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South African physical sciences teachers' perceptions of new content in a revised curriculum

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This paper reports on South African teachers' perceptions of the educational value of new topics in a revised physical sciences high school curriculum, their content knowledge competency of these topics, and their pedagogical content knowledge in teaching them. In view of the historical inequalities of the South African education system, a focus of the study was comparison of these perceptions of teachers based at schools which are diverse in terms of location, student population, and availability of resources. We adopted a mixed methods approach in collecting and analysing data from a large-scale survey of teachers through a structured questionnaire, and followed this with interviews with 10 teachers in seeking more in-depth explanations of the findings. The study revealed that teachers at township and rural schools previously designated for black students, and suburban and city schools previously reserved for white students, have a positive perception of the new topics introduced into the revised curriculum. However, teachers at all these schools expressed uncertainly as to their content knowledge and pedagogical knowledge of the new topics.

Keywords: content knowledge; pedagogical content knowledge; pedagogical knowledge

Introduction

This study investigates South African teachers' perceptions of the educational value of new topics in the physical sciences National Curriculum Statement (NCS) (Department of Education [DoE], 2003) and their views on their content-related knowledge competency of these topics. Studies in other countries have reported that when new topics were introduced to the curriculum, teachers often experienced uncertainty about their content knowledge (Henze, Van Driel & Verloop, 2008; Lee & Luft, 2008) and this influenced the implementation of curriculum reform (Henze, Van Driel & Verloop, 2007; Makgato & Mji, 2006). According to Roehrig & Kruse (2005:421), "the role of teachers' content knowledge in the implementation of reform-based curriculum needs to be addressed." In a review of research on alternative conceptions in science conducted by Wandersee, Mintzes & Novak (1994:189) it was noted that "teachers often subscribe to the same alternative conceptions as their students", which is a critical issue as teachers' misconceptions are often transferred to their students (Bayraktar, 2009).

Teachers use multiple pedagogical strategies to transform their knowledge of the subject content into a form that can be easily understood by learners, referred to be Shulman (1986) as 'pedagogical content knowledge' (PCK). PCK is topic-specific because a teacher develops knowledge of teaching a particular topic in a certain way that is unique to it (Hashweh, 2005). Studies on the relationship between teachers' content knowledge and their classroom practices show clearly how teacher content knowledge influences their PCK, and reveals that teachers who lack specialist content knowledge are reluctant to implement inquiry-based teaching strategies in their classrooms. Instead they resort to a more closed and constrained pedagogy (Adams & Krockover, 1997) with a heavy reliance on the textbook (Lee & Luft, 2008). This paper is based on an investigation of teachers' perceptions of their content knowledge of new topics in the curriculum, in addition to their topic-specific PCK in relation to them.

In motivating the case for research on the content-related knowledge of high school science teachers, Arzi & White (2007) allude to studies which have been limited to the pre-service period, rather than practicing high school science teachers (e.g. Davis, Petish & Smithey, 2006; Gess-Newsome & Lederman, 1999). They pointed out a lack of research in this area, due to "the sensitivity of teachers who can find repetitive probing threatening, reflecting disrespect for their professional credentials, particularly so for experienced secondary teachers who are expected to be subject experts" (Arzi & White, 2007:222).

The focus of this study is the perceptions of South African high school physical sciences teachers on the new topics in a reformed curriculum. In particular, we compared the perceptions of teachers at schools which are diverse in terms of location, student population and resources. These may be due to historical inequalities in the South African education system.

