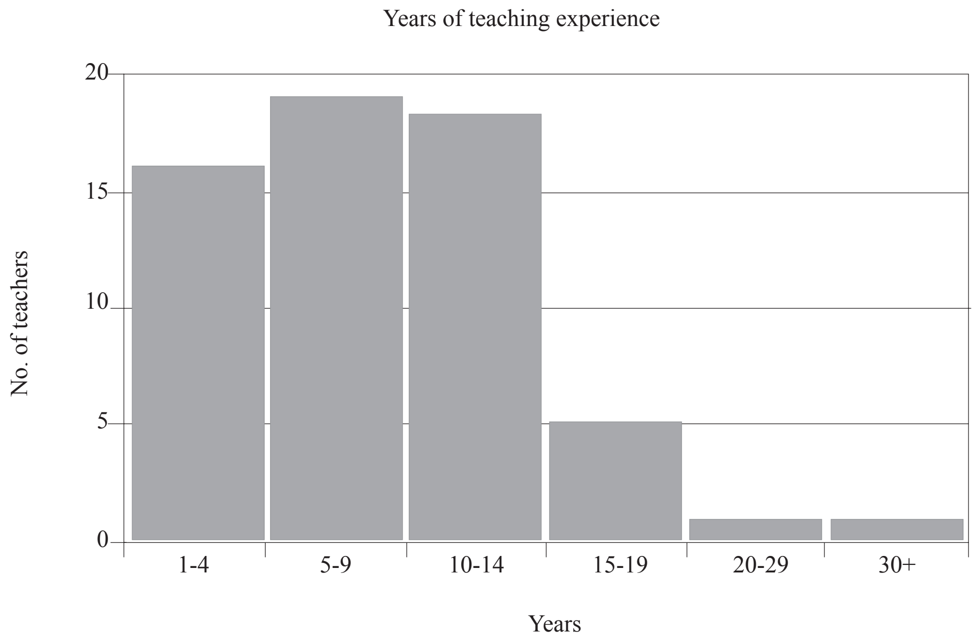

Figure 1: Years of physical sciences teaching experience

Teacher knowledge: Curriculum knowledge

Curriculum knowledge is knowledge on concepts and procedures. Teachers found the curriculum challenging, but they indicated it as a positive and not a negative experience. One teacher expressed that she "sees it as a challenge to improve" while another said "it made me want to read more and want to study BEd (Hons) in physical sciences". This is in accordance with what Bell and Gilbert (1996) reported; that teachers who changed because of a changing process viewed the changes as positive challenges rather than problems or threats. They were conscious about the LOs and specifically mentioned LO3. The relationship of the curriculum to the world outside the classroom, the integration of science with everyday life, the practical world and tertiary education were applauded.

An important aspect of the curriculum is that it has the same themes in all three FET grades and that there is progression between the grades. Teachers have to change their teaching practices and they have the opportunity to learn new teaching strategies and subject matter. Teachers revealed that their teaching has become more meaningful since they have "new and exciting things" to teach and that teaching now includes activities and experiments. One teacher thought that "experimental work makes learning and teaching much easier".

Content overload was reported as a constraint and that there was not adequate time available to implement all aspects required by the curriculum. In addition, not enough time was allocated for the subject physical sciences in the school programme.

Teachers found it time consuming to evaluate each learner according to the LOs and ASs. There seem to be gender-dominated trends around assessment, the overload of content and the associated time constraints. All male teachers complained about the ASs, the evaluation of individual learners according to the LOs, the setting of rubrics and too much marking. The female teachers, on the other hand, had concerns about the learning programme being too long and that they found it difficult to finish everything that is expected during the course of the school year.

We will elaborate on teachers' subject content knowledge at the end of this section.

Teacher views and beliefs: Teaching of subject

Although teachers hold positive views about the new content prescribed in the NCS, they expressed concerns about teaching it. Even though these were experienced teachers (see figure 1), they were anxious that they did not have the necessary skills to deal with the content and many of them did not have any formal training in some of the topics such as electronics and semiconductors. The fact that 80% of them had not been specifically trained in the natural sciences (physics and/or chemistry) might have an influence on their capacity and confidence to teach new content.

