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RUNNING HEAD MENTORING PHYSICAL SCIENCE SUBJECT ADVISORS

KEYWORDS Acid-base titration, content knowledge, pedagogical content knowledge (pck)

ABSTRACT This study reports on mentoring as a form of professional support for South African Physical Sciences subject advisors coping with curriculum reforms. The study focused on the subject advisors' content knowledge, competency and their pedagogical content knowledge in facilitating the teaching of a new topic in a revised physical sciences high school curriculum. Using a case study method, the study investigated one case of mentoring. The case explored a mentoring relationship between an experienced Physical science teacher educator and 16 experienced Physical science subject advisors. This study referred to them as 'bedrock' of the profession basing on their job description. They either make the South African Physical science teachers swim through or drown in the challenges presented by the reforms in the Physical Science curriculum since they are the teachers' mentors. The study revealed that beside subject advisors being referred to as the 'bedrock' of

the profession, they expressed uncertainly as to their content knowledge, apparatus handling skills and pedagogical knowledge of this topic. In spite of the case study following the cascade model of in-service training consisting of short one-shot workshops still a common practice in South Africa, the findings suggest that mentoring, although complex does provide a viable means through which professional development efforts can be consolidated. Implications and recommendations for further study are suggested.

~~BACKGROUND AND RATIONALE~~

INTRODUCTION

The South African curriculum has undergone a metamorphosis of revisions since 1994. In trying to address the imbalances in the education system, a new outcomes-based curriculum [Curriculum 2005] promulgating a student-centred constructivist approach to teaching was introduced in 1998 (Department of Education [DoE] 1997). The introduction and implementation of outcome-based education (OBE) through Curriculum 2005 saw quite a number of changes in the Physical Science curriculum (Ramnarian and Fortus 2013). OBE replaced the content-based approach, which defines what learners do during the learning process. The changes back then saw the removal of some concepts/topics such as the teaching and learning of titration and basic polymerization (plastics and polymers) under the Chemistry section. According to Chisholm (2005), a review of Curriculum 2005 in the year 2000 directed the way forward to the design of the National Curriculum Statement (NCS). Ramnarian and Fortus (2013) highlight that 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. Many topics from the previous curriculum were retained, but were redirected and reworked so that their utility value and relevance are emphasised. The NCS introduced together with the Outcomes-Based Education philosophy in 2005 has been recently revisited. The aim was to produce national Curriculum and Assessment Policy Statements (CAPS) as a “refined and repackaged” version of the original documents, and not create new curricula (Vinjevold 2012). The introduction of CAPS saw the re-introduction of some concepts/topics such as the teaching and learning of titration and basic polymerization (plastics and polymers) under the Chemistry section which had been scrapped off during the implementation of C2005.

Studies in other countries have reported that when new topics were introduced to the curriculum, teachers often experienced uncertainty about their content knowledge (Henze et al. 2008; Lee and Luft 2008) and this influenced the implementation of curriculum reform (Henze et al. 2007; Makgato and Mji 2006). According to Roehrig and Kruse (2005:421), "the role of teachers' content knowledge in the implementation of reform-based curriculum needs to be addressed." In the South African context, Roehrig and Kruse's concern needs to be taken seriously. Experienced teachers received their qualifications at teacher training colleges during the apartheid era. These colleges, especially those that were situated in the homelands, had deficiencies in the teaching of specific content knowledge, leaving their students with knowledge gaps (Rusznyak 2008; Gordon 2009). Some of these teachers went on to upgrade themselves professionally by taking in-service courses at universities after the closure of teachers' colleges, graduating with qualifications like 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 2000). As stated by Ramnarian and Fortus (2013:3), the ACE qualification was a way in which the government gave a firm mandate to train more teachers and provide additional training for those already in the service and as a way of addressing the shortage of qualified teachers to teach Physical sciences and other subjects. Despite the upgrading, most teachers still have knowledge gaps as in-service courses at universities such as the ACE focus more on pedagogy rather than the content (Hwenha 2013). Teachers who recently graduated from universities after the closure of teachers' colleges are not spared either of having knowledge gaps. They go through a curriculum designed in a manner not likely to equip the students with enough content knowledge (Hwenha 2013). A ministerial task team established to investigate teaching in mathematics, science and technology in 2014 published a 'damning report' about South Africa's education system. It noted that universities were not training teachers adequately, and district officers were largely unable to provide adequate support to teachers and there was a shortage of qualified teachers (SAPA 2014). In other words, the students are churned out half-baked. Most of the teachers are under- and some even unqualified in the areas of Science and pedagogical content knowledge. The severity of the challenge has been evident in the learners' achievement outcomes, which are low in a subject such as Physical science as evidenced by its low pass rate. In one way or the other, the practising teachers have to be workshoped in these new topics if changes advocated by reform visions on the curriculum such as the introduction of new topics are to be a success. As Spillane (1999) puts it, virtuous implementations of such reform visions ultimately rely on teachers. To assist in lessening the burden on teachers, they [teachers] have to be mentored especially when it comes to the teaching of new topics. However, mentoring has to start with subject advisors because they are the ones who play a mentoring role to the teachers.