Background

In trying to address the imbalances in the education system, a new outcomes-based curriculum (Curriculum 2005) (Department of Education [DoE], 1997) promulgating a student-centred constructivist approach to teaching was introduced in 1998. A review of Curriculum 2005 in 2000 directed the way forward to the design of the National Curriculum Statement (NCS) (Chisholm, 2005). One of the key principles upon which the NCS is based is the relevance of what is being learned (DoE, 2003). According to Aikenhead (2007:886), most research into the science curriculum concludes that school science transmits content that is "socially sterile, impersonal, frustrating, intellectually boring, and/or dismissive of students' life-worlds." In physical sciences, curriculum planners were therefore tasked with developing a curriculum with content that would be meaningful, accessible and relevant to all students. This resulted in restructuring of the existing content and the addition of new topics. The NCS physical sciences curriculum structured content knowledge into six core areas: matter and materials; chemical systems; chemical change; mechanics; waves, sound and light; and electricity and magnetism (DoE, 2003). Many topics from the previous curriculum were retained, but are now redirected and reworked so that their utility value and relevance are emphasised. For example, the chemistry of chlorine and its compounds which previously formed an autonomous unit of work is now infused into a section called 'the chloroalkali industry', carried out to provide students with a real-life context in which the chemistry of chlorine could be learned. New topics that have been introduced include, amongst others, moment of force, Doppler effect, shock waves and sonic boom, electron microscope, lasers, capacitance and inductance, Wheatstone bridge and electronics for Grades 11 and 12 students.

A key factor identified in the implementation of the science curriculum was the professional development of teachers. In addressing the shortage of qualified teachers to teach physical sciences, the government gave a firm mandate to train more teachers and provide additional training for those already in service. An example of this initiative is the training of teachers in physical sciences and other subjects by way of the Advanced Certificate in Education (ACE). The ACE was envisaged as a professional qualification which would enable educators to develop their competencies or to change their career path and adopt new educator roles (Department of Education [DoE], 2000). In this way the shortage of qualified physical sciences teachers would be overcome.

The new curriculum with its significant restructuring was well received and supported by the majority of teachers (Rogan, 2007). However, Rogan (2007) also argues that this endorsement of the new curriculum could have been motivated by political affiliation to the new government rather than teacher belief that it was an improvement on the previous one.

Against this background of curriculum reform, the following research questions were formulated for my research:

1. How do South African teachers in various locations perceive the educational value of the new topics in the revised physical sciences curriculum?
2. How do these teachers perceive their content-related knowledge of the new topics?

Framing teachers' content-related knowledge

The study was grounded in research related to teachers' knowledge (Shulman, 1987), which in order for them to be effective in the classroom should be well-developed. Shulman (1987) proposed seven categories of teacher professional knowledge, two of which are content-related (i.e. content knowledge and pedagogical content knowledge). The other categories refer to general pedagogy, students and their characteristics, educational contexts, and educational purposes (Shulman, 1987).

Our study focused on teachers' content-related knowledge, so in this paper we will elucidate only the categories of content knowledge and pedagogical content knowledge. Content knowledge refers to knowledge of the substantive and syntactic structures of a discipline (Grossman, Wilson & Shulman, 1989), substantive knowledge to the global structures or principles of conceptual organisation of a discipline. It includes knowledge of facts, concepts, and principles within a content area and knowledge of the relationships between them. Syntactic knowledge encompasses knowledge of the "historical and philosophical scholarship on the nature of knowledge" in a discipline (Shulman, 1987:9). Applied to the sciences, syntactic knowledge therefore corresponds to an understanding of the nature of science. Since our focus was on new topics we excluded syntactical knowledge as a construct that was not topic-specific. The content knowledge mentioned within the context of this study therefore refers primarily to the substantive structure of the subject.

PCK represents "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of the students, and presented for instruction" (Shulman, 1987:8). Based on their PCK, teachers translate subject content knowledge into useful forms of representations of ideas in the form of "powerful analogies, illustrations, examples, explanations and demonstrations" to facilitate comprehension by students (Shulman, 1986:9). Good teaching therefore entails a deep and comprehensive knowledge of content and an understanding of alternative ways of representing such knowledge so that it becomes understandable to students (Botha & Reddy, 2011).