Teachers worried about the effort that needs to be spent on lesson preparation. Reading about the new topics takes a great amount of time. The importance of being well prepared was emphasised as a condition for success. As one teacher claimed: "to be a successful teacher I need more time to prepare experiments, worksheets, etc., which I don't get now because I am teaching four different subjects in two grades (i.e. I have four different preparations)". All teachers were stretched by the amount of administrative work to be done. They felt that plenty of paperwork had been added that did not serve a purpose for improved teaching. According to them, the time "wasted" on paperwork could, for example, have been spent on proper lesson preparation.

The amount of content to be covered and the time constraints associated with it was a prominent issue. All teachers essentially stated that there was too much content and motivated the statement by indicating that more time was needed for learners to make proper sense of the content. When asked what they would change about physical sciences if they were in a position to do so, half of the teachers cited a reduction in the amount of content as the most important recommendation. Teachers realised that they had to focus on concept development, but they felt constrained by the large amount of content that needed to be covered during one year. Twenty percent of the teachers were of the opinion that they should have fixed work schemes, that everybody should teach the same content and in the same sequence. One teacher summarised the general feeling: "We need a clear curriculum and clear guidance".

Learners found the new content interesting, but "they are stressed by too much work", as one teacher put it. Most referred to the content as being too difficult and too challenging for learners in Grade 10. An example is the introduction of motion in mechanics that has been shifted from Grade 11 to Grade 10. Mechanics and waves were indicated as the most difficult topics. A few comments were made about matter and materials and electricity being too easy. There was a common feeling among teachers that they did not know to what depth they had to teach each learning area. This appeared to be the case for both the old and new content.

The last question of the questionnaire specifically asked teachers *What do you need to be a successful physical sciences teacher?* The most important answer to this question was support. Support in this context meant more training to them. Thirty six per cent felt that they were not adequately trained and were desperate since they were unsure about "how, what and how much". They emphasised that professionals and experts should perform the training and that enough time should be allocated for it. They also felt that the training should be continuous for at least six months. There was an expectation that more training was needed on the new content, as well as on prescribed and other possible experiments that could be done with learners. A few also requested bursaries to improve qualifications.

Teacher views and beliefs: Students as learners

Teachers' views and beliefs about students as learners refer to the abilities and talent for science and mathematics. It includes differences between individuals or groups of learners. When referring to learners, teachers' most frequent negative comment was that learners enter the FET phase without the necessary skills they ought to have developed in the lower grades, especially mathematics knowledge and skills. Teachers complained that they had to teach the basics as well as the prescribed content of the particular grade. They said that learners thought that mathematics was something separate from science; when they are in the science class they cannot apply what they have learnt in the mathematics class. Another concern was about mathematics literacy, as illustrated by one teacher: "Learners should not be allowed to do science together with maths literacy when they do not even cope with maths literacy".

Teacher attitude: Students (learners)

Teacher attitude could include affection and enthusiasm toward learners. Teachers were confident that learners were involved. They said that learners participated actively, obtained firsthand experience of doing experiments and enjoyed working in groups. Some also found it more exciting to teach science these days, since learners "ask questions all the time and are more open-minded".

Teacher attitude: Teaching of subject

Teachers' attitudes toward teaching are influenced by their perceptions about the availability of resources for teaching. Twenty per cent of the teachers thought that the lack of resources was the worst thing about the implementation of the NCS. When talking about resources, complaints about a lack of equipment to do experimental work or demonstrations dominated the responses, followed by the overcrowding in classrooms and then the problems experienced with textbooks. Laboratory space and equipment were perceived as preconditions for successful science teaching. The overcrowding of classrooms with, in many cases, 40-60 learners at a time, puts a huge burden on teachers. Teachers have access to textbooks themselves, but they do not have textbooks and other learning materials, such as library books and access to computers and the Internet, available for learners. Teachers with weak subject content knowledge are prone to adopt the structure portrayed in the texts available to them (Gess-Newsome, 1999). They are further frustrated by "too many science books" that "have different viewpoints".

Teacher knowledge: Subject content knowledge

The specific need and demand expressed for additional, better and more appropriate training strengthened our perception that physical sciences teachers lack the necessary subject content knowledge as well as pedagogical content knowledge. Of the 26 teachers who participated in the subject matter survey, only two attained more than 80%. The most alarming result was the 14 teachers (more than half of them) who did not even manage 50% (figure 2). These results cannot be generalised, however. In a study of 75 physical science teachers teaching Grades 10-12 in South Africa it was found that only 75% felt it was their responsibility to study sections they did not understand (Kriek & Grayson, 2009).