CONCEPTUALIZING MENTORING

Mentoring is ‘off line help by one person to another in making significant transitions in knowledge, work or thinking’ (Megginson and Clutterbuck 1995:13). This activity is an important part of learning by adults because it represents a holistic and highly individualized approach to learning in an experiential fashion (Lester 1981). According to Megginson and Clutterbuck (1995), mentoring is very complex and varies from one situation to another. As such, it is interpreted in different ways by different people. Thus, it is important that the purpose and intentions of mentoring in a particular context are made explicit. Making use of mentoring relationships as a way to enhance professional development activities is not a new idea. However, mentoring has increased in popularity as a means through which a teacher experiencing shortcomings in his/her practice can be supported by a skilled and experienced colleague (Bradbury 2010). There is no agreed definitive conceptualisation of mentoring (Lai 2010). A possible reason for this is that mentoring in teacher education involves complex personal interactions ‘conducted under different circumstances in different schools in which it cannot be rigidly defined’ (Wildman et al. 1992:212). The lack of consensus as to what constitutes mentoring may be the result of researchers attempting to focus on different dimensions of mentoring (Lai 2010).

Ramnarian and Ramaila (2012:256) acknowledge that a review of literature undertaken by Lai shows that ‘mentoring has been conceptualised in light of its relational, developmental and contextual dimensions’. Lai (2010:3) points out that ‘the groupings are based on differing degrees of emphasis given to each of the three dimensions by particular conceptualizations, and they are not intended to be exclusive’. The relational dimension of mentoring refers to the relationship between the mentor and the mentee. According to Franke and Dahlgren (1996), the mentor and mentee collaborate as partners to solve problems of practice within a community of practice. Communities of practice are characterised by members who are informally bound by what they do together, from engaging in discussions to solving difficult problems, and by what they have learned through their mutual engagement in these activities (Wenger 1998). From a relational perspective, this conception of mentoring promotes an egalitarian relationship and the delineation between the novice and the expert becomes blurred (Koballa et al. 2008). This conception is applicable to this study since the subject advisors were seen as 'bedrock' to the profession hence the delineation between them [subject advisors] and the mentor was blurred. Another conception of mentoring from a relational perspective emphasizes the role of a mentor as an emotional supporter and critical friend (Bradbury 2010). The mentor is viewed as someone who helps the novice teacher lessen the stress of the transition into teaching by providing critical emotional support (Gold 1996). A study by Evertson and Smithey (2010) is a good example of mentoring from a relational perspective. The study highlights the benevolent, empathy, engagement, authenticity, nurturing and compassionate aspect of mentoring.

To Lai (2010: 3), the developmental dimension of mentoring focuses on 'mentoring functions and behaviours aimed at promoting the professional and/or personal development of both the mentor and mentee.' The process occurs in a sequence. Firstly, the developmental level of the mentee is recognized by the mentor who then shifts the novice towards a higher level of development (Wang and Odell 2002). 'This does invoke the notion of scaffolding that emerged from socio-constructivist views of learning, particularly Vygotsky's (1978) notion of learning in the zone of proximal development (ZPD)' (Ramnarian and Ramaila 2012: 257). This zone is the difference between a person's actual level of development, as determined by activities that can be performed without assistance, and the potential level of development as determined by performance of tasks under the guidance of a more capable person who guides a learner through the ZPD towards a new level of development in a gradual process of scaffolding (Van der Valk and De Jong 2009). Second, over time there has to be a gradual withdrawal of support to enable the mentee to become more autonomous in his or her practice. In this mentor-novice relationship, the interactions with the more capable or experienced others are critical in order for novice to acquire knowledge beyond the independent level of exploration (Vygotsky 1978).