Method

The study adopted a mixed methods approach, combining both quantitative and qualitative research approaches. In addressing the research questions, quantitative data were collected by means of a structured questionnaire that was posted to 660 high schools in the province of Gauteng. The sample of schools was considered representative of South Africa as Gauteng contains a cross-section of schools located in socio-economically diverse communities. Section A of the questionnaire sought information about the teacher, such as the number of years teaching experience in physical sciences, teaching qualifications, as well as information about the school such as location, annual school fees and the availability of resources. Sections B, C, and D comprised Likert scale items, all seeking data on teacher perceptions and experiences of teaching the new physical sciences curriculum. Section B was composed of items related to the new topics in the new curriculum. The items were of three types. Some required teachers to respond to what extent they agreed with a statement, for example: "I understand most of the content in the new topics" while for other items they had to indicate the extent to which an occurrence happened: "My learners find the new topics interesting". The third type required teachers to rate their content knowledge of topics in the curriculum as *excellent*, *good*, *poor* or *very poor*. Section C sought data on teacher planning and preparation, and section D focused on teacher perception and approach to practical work. At the end of the questionnaire the teachers were invited to comment on any of the issues being referred to as well as to indicate their availability for a follow-up interview.

In developing the questionnaire items we firstly conducted a focus group interview with six physical sciences teachers. Through this interview we were able to identify the core issues surrounding teachers' views on the new topics, and their planning and teaching of lessons on the new topics. This interview was guided by the following questions: "What is your view of the new topics that have been introduced?", "Do you feel confident in teaching the new topics?" and "Do you do anything different in planning your lessons on the new topics?" The interview data enabled us to formulate items which related to the teachers' perceptions on the educational value of the new topics, their content knowledge of these topics, and their PCK. The content validity of this questionnaire in terms of which items related to each of these three categories was established by having it reviewed by three researchers in science education at three South African universities. The instrument was then field-tested with a group of 20 physical sciences teachers who were attending a professional development programme at a university. We asked them to identify and comment on items which were considered unclear or unreadable. We also interviewed five teachers thereafter on the readability of the items. As a result of this feedback we reworded two items in the questionnaire. Due to the length of the questionnaire (110 items) we do not include it in this article but rather describe briefly the items referred to.

Of the 660 questionnaires that were sent out, 263 were returned. There was a reasonably large representation of respondents from suburban (51.2%), township (24.8%) and city (20.9%) locations. In comparison, only a few teachers from rural schools responded (3.1%). According to apartheid legislation, suburban and city schools were previously designated for white students, while township and rural schools were occupied by black students. Due to the similarity in the demographics of rural and township schools in terms of race, physical resources, and the socio-economic status of the community in which the schools were located, they were considered collectively in the data analysis. The suburban and city schools were considered separately as most suburban schools in Gauteng remain substantially populated by white students, while city schools have experienced a steady influx of black students from neighbouring townships (Chisholm & Sujee, 2006). The population of city schools is therefore racially mixed.

The responses to the questionnaires were analysed statistically using the PASW version 18.0 for *Windows* software. Firstly, frequency tables of data collected for Section A were generated, enabling us to construct a profile of schools and teachers who had responded to the questionnaire. Secondly, we generated frequency tables for items in Sections B, to identify trends and patterns in responses. This informed us on the perception of respondents towards the new topics, in particular their competence, the value of the new topics and their planning for teaching them. We also carried out chi-square tests in exploring relationships between the location of school in which a teacher taught and his/her perception of this reform. The chi-square is a test used to explore the relationship between two categorical variables, where each can have two or more categories (McMillan & Schumacher, 1993). The test is a means of answering questions about association based on frequencies of observations in categories. In this study we chose the one categorical variable as the location of the school, then explored using the chi-square how the frequency of observations in the categories suburban, city and township schools (including rural schools) related to the frequency of observations made on categories for the teacher perceptions on their content-related knowledge of the new topics.

We collected qualitative data from interviews with 10 teachers who had responded to the questionnaire and agreed to be interviewed. The overriding criterion in the selection of the teachers was that they were representative of the diversity of schools in Gauteng. Furthermore, we ensured that the location of the schools in which they taught was convenient as they were accessible to us in terms of travelling distance. Table 1 provides a demographic description of the teachers in this sample.