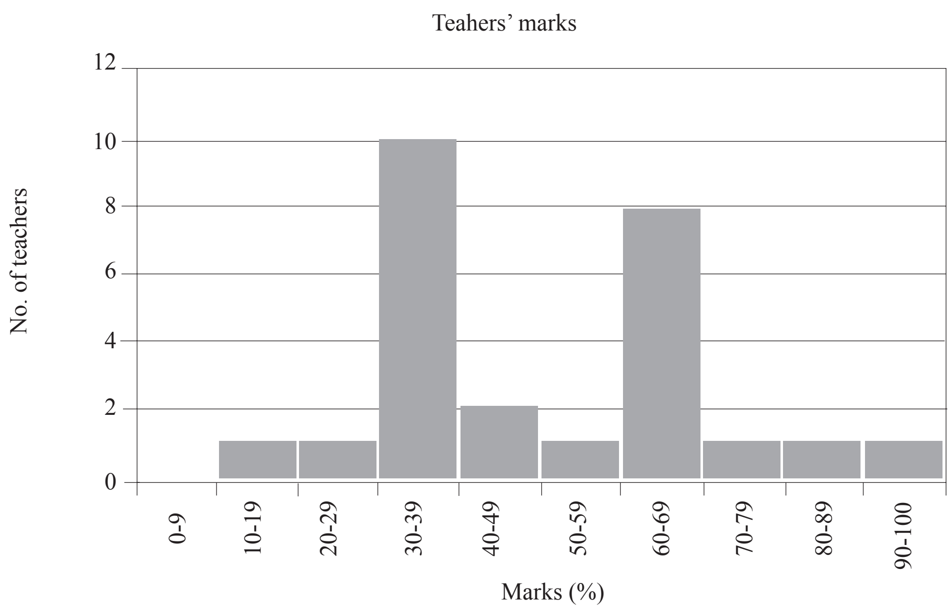

Figure 2: Results of subject matter survey

Three examples from the survey illustrate the seriousness of the problem. The first question on electrostatics showed two particles, A and B, with a net charge of –2 units and +1 unit respectively. The teachers were requested to select from five possibilities the pair of forces (shown by arrows) that correctly compared the electrostatic force on A (caused by B) with that on B (caused by A). Only five teachers (19%) answered correctly. Half of them indicated the force on A as bigger than the force on B and 15% thought the opposite, namely that the force on B was bigger than the force on A. One teacher even showed the nature of the force between two particles with opposite charges as repulsive. Another two knew that the forces were equal, but indicated the directions incorrectly. The only conclusion here is that at least 80% of these teachers have serious misconceptions about electrostatic forces and that they would convey these incorrect ideas to their learners. Furthermore, if forces are introduced as acting in one direction rather than as interactions, these alternative conceptions will be reinforced.

The second example is from a question that showed a diagram illustrating a single bulb connected to a battery. The question stated that a second identical bulb was added to the circuit as shown on the adjacent diagram (figure 3). Participants had to compare the current at point A in the circuit with the two bulbs to the current when only one bulb was connected. Six teachers (23%) answered correctly. Ten (38%) thought that the current remained the same and four (15%) that the current was halved. The idea that the current remained the same is in accordance with other research findings (Smith & Neale, 1991) that students consider a battery as a source of constant current. Three were on the right track, that the current was larger than before, but they did not know that, if the bulbs were identical, the current would actually double. Another three thought that the correct answer was not provided as an option. The fact that more than 75% of this group of teachers could not interpret one of the most basic direct current applications correctly, that of two resistors connected in parallel, has profound implications for the possible success of the learners in the subject they are teaching. We did not have the opportunity to ask these teachers about their teaching practice and their own training in physics, but these results could indicate that they had no or very little opportunity during their own training to experiment with simple electrical circuits, and that they possibly learnt only by rote. Similarly, McDermott and Shaffer (1992) found that most students had no observational or experiential base that they could use as a foundation for constructing the formal concepts of introductory electricity. It seems that, since then, not much has changed in this regard for these South African physical sciences teachers either.

The first two examples underpin findings by others that the teachers did not have a clear understanding of the underlying mechanisms of electric circuits and most likely the result of a weak or no connection between electrostatic and electro-kinetic phenomena (Engelhardt & Beichner, 2004; Cohen, Eylon & Ganiel, 1983).