The contextual dimension focuses on a complex web of cultural and situational features unique to each mentoring setting (Lai 2010), and recognises the powerful influence of the school organization and culture on teaching and learning. A good example of this dimension according to Lai (2010:446) is the view of 'induction as an enculturation process' advanced by Feiman-Nemser (2003). Along the same line, Feiman-Nemser (1996:2) suggested that mentoring should be 'linked to a vision of good teaching, guided by an understanding of teacher learning, and supported by a professional culture that favours collaboration and culture.' The conceptualization of mentored learning to learn as enculturation implies that mentoring is about helping mentees fit into the organisation and culture of a particular community of practice. Mentoring is a multi-faceted and complex concept, and this study takes a position that it is best understood from the three perspectives outlined. The researcher hopes to uncover some of this complexity in the single case of mentoring researched by framing the work according to these dimensions.

Acid-Base titration- the phenomenon under study

Acid-base titrations are common experiments carried out by students in introductory chemistry classes. The topic has been a regular component of introductory chemistry curricula for decades, and receives wide coverage in introductory texts and related laboratory manuals (Dingrando et al. 2002). The most frequently conducted titrations involve the neutralization of strong acids with strong bases, with students being required to calculate the concentration of unknowns using this method. Aldridge (1996) notes, a framework for high school science education suggests that students in grade 11 should be able to use the pH scale to investigate changes in pH that occur during titrations. The treatment of titration curves in introductory chemistry classes is usually non-mathematical, and they are most often included as a means of determining the most appropriate indicators to use in particular titrations.

Acid-base chemistry has posed student and teacher difficulties and the causes have been ascribed to the existence of many alternative conceptions or misconceptions (Demerouti et al. 2004; Demircioglu 2005), a poor understanding of the particulate nature of matter (Smith and Metz 1996), difficulties with the use of different models used in acid–base chemistry (Furio-Mas et al. 2005; Kousathana et al. 2005) and confusion between acid–base terminology and everyday words (Schmidt 1995). Ross and Munby (1991) notes that high school students demonstrated a good qualitative understanding of pH, while in contrast, Nakhleh (1990), in a more in-depth study, notes that high school students had relatively poor qualitative understanding of pH. In addition, students thought that there were neither hydroxonium nor hydroxide ions in the resulting solution. Schmidt (1995) reported that students consider the products of neutralization reactions to always have a pH of 7 and he described neutralization as a ‘hidden persuader’. Schmidt (1991), who investigated high school students’ conceptions about the neutralization concept, found that students thought neutralization reaction always resulted in a neutral solution. In the same vein, Furio-Mas et al. (2005) states that Spanish chemistry teachers interviewed in their study had the same alternative conception. Similar finding were reported common among student teachers in South Africa (Bradley and

Mosimege 1998). Given these reported issues, it seems likely that both teachers and students have difficulty with understanding what is happening to the values of pH during a titration.

To ensure that subject advisors have a good grasp of content knowledge, practical skills and pedagogical content knowledge on acid-base titration which they can relay to practising teachers, this study investigated South African Physical Science subject advisors' understandings on their content-related knowledge competency of this topic. The study then went on to mentor subject advisors on concepts where they would have expressed uncertainly as to their content knowledge. In particular, focus was on acid, base, neutralization, endpoint, equivalence point, calculations and the conceptualization of the whole process of acid-base titration.

RESEARCH QUESTIONS

The following research question was formulated: How does mentoring enable Physical Science subject advisors to overcome some of the challenges posed by curriculum reform in particular, the acid-base titration topic?

THEORETICAL FRAMEWORK

The study was grounded in research related to two constructs: teachers' knowledge (Shulman 1987), which in order for them[teachers] to be effective in the classroom should be well-developed; and conceptual change (Vosniadou and Brewer 1987), which describes learning as a process that requires the significant reorganization of existing knowledge structures and not just their enrichment.