Table 1 Demographic description of teachers interviewed

Teacher	Gender	Age	Qualification	School type	Average class size	Resources
Teacher 1	Male	35	T	Township	47	P
Teacher 2	Female	44	T	Township	45	P
Teacher 3	Male	29	E	Township	46	P
Teacher 4	Male	37	S	Township	40	P
Teacher 5	Female	45	E	Suburban	32	W
Teacher 6	Female	34	S & T	Suburban	29	A
Teacher 7	Male	43	T	Suburban	32	A
Teacher 8	Female	30	T	Suburban	35	W
Teacher 9	Male	37	T	City	33	A
Teacher 10	Female	40	T	City	35	A

P = poorly resourced, A = adequately resourced, W = well-resourced
T = teaching diploma, E = education degree, S = science degree

In this profile, a *well-resourced* laboratory is considered to have water, electricity and gas connections, a supply of apparatus and chemicals for all learners to do practical work, and work benches for all learners. An *adequately resourced* laboratory has a reasonable supply of apparatus and chemicals, but not sufficient for all learners to do practical work. A *poorly resourced* laboratory is lacking in apparatus and chemicals for practical work.

In these interviews we sought more in-depth explanation of some of the findings to have emerged from the quantitative survey. The interviews were guided by an initial question, "What is your view of the new topics in the physical sciences curriculum?" Each teacher had the freedom to respond in his/her own way and we asked follow-up questions to seek clarity when necessary and also to probe teachers on the views they were expressing. The interviews were transcribed and analysed using computer-aided qualitative data software, *Atlas.ti*. Data were then coded and classified, a process largely guided by the trends and patterns that had emerged from analysis of the questionnaire data in relation to the teachers' perceptions on the new topics. For example, one of the trends identified was the difficulty teachers experience with some of the concepts in the content knowledge associated with the new topics. The relevant text from the interview transcripts was therefore coded according to the difficulty with the new concepts. Codes such as "challenging content" and "hard to understand" were then grouped into a category titled "difficulty with new content."

Findings

The findings from the analysis of the survey were integrated with the findings from the teacher interviews into a coherent whole. Questionnaire items 5, 7, 9, 10, 17 and 18 elicited data on teachers' perceptions of the educational value of the new topics. Item 12 referred to the perceptions of teachers on their content knowledge of the new topics. Items 20 and 25 related to teacher perception on their PCK of the new topics. Due to the particular focus of this article, items that related to other aspects of teacher perception on curriculum reform, such as the investigative approach to practical work included in section D of the questionnaire, are not included in the analysis reported here.

Table 2 shows the frequency of responses to questionnaire items on the teachers' perceptions of the new topics.

The interview data explained some of the findings which emerged from the questionnaire analysis. This integration of quantitative and qualitative data supported the production of assertions (Gallagher & Tobin, 1991) about how teachers perceive the new topics in the curriculum. These assertions are now presented.

Assertion 1 was generated in addressing the question on teacher perception of the educational value of the new topics.

Assertion 1: Teachers at all locations of schools have a positive perception of the new topics introduced and the restructuring of the existing topics, but believe the demand to plan and cover all topics is overwhelming.

Items 7 (*The new topics help to make science more relevant to the students*) and 18 (*My students find the new topics interesting*) from Section B in the questionnaire related to teacher perception of the educational value of the new topics. A chi-square test exploring the relationship between the location of the school in which the teacher taught and his/her perception that the new topics help make science more relevant to the students indicated no significant association. A chi-square value (χ^2) of 3.54 was