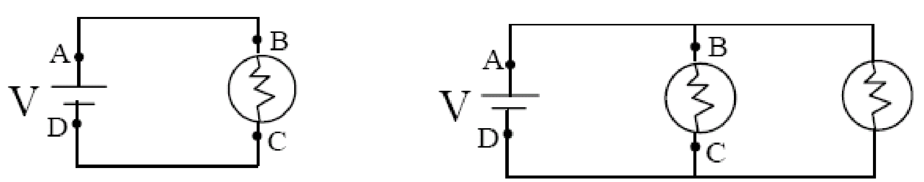

Figure 3: Example of a question on simple direct electrical current circuits

The third example is a simple unit conversion exercise. The question stated that the volume of a cool drink bottle is 0.75 litres. It was given that 1 litre = 10^3 cm^3 and that 1 cm = 10 mm. They were then asked to select the volume in mm^3 from five possible answers. An astounding 70% of participants could not indicate the correct answer. It should be emphasised, again, that these are teachers with an average age of 38 and with years of teaching experience.

The results confirmed that the challenges in the two regions are similar and indicated that the teachers were not in command of even the basic subject matter. The possibility that they would be able to deal with the new content correctly in teaching situations would also be extremely slim.

Conclusions

Educational reform, which has been a part of the South African school system since the mid nineties, has an influence on teacher behaviour. A revised framework on teacher behaviour, which includes three factors, namely teacher knowledge, teacher views and beliefs, and teacher attitudes, was used to analyse the data.

Teachers' knowledge about the curriculum revealed that the 68 teachers are mostly positive about the curriculum. However, matters such as content overload and insufficient time to cope with all aspects of implementing the curriculum seemed to hamper their implementation efforts.

The content survey confirmed that the subject content knowledge of these physical sciences teachers from township and rural schools was not sufficient. Our survey was based on the most basic content that has been in the curriculum for many years. The addition of new content, such as electronics, could complicate the situation even further since most teachers did not have any prior training on some of the new topics. Our study did not address teacher knowledge on PCK and student learning.

Teachers' views and beliefs on the teaching and learning of physical sciences revealed the need for resources and training, and that their learners enter the FET phase without the necessary skills they ought to have developed in lower grades. Teachers expressed their need for proper and appropriate training by professionals and experts to deal with the content and methods of teaching. Teachers' attitudes towards teaching are influenced by their perceptions about the lack of resources for teaching, but they were encouraged by the learners' more active participation when the NCS was being taught.

We have to conclude that the teachers from all the regions visited are not adequately equipped to guarantee a successful implementation of the curriculum – or to improve the teaching and learning of physics at the secondary school level from the levels of the past. Our results are in accordance with findings and statements of the Centre for Development and Enterprise (CDE) published in a report on the "maths and science challenge in South Africa's schools" (CDE, 2007:452). According to the report, two of a number of interlocking factors that account for the inadequate maths and science output of secondary schools is an insufficient supply of teachers with high levels of subject content knowledge, and the demands of the NCS curriculum itself. We are not in agreement with the report that teachers are not determined to teach the curriculum fully and well; those who we worked with are simply not equipped and it seems that their plight regarding training, support and resources has not yet been heard.

New findings indicated that teachers were positive about the NCS curriculum and eager to undergo professional development. The problems identified with the lack of teachers' subject content knowledge cannot be blamed on the curriculum. They cannot, therefore, be fixed by curriculum changes, but with attention to proper and appropriate training instead.

Acknowledgements

We thank the curriculum advisors who invited us to the cluster meetings and all the teachers who shared their views and experiences with us. A special word of appreciation is conveyed to those teachers who participated in the conceptual survey.

References

Basson I 2002. Physics and mathematics as interrelated fields of thought development using acceleration as an example. *International Journal of Mathematical Education in Science and Technology*, **33(5)**:679-690.

Bell B & Gilbert J 1996. *Teacher development: A model from Science education*. Washington, DC: Falmer Press.

Carlsen WS 1993. Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms. *Journal of Research in Science Teaching*, **30(5)**:417-481.

Carlsen WS 1999. Subject-matter knowledge and science teaching: A pragmatic perspective. In: J Brophy (ed). *Advances in research on teaching*. Greenwich: JAI.

Centre for Development and Enterprise 2007. *Doubling for growth: Addressing the maths and science challenge in South Africa's schools*. Retrieved on 10 October 2010 from http://www.cde.org.za.