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). Focus of this paper is on subject advisors' content-related knowledge on acid-base titration, so the study elucidates only the categories of content knowledge and pedagogical content knowledge. Content knowledge is a term used by Shulman to refer to 'going beyond knowledge of the fact or concepts of a domain and requires understanding of the structures of the subject matter' (Shulman 1986:9). To Grossman et al. (1989), content knowledge refers to knowledge of the substantive and syntactic structures of a discipline where substantive knowledge refers to the global structures or principles of conceptual organisation of a discipline. Constructs such as knowledge of facts, concepts, and principles within a content area and knowledge of the relationships between them are included in substantive knowledge (Ramnarian and Fortus 2013). According to Shulman (1987:9), syntactic knowledge encompasses knowledge of the “historical and philosophical scholarship on the nature of knowledge” in a discipline. This would correspond to an understanding of the ‘nature of science’ if syntactic knowledge is applied to the natural sciences. Since the focus of the paper is on topic specific- acid-base titration, syntactical knowledge as a construct is excluded. The content knowledge mentioned within the context of this study therefore refers primarily to the substantive structure of the subject.

Pedagogical Content Knowledge (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). 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). 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 and Reddy 2011). Teachers use multiple pedagogical strategies to transform their knowledge of the subject content into a form that can be easily understood by learners. 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 and Krockover 1997) with a heavy reliance on the textbook (Lee and Luft 2008).

The *conceptual change* theoretical framework focuses on knowledge acquisition in specific domains. Vosniadou et al. (2001) assert that this learning of science differs in important ways from the usual empiricist approach, which says science learning is mostly a matter of enrichment and improving existing conceptual structures. These structures are built on the basis of experiences that are initially concrete and limited. The conceptual change approach has its own critics. To Vosniadou et al. (2001), some researchers have criticized the conceptual change approach on the grounds that earlier beliefs do not disappear when the currently accepted scientific explanations are understood. This disappearance of earlier representations is not, however, a necessary requirement of the conceptual change approach. The conceptual change approach forces the creation of new, qualitatively different representations. The old representations may continue or may disappear. This is a question for empirical research to determine which is beyond the scope of this study.

RESEARCH METHODOLOGY

The study followed a generic qualitative case study design, as the researcher wanted to understand the nature, dynamics and complexity of mentoring at a selected training centre as a case of mentoring of subject advisors (Cohen et al. 2002). The case study research method was deemed appropriate for its in-depth particular research and effective to attain a desired goal in a short time by emphasizing detailed contextual analysis of a limited number of events or conditions and their relationships (Çepni 2003).

Sample:

The sample consisted of 16 Physical Science subject advisors (7 males and 9 females) drawn from the whole of the North-West Province of South Africa. Each participant represented an Area Project Office (APO) and was a mentor to all Physical Science teachers under his cluster who teach at Further Education and Training (FET) band, that is, Grades 10-12. The participants were selected purposefully as they depicted a single case where subject advisors of the Physical Sciences were involved in a mentoring relationship. The participants were considered as a single case during the mentoring process and not as multiple cases. This was then the bounded system within which the study was conducted. The location of the training centre was convenient as both researcher and the participants were booked at the same place hence accessible in terms of contact time and consultation.

RESEARCH METHODS

Data were collected through performing the actual prescribed experiment (acid-base titration), observations during the activity, interviews, listening to discussions between the subject advisors during the activity and written responses to post activity questions. The experiment (prescribed experiment number 3) is exactly the same as the one the teachers in the province perform with their learners in the classroom in Term 2 according to the recent

CAPS document. The interviews, discussion and classroom observations were all audio-recorded and later transcribed. In total, 3 interviews were conducted with each lasting approximately 30 minutes, observations related to the manner in which subject advisors elicited their solution preparation and titration techniques throughout the experiment, and listened to pair and class discussions that varied between 15 to 30 minutes. The class discussions were held after individual completion of the worksheet questions.

DATA ANALYSIS APPROACHES

The data were analysed using the Atlas.ti software. The analysis began with an open coding of the data by assigning codes to segments of the text. As suggested by Henning et al. (2004:132), this was followed by axial coding where ‘the parts of the data identified and separated in open coding back together in new ways to make connections between categories or the codes’ were then put. Various dimensions of mentoring, content knowledge particularly substantive structure of the subject, pedagogical content knowledge and conceptual change constructs guided this process. The codes were grouped into code families, which to a large extent corresponded with mentoring dimensions and the respective constructs within which the study is framed. The researcher and two colleagues (members of a research team where the researcher is based) sought to establish reliability in this process of coding and grouping codes into families by doing the coding independently. An 89% percentage of agreement was obtained in this process of data analysis. This paper reports on challenges that subject advisors faced during the mentoring process based on the themes that emerged as result of this analysis. Since this is a single case, first to be reported is the profiling of the performed activities, and then the mentoring relationship between the mentor and the mentees is described in terms of its relational, developmental and contextual dimensions. However, when doing this, all is related to content knowledge, pedagogical content knowledge and conceptual change constructs. No real names are used this study. All names used are pseudonyms.