Table 2 Teacher perceptions of the new topics

Item No.	Focus of item	Frequency of responses (%)					
		Strongly disagree	Disagree	Agree	Strongly agree	Uncertain	No response
5	It was a mistake to introduce the new topics	23.6	49.4	11.8	4.3	8.7	2.2
7	The new topics help to make science more relevant to the students	2.3	9.5	43.0	38.0	5.7	1.5
9	The new topics are an extra burden on physical sciences teachers	14.8	31.9	30.4	13.3	6.5	3.1
10	I see no reason to teach a new topic if it is not going to be examined in the National Senior Certificate Examination	14.1	29.7	28.1	25.1	2.2	0.8
12	The new topics have concepts which are difficult for me to understand	15.6	47.5	25.9	4.9	3.8	2.3
20	I struggle to make the new topics understandable to students	15.2	17.1	33.1	29.7	1.9	3.0
25	It is more demanding to find ways to teach the new topics compared to the old topics	11.4	16.7	34.2	31.9	3.4	2.4
		Never	Seldom	Sometimes	Often	Very often	No response
17	I spend more time in planning lessons to teach the new topics compared to old topics	0.8	9.1	30.0	35.0	22.1	3.0
18	My students find the new topics interesting	0.3	11.8	53.2	28.5	4.6	1.6

obtained. With 8 degrees of freedom (df), a significance level (*p*) of 0.73 was achieved. This falls above the 0.05 alpha level. It can therefore be concluded that there is no significant association between the type of school and the teachers' response to this item. A similar result was obtained for the chi-square on the location of school and the teacher perception that students find the new topics interesting ($\chi^2 = 10.2$, df = 8, $p = 0.6$). It is evident from Table 2 that the great majority of teachers believed that the new topics add relevance to science learning, with 81% of all teachers either agreeing or strongly agreeing that the new topics made the learning of science more relevant to the students. Furthermore, 33.1% of teachers believed that learners found the new topics interesting either 'often' or 'very often', while only 12.1% of teachers felt otherwise.

One of the teachers interviewed explained the issue of relevance by reporting that the introduction of the new topics illustrated to students the utility of what they were studying so that "they can see immediately why they are doing the topic by seeing some of its applications and how learning about it will be of value to society."

This finding on the value of the new topics was supported by teacher responses to item 5 (*It was a mistake to introduce the new topics*) from Section B, which indicate that only 16.1% believed that it was a mistake to introduce the new topics (Table 3). A chi-square test for independence indicated no significant association between the type of school and the teachers' views on whether it was a mistake to introduce the new topics ($\chi^2 = 9.81$, df = 8, $p = .63$).

Apart from making the learning of science more relevant to the students and generating interest in the subject, the interviewed teachers also believed that the new topics invite critical thinking and "engage students in debate on issues which affect their lives either directly or indirectly." However, it is also interesting to learn that despite a perceived educational value of the new topics, a substantial number of teachers (43.7%) in responding to item 9 from Section B (*The new topics are an extra burden on physical sciences teachers*) believed the new topics were an extra burden on them (Table 2). A chi-square test for independence indicated no significant association between the type of school and the teachers' views on whether the new topics were burdensome ($\chi^2 = 13.9$, df = 8, $p = .31$).

Planning time appeared to be a factor in the perception of the new topics as the cross-tabulation (Table 3) showed that of the 115 teachers who perceived the new topics to be a burden, 78 indicated they spent more time in planning lessons on the new topics – item 17 in Section B (*I spend more time in planning lessons to teach the new topics compared to old topics*). The chi-square test for independence showed no significant association between the type of school and the time teachers spent on planning for the new topics compared to the old ones ($\chi^2 = 14.8$, df = 8, $p = .26$).

Furthermore, despite the positive perception of the new topics, teachers indicated they would only teach them if they were going to be examined in the Grade 12 national senior certificate examination. This was clearly evident in teacher responses to item 10 from Section B, in which over half the teachers (53.2%) agreed or strongly agreed

Table 3 Cross-tabulation of teacher perception on demand of new topics and time spent planning lessons on these topics

Item 9, Section B	Item 17, Section B					
	Never	Seldom	Sometimes	Often	Very often	Total
Strongly disagree	1	5	12	11	10	39
Disagree	1	9	31	29	14	84
Agree	0	4	27	29	21	80
Strongly Agree	0	2	4	17	12	35
Uncertain	0	4	5	7	1	17
Total	2	24	79	92	58	255

with the statement *(I see no reason to teach a new topic if it is not going to be examined in the National Senior Certificate Examination*). A chi-square test for independence indicated no significant association between the type of school and the extent of teacher agreement with this statement ($\chi^2 = 11.5$, df = 8, $p = .17$).