Cohen R, Eylon B & Ganiel U 1983. Potential difference and current in simple electric circuits: A study of students' concepts. *American Journal of Physics*, **51(5)**:407-412.

Cohen L, Manion L & Marrison K 2007. *Research Methods in Education*. New York: Routledge.

Department of Education 1997. *Curriculum 2005*. Retrieved from http://www.polity.org.za/govdocs/misc/curr2005 html.

Department of Education 2003. *Physical Science National Curriculum Statement. Grades 10-12 (General) Policy*. Pretoria: Department of Education.

Department of Education 2006. *Physical Science National Curriculum Statement. Grades 10-12 (General) Content*. Pretoria: Department of Education.

Department of Education 2010. *Curriculum and Assessment Policy Statement. Physical Sciences (CAPS)*. Pretoria: Department of Education.

Engelhardt PV & Beichner RJ 2004. Students' understanding of direct current resistive electrical circuits. *American Journal of Physics*, **72(1)**:98-115.

Gess-Newsome J 1999. Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction. In: J Gess-Newsome & N Lederman (eds.), *Examining pedagogical content knowledge*. Dordrecht: Kluwer.

Jansen J & Taylor N 2003. Educational change in South Africa 1994-2003: Case studies in large-scale education reform. *Education Reform and Management Publication Series Vol. II No. 1 October 2003*. Retrieved on 11 October 2011 from http://www.jet.org.za/publications/research/Jansen%20and%20Taylor_World%20Bank%20report.pdf.

Koehler MS & Grouws DA 1992. Mathematics teaching practices and their effects. In: DAGrouws (ed). *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics*. NY: Macmillan.

Kriek J & Basson I 2008. Implementation of the new FET Physical Sciences curriculum: Teachers' perspectives. *African Journal of Research in SMT Education*, **12**:63-76.

Kriek J & Grayson DJ 2009. A Holistic Professional Development model for South African physical science teachers. *South African Journal of Education*, **29(2)**:185-204.

Leinhardt G & Greeno J G 1986. The cognitive skill of teaching. *Journal of Educational Psychology*, **78**:75-95.

Mabogoane T 2006. Recognising behaviour that increases learning: The possible role of incentives in the teaching profession. *Perspectives in Education*, **24(2)**:127-139.

Magnusson S, Krajcik J & Borko H 1999. Nature, sources and development of pedagogical content knowledge for science teaching. In: J Gess-Newsome & NG Lederman (eds). *Examining Pedagogical Content Knowledge*. Dordrecht: Kluwer.

McDermott LC & Shaffer PS 1992. Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding. *American Journal of Physics*, **60(11)**:994-1003.

Redish EF 2003. *Teaching physics with the Physics Suite*. USA: Wiley.

Resnick LB 1987. *Education and learning to think*. Washington DC: National Academy Press.

Shulman LS 1986. Those who understand: Knowledge growth in teaching. *Educational Researcher*, **15(2)**:4-14.

Shulman LS 1987. Knowledge and teaching: Foundations of the New Reform. *Harvard Educational Review*, **57(1)**:1-22.

Smith DC & Neale DC 1991. The construction of subject content knowledge in primary science teaching. In: J Brophy (ed). *Advances in research on teaching*. Greenwich; JAI.

Sternberg RJ & Horvath JA 1995. A prototype view of expert teaching. *Educational Researcher*, **24(6)**:9-17.

Talbert JE, McLaughlin MW & Rowan B 1993. Understanding context effects on secondary school teaching. *Teachers College Record*, **95(1)**:45-68.

Taylor N & Vinjevold P (eds.) 1999. *Getting learning right: Report of the President's Education Initiative Research Project.* Johannesburg: The Joint Education Trust.

Tustin DH, Ligthelm AA, Martins JH & Van Wyk H de J 2005. *Marketing research in practice.* Pretoria: Unisa Press.

Van der Sandt S 2007. Research framework on mathematics teacher behaviour: Koehler and Grouws framework revisited. *Eurasia Journal of Mathematics, Science and Technology Education*, **3(4)**:343-350.

Wilson SM, Shulman L & Richer AE 1987. 150 different ways of knowing: Representations of knowledge in teaching. In: J Calderhead (ed). *Exploring teacher thinking*. Sussex: Holt, Rinehart & Winston.