RESULTS

Profiling the performed activities

Before performing the activities, the mentor gave a power point presentation on acid-base titration concepts, namely; definition of acids and bases, conjugate acid-base pairs, ampholyte, neutralization, endpoint, indicator and hydrolysis, then moved on to the experiment. The experiment was titled *titration of oxalic acid against sodium hydroxide base*. It was an experiment in two parts. First was preparation of the standard solution (hydrated oxalic acid- $H_2C_2O_4$. $2H_2O$). The subject advisors were then asked to calculate the concentration of oxalic acid solution they had prepared. The worksheet also asked them to explain what they understood by a standard solution. Three additional questions were asked by the mentor, namely: (1) Why is it necessary to be particularly careful when adding the last few drops of water to the volumetric flask? (2) When a solution has been made up, why is it necessary to mix the contents thoroughly? What feature of the volumetric flask makes this particularly necessary? (3) Why is a funnel used in transferring the solution from the watch glass to the volumetric flask?

Second part involved the titration of the prepared oxalic acid solution against sodium hydroxide. The participants were asked to record any colour changes they observed after adding 3-5 drops of phenolphthalein indicator to the oxalic acid. They were also required to note down the colour change they observed at endpoint during titration. Other questions on the worksheet included asking the participants to write down the balanced chemical equation for the neutralisation reaction that had taken place. The participants were also asked to calculate the unknown concentration of sodium hydroxide used in the titration to neutralise oxalic acid. Finally on the worksheet, the participants were asked to motivate why they thought phenolphthalein is the best indicator for this experiment. Eight (8) additional questions were posed by the mentor to aid on the skills, comprehension and conceptualization of the titration process. Some of questions include; (1) Why is a conical flask, rather than a beaker, used in this experiment? (2)Why is the funnel removed from the burrette after adding the base solution? (3) In using a burette, why is important to: (a) rinse it with a little of the solution it is going to contain; (b) clamp it vertically; (c) have the part below the tap full. (4) The following procedures were carried out during the titration: (a) The sides of the conical flask were washed down with deionised water; (b) The conical flask was frequently swirled or shaken. Give one reason for carrying out each of these procedures.

Relational dimension: A mutually dynamic beneficial relationship that is built when the mentor and mentee collaborate as partners to solve problems of practice within a community of practice

The relationship between the mentor (researcher) and the mentees (subject advisors) was one that was built on benevolence, engagement and nurturing among other traits. An egalitarian association had to be promoted since the mentor had perceived the delineation between the mentor and mentees to be blurred. For one to be appointed as a subject advisor, they have to have garnered enough teaching experience with them executing their duties extremely well in the classroom. The individuals must also show willingness to staff develop themselves overtime, hence, referred to as substratum of the profession in this study. As a result most of the participants were holders of Master of Science Education degrees. This did not mean that all the participants were well versed with acid-base titration concepts. In responding to the first additional question on why one had to be extremely careful when adding the last few drops to the volumetric flask? All participants elicited that they did not know the definition of a standard solution. Some just thought that if a solution was labelled 1.0M, then it was standard. Of the 16 participants, no one stated that a standard solution is one whose concentration is accurately known. When asked during discussion, what they would recommend to teachers if they had over shoot the mark, some suggested teachers should just proceed with the experiment. Mr Seoke said, “I would recommend them to continue with the experiment” Again this showed that the definition of a standard solution was not well understood by some of the participants. The other question where the mentor had to exude empathy is the additional question focusing on why the conical flask, rather than a beaker, was used in the experiment. All 16 participants went blank. No individual got it correct. The mentor then asked all the participants to put some acid or base in a beaker in front of them and try to swirl it in a mixing fashion. Some spilled the solutions in the process and the mentor asked them to repeat the process using a conical flask. To their amazement, all shouted “for easy mixing without spilling”, much to the respect of the mentor. This showed that participants lacked knowledge of facts and principles and relationships between these practices and constructs.