A possible reason for teachers planning to teach only the examined content is the perceived content overload due to the addition of the new topics. This is reflected in the following interview responses and comments made by teachers on the questionnaire:

> The new physical sciences curriculum is of a high standard and the new topics prepare the students for future studies, but the main problem is that there is not enough time to complete all the work in class time. Students are therefore expected to attend afternoon classes, weekend classes, and holiday schools. It is very long and pupils battle to have proper knowledge of all the science concepts. The curriculum should be made shorter! There are interesting topics but the syllabus is too long and vast. There is not enough time for students to really apply what they have learned. It lends itself to rote learning like before.

The following assertion relates to the teachers' perception on their substantive content knowledge of the new topics.

Assertion 2: Teachers at all location of schools have difficulty with concepts in the new topics.

A chi-square test for independence was used to explore the relationship between school type and teachers' views on their comprehension of the content knowledge required to teach the new topics. Item 12 (*The new topics have concepts which are difficult for me to understand*) of Section B provided data on the teacher view of his/her comprehension of the new topics. No significant association between school type teachers' views of their comprehension of the relevant content knowledge was found

($\chi^2 = 7.75$, df = 8, $p = .26$). From Table 2 it is evident that a significant number of teachers (30.8%) had difficulty understanding concepts in the new topics.

The chi-square test for independence showed no significant association between teachers' perception of their understanding of the concepts in the new topics and whether or not they had a minimum teaching qualification in physical sciences, namely, a teaching diploma ($\chi^2 = 3.48$, df = 4, $p = .5$) or an education degree ($\chi^2 = 6.51$, df = 4, $p = .16$) in physical sciences.

Teachers were asked to rate their knowledge of new and existing topics. An equal interval rating scale ranging from 1 to 4 was used, with a rating of 1 indicating *excellent* (very knowledgeable of topic) and a rating of 4 meaning *very poor* (serious knowledge gaps in topic). They rated more poorly their knowledge of new topics such as electronics (mean = 3.31) and the electron microscope (mean = 3.11) in comparison to topics such as Newton's laws of motion (mean = 1.35) which appeared in the previous curriculum.

Four of the 10 teachers who were interviewed indicated that they had difficulty with the new topics, and expressed the need for more training in them. There were also comments to this effect in the teacher questionnaires. The following comments by two interviewed teachers attest to this:

> The new curriculum is really interesting, though as educators we will need more training on some of the new concepts in the curriculum itself. To tell you the truth, I felt I could handle the new stuff, but when I started teaching and the students asked questions, I was not sure. I feel sometimes I must go to back to school myself.

Another teacher indicated that she felt uneasy and insecure when teaching concepts in these new topics. She stated that although she subscribed to an activity-based and student-centred approach, the uncertainty she experienced around the new topics meant she had to adopt a teacher-centred approach "so that students will be quiet and not ask too many difficult questions."

The third assertion refers to teachers' perceptions on their PCK in relation to the new topics.

Assertion 3: Teachers at all locations of schools have difficulty making the new content accessible to their learners.

Item 20 (*I struggle making the new content understandable to students*) and item 25 (*It is more demanding to find ways to teach the new topics compared to the old topics*) related to the pedagogical content knowledge of teachers. In responding to item 20, 62.8% of all teachers indicated they either *agree* or *strongly agree* that they struggled to make the new content understandable to students. With regard to item 25, 66.1% of all teachers found it more demanding to find strategies on how to teach the new topics compared to the old ones (Table 2). The chi-square test for independence showed no association between the school type and the teachers' perceptions of their PCK, as indicated by item 20 ($\chi^2 = 8.91$, df = 8, $p = .35$) and item 25 ($\chi^2 = 5.64$, df = 8, $p = .4$).