Developmental dimension: Developing PCK through reflective discussions and exploiting each other’s strengths in overcoming deficiencies in their practice

Participants showed that they struggled with questions related conceptual knowledge rather than procedural knowledge. When asked an additional question related to the first part of the activity; when a solution has been made up, why is it necessary to mix the contents thoroughly? What feature of the volumetric flask makes this particularly necessary? Participants did not do justice by giving convincing answers to this question. This question further revealed that the participants did not know the relevance and usefulness of certain apparatus. Of the 16 participants, not even one managed to mention the narrow neck of the volumetric flask as a feature necessary for obtaining a homogenous mixture. This shows how conceptually challenged the participants were regarding this concept.

The other additional question which posed problems is one which dealt with titration procedures. Participants were asked to give just one reason for carrying out each of the following procedures; (a) the sides of the conical flask were washed down with deionised water, (b) the conical flask was frequently swirled or shaken. Nine (9) of the participants got the answers to this two-part question correct and 7 participants got it totally wrong. One participant, Mrs Paulus wrote, “Deionised water must not be added to wash down the sides of the conical flask as this will change the concentration of the resultant solution”. During interviewing, when asked to elaborate on her written response, Mrs Paulus said,

“During the preparation of the standard solution of oxalic acid, we made sure that we did not exceed the calibration mark when adding water to the volumetric flask so that our concentration becomes accurate. In the same manner, if we add water, I thought it would affect the concentration of the resultant solution.”

This is a clear misconception where the terms “moles” and “concentration” and the titration concept as a whole are ill-conceived. During the discussion session, Mrs Paulus argued vehemently for her point only to say after 15 minutes of debate, “I did not do this during my training, now I understand.” One participant, Mr Madito answered part (b) by saying the conical flask was frequently swirled or shaken so that the reaction can take place. When asked to clarify his written response, he said “shaking enables the reactants to react.” Maybe this has to do with language issues in science or the concept of titration itself. Another aspect which was worrisomely observed by the mentor is how the subject advisors performed the titration. Since they were doing the experiment in pairs, one was opening the tap of the burrette whilst the other was shaking the conical flask. The mentor did not demonstrate initially as he wanted to see how much of the good practices the participants harboured. Having ascertained the developmental level of the participants, the mentor-mentee and mentee-mentee relationships were used during the discussion session to shift the mentees toward a higher level of development. The mentor demonstrated how to hold the tap and swirl the conical flask when performing the titration. In so doing, based on their PCK, subject advisors translated subject content knowledge into useful forms of representations of ideas in the form of demonstrations, powerful analogies, explanations, illustrations and examples to facilitate comprehension by teachers they mentor.

Contextual dimension: A community of practice conducive to mentoring confined to subject advisors' areas of influence

All participants got the third additional question relating to the first part of the experiment correct. The question was, why is a funnel used in transferring the solute from the watch glass to the volumetric flask? However, problems were encountered in answering additional questions related to the second part of the experiment which is titration process. The question which gave problems to participants states: In using a burette, why is it important to: (a) rinse it with a little of the solution it is going to contain; (b) clamp it vertically; (c) have the part below the tap full. Most of the participant's answers (10) were not precise. Mrs Methikge's responses to parts (a) and (b) were, "to ensure that the burette is clean" and "to make it full" respectively. During interviewing, she was asked; would the burette not be clean by cleansing it with water only? She responded, "It will be clean but not very clean." Issues of dilution were missed here. During the discussion session, the participants were first asked to help each other consolidating the mentee-mentee relationship before the mentor popped in to assist with strategies of good teaching, guided by an understanding of teacher learning promoting the mentor-mentee relationship. Participants assisted each other well during discussion and it could be seen they need more of this peer-to-peer environment. The mentor reiterated collaborations and formation of communities of practice so as for them [participants] to assist teachers with knowledge acquisition in specific domains.in their respective districts.

DISCUSSION OF FINDINGS

The findings of this study show that, mentoring has provided a viable and sustainable means through which content knowledge, pedagogical content knowledge and conceptual change efforts were consolidated in this single case. The dynamic nature of the mentoring relationship, from a relational perspective became more egalitarian and the initial delineation between the roles of mentor and mentees was becoming increasingly blurred. Initially, the mentees had a strong dependency on the mentor in seeking advice on how to overcome the challenges they were experiencing as they prepared to go and mentor teachers in their area project offices regarding acid-base titration. They listened attentively and took notes solemnly as the mentor continued with his presentation during the initial period. As the day progressed, the mentoring roles changed as the mentor-mentee relationship evolved. The initially one sided relationship changed and mentees started to assist each other with explanations through use of models and examples during discussion assisting their colleagues. The mentee-mentee relationship got stronger making the mentor-mentee relationship even more blurred, as the participants who had grasped the concepts took control and the relationship resembled that of a collaborative mentor-mentor relationship. The mentor became more of a critical friend.