When probed on this perception at the interviews, six of the 10 teachers indicated they were having difficulty with their PCK on the new topics. This difficulty appeared to relate to how to represent the content knowledge on these new topics in forms that were comprehensible to the students. The following excerpts suggest this:

> It is because I am not too familiar with the new topics that I cannot seem to plan on how to find examples to make it more concrete to them. Over the years I found ways on how to teach the other topics in an easy way, but now I am struggling with these. Let us look at something like capacitance. I cannot see how to make this easy for the learners. What are the ways to do it? I must now think deeply on how to approach a topic like this.

It would therefore appear that teachers, due to their unfamiliarity with the new topics, struggle to find ways in which to make this scientific knowledge more accessible to students.

Discussion of findings

The findings of this study showed that, despite the endorsement of the new topics, a substantial number of teachers had difficulty understanding concepts related to these topics, and this consequently compromised their PCK. This problem appears to be widespread because there was no significant association between teacher perception on the new topics and the location of the school. This was an unexpected result in view of the diversity of schools in this country. Studies on the implementation of the new curriculum have focused on disadvantaged schools in townships and rural areas, and have pointed to gaps in the teachers' content knowledge (Kriek & Basson, 2008). It is now apparent from the findings of our study that teachers at suburban and city schools share a perception of their content knowledge of the new topics as their counterparts in the township and rural schools.

An implication of this finding is that when an innovation is far removed from the existing practice of teachers, the implementation problems can extend over a diversity of schools. As was revealed by the chi-square test, the qualification of the teacher appeared not to be a factor in the perception of teachers on the new topics. It is conceivable that teachers who did have an undergraduate degree in science did acquire knowledge in some of these new topics. However, Arzi and White (2007) point out that when knowledge is not regularly accessed, such as when planning lessons, it can become more difficult to access. Arzi and White (2007:223) further explain that teachers are learners, and a "teacher's knowledge is dynamic, changing in organization as well as in accretion and forgetting". To an extent this would explain why well-qualified teachers indicated uncertainty in their knowledge of the new topics.

The finding on teachers expressing inadequacies in their PCK on the new topics is related to their unfamiliarity with the content knowledge of them. There is abundant research evidence to support this. For instance, Gess-Newsome and Lederman (1995: 317) compared teachers' content knowledge with their classroom practice, and concluded that the "level of content knowledge had a significant impact on how content was taught." With regards to the teaching of specific topics, Smith (1987) observed that science teachers' difficulty with the physics of light affected their ability to focus on the conceptual understanding of light in science activities and limited their use of examples and metaphors. In teaching the new topics, teachers struggle to find ways to represent the new content so that it comprehensible to students, and hence spend more time on planning for lessons on these topics. Teachers interviewed made reference to how this uncertainty had shifted their pedagogy towards a more teacher-centred approach and so offered them more authority in directing learning. Lee (1995) found evidence of this in a case study of a middle-level science teacher who had limited content knowledge. The teacher exhibited a heavy reliance on the textbook as a tool, and the avoidance of class discussions.

Conclusion

In plotting the way forward it is recommended that further research be undertaken on the practice of teachers in investigating the interaction between teacher content knowledge of new topics and how teachers engage in the reorganisation and reconstruction of this knowledge, one of the hallmarks of good PCK. The deficit in content knowledge as perceived by teachers in this study invokes the need for a professional development programme that is tailored to the particular needs of teachers. The traditional 'one-shot' approaches to professional development have been inadequate and inappropriate in addressing the developmental needs of teachers (Dass, 1999:2). According to Kriek & Grayson (2009:198), a "longer, sustained and intensive professional development programme is more likely to have an impact than a half-day event or a few after-school". This imperative is encapsulated in the National Strategy for Mathematics, Science and Technology (Department of Education [DoE], 2001) that expressed the need for higher education institutions to develop rigorous, high quality and relevant training programmes for teachers that will strengthen both subject matter expertise and pedagogical content knowledge. In light of the findings of the study it may be an opportune time to revisit and refocus on this strategy.

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