This finding is in agreement with Ramnarian and Ramaila's (2012) findings which showed that with time one of the novice teachers with his increasing confidence and competence started to engage more collaboratively with his mentor. The implication of this for mentoring is that it cannot be conceived as a static relationship, but is dynamic by nature instead. It was also apparent that at any given stage in this relationship there was empathy and respect. The participants laid out their concerns about their lack of conceptual understanding on some of the processes and skills without reluctance. As much as the participants were conceptually challenged with aspects which seemed easy basing on their 'bedrock' nature to the profession, the mentor had to exude empathy as there had been reciprocal mutual trust. On a professional level the subject advisors developed capacity in addressing the challenges in their practice at the end of the day.

From a developmental perspective, it was apparent that development was taking place in both the professional and personal domains of the subject advisors. Regarding the mentor-mentee relationship, Mrs Paulus, for example, in the professional domain showed misconceptions where she used the terms 'moles' and 'concentration' interchangeably in arguing against addition of deionised water to the sides of the conical flask during titration. After the mentor tried several times to explain the difference between these two terms, she partially understood and was not convinced. It was now left to the mentee-mentee relationship to try and bridge the gap. Two participants stood up to the task one after the other and used models to explain to their colleague so as to address the shortcomings. At the end of the day, Mrs Paulus became more confident in her own ability and the initial apprehensiveness that she experienced when responding to additional questions posed after the activity was no longer evident. A possible explanation for this might be that through a reflective process and the advice she received, Mrs Paulus was able to initiate steps in improving her comprehension of these concepts. In particular she was able to develop her content knowledge and using the model explanation rendered by her colleagues. At the end of the workshops, she openly said her PCK had developed and she would explore strategies on how best to make scientific knowledge more accessible to teachers under her tutelage. The analogy given on the use of microscopic representations during titration is one example which resulted in participants acknowledging conceptual change in the whole process of mentoring on this topic. Through collaboration the subject advisors were able to improve their conceptual understanding and acquired knowledge beyond their independent level of exploration of this topic

The findings with regard to the contextual dimension of mentoring suggest that a more concerted effort needs to be made in creating conditions that would facilitate a community of practice in which mentoring may thrive. Although, these results differ from some published studies (Evertson and Smithey, 2010; Lai 2010), they are consistent with those of Ramnarian and Ramaila (2012) with South African teachers. Peer-peer collaborations need to be promoted. In this regard subject advisors need to be instrumental in initiating communities of practice so that teachers under their guidance engage collaboratively on curriculum issues that are significant for the context in which they teach. As they [subject advisors] have been identified as the 'bedrock' of the profession, they need to make formal arrangements and move from school to school mentoring Physical science teachers as per their job description. They can even assist the teachers in small groups in their respective districts. In the process, the subject advisors should also encourage formation of communities of practice by the teachers so that the teachers may end up providing support to other teachers who are in need of professional development in the absence of the subject advisors. This might result in teachers developing a culture of working together for a good cause linked to a vision of good teaching, guided by an understanding of teacher learning, and supported by a professional culture.

CONCLUSION

The findings of this study have provoked further questions on mentoring that should be addressed in subsequent studies. Research questions that could be asked include: What factors limit the success of mentoring relationships and what can be done to overcome them? To what extent does mentoring eliminate misconceptions? What type of impact does mentoring have on the classroom practice of mentored teachers? What level of support in a mentoring professional development is ideal? What factors support mentoring relationships between subject advisors and teachers? In crafting the way forward it is recommended that further research be undertaken on mentoring in science education and that other methodologies for inquiry be employed to investigate mentoring beyond single cases. In addition, more case studies of mentoring across diverse settings that is synonymous with the South African educational landscape would validate the viability of mentoring as a widespread form of professional support for teachers. As Achinstein and Athanases (2006:12) point out, ‘mentors are not born, but made, and are in a continuing process of becoming’ and ‘making mentors is a deliberate act’. Deliberate effort is therefore needed to produce new mentors from teachers to be mentored by the subject advisors and to sustain their learning over time.

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