Lucid Perspectives on the Art of Physical Science Teaching from the South African Context

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Abstract

This paper presents the literature reviewed to articulate lucidly the nature of science, the purpose of teaching science, general teaching challenges in physical science as well as teaching as an art in the context of teaching in the high school. The teaching of science involves many facets such as the nature of science and the nature of teaching challenges in physics. The purpose of this presentation is to add into the resources for in-service training. The paper should induce discussions within the community of practice in the physical science as to how facets involved in the crafting of the art of teaching physical science shape it. It is also envisaged that the presentation should form some basis for further studies that focus on the indicated facets on how they shape the teachers art in practice which should in turn influence further research on the kind of appropriate in-service training to hone the teacher's art.

Keywords*: art, teaching, science, nature, challenges*

1. Introduction

With the current state of the teaching of physical science in some parts of the Republic of South Africa blurry, it is important to explicate some perspectives on the art of its delivery. As much as music is a talent, its delivery is horned to shape the kind of music produced. It is from this perspective that this paper interrogated the literature associated with the teaching of physical science. This is to create a fertile ground for engagement on the teaching of physical science as an art which is shaped by the teacher's perspectives on the nature of science, purpose of science teaching and teaching challenges in science. The literature reviewed is not exhaustive of all the materials that speak to the focus outlined here, but rather what has been reviewed should add to the debate. The paper should also induce debates and discussions on the teaching of physical science as an art.

2. The Nature of Science and the Purpose of Teaching Science

The nature of science is the epistemology of science, which realises science as a way of knowing tentative knowledge (Akarsu, 2010; Akerson & Donnelly, 2010; Abd-El-Khalick & Akerson, 2009; Karakas, 2008 and Lederman, 1992). There are various ways of knowing science of which one is through the teaching of science (Abd-El-Khalick and Akerson, 2009). Consequently, some scholars in science education (Abd-El-Khalick & Akerson, 2009 and Magnusson et al., 1999) are of the view that science must be taught through inquiry, conceptual change, process, discovery and didactic approaches amongst other approaches. Moreover, the nature of the subject demands that students should learn science to develop inquiry and problem solving skills (Abd-El-Khalick and Akerson, 2009). Therefore, science teaching is the act and art of teaching students to develop problem solving and inquiry skills. Furthermore, during science teaching students must make meaningful learning (Leach & Scott, 2003 and Nola, 1997). Science teachers should also embrace the notion that science teaching is a means to an important end. Thus the impact of teaching is customarily manifested in student performances. If the students are not performing, teachers should accept some responsibility for their students' struggles (Staver, 2007). This is to ensure that the purpose of teaching science is achieved. The primary purposes of science teaching are to develop inquiry and problem solving skills. Yet, secondarily the purposes of teaching science are to prepare students to study science at higher levels of education, to prepare students to enter the workforce and take up careers, and to prepare students to become more scientifically literate citizens (Staver, 2007). However, Staver (2007) indicates that some Science teachers believe that their responsibility is to teach Science and the responsibility of students is to learn what has been taught. According to this view, if students struggle to understand, the responsibility rests only with students. This is a deceptive interpretation of the Science teacher's responsibility which will neither enhance the purpose of teaching science nor improve students' performance.

As such the teacher's perspectives of the nature of science and the purpose of teaching science are intertwined. Yet, these perspectives should summarily serve to shape the art of how the teacher teaches. It is not expected of the teacher to elucidate his views of the nature of science and the purpose of teaching it verbally. Nevertheless, through the presentation of lessons, it should be diagnosed. It follows then that to shape or nature the teacher's art of teaching science it needs to be of outermost importance to also diagnose the teacher's views on the nature of science and the importance of teaching it. It cannot be an issue of content knowledge and its pedagogy as it is usually done (Mudau, 2013).

3. Teaching Challenges

It is a pre-requisite for a teacher to understand the topics in physical science they are going to teach at a deeper level (McDermott, 2006). This is so because having taught a particular physics topic does not necessarily improve the comprehension of that topic. Furthermore, she indicates that many teachers lack an understanding of very basic concepts in physics. These assertions are applicable to the South African teacher. Many of the teachers were trained in the former colleges of education and as such have limited content knowledge (Rollnick et al., 2008). They were not taught such that they have a deeper understanding of what they were going to teach. Hence, the DoE (2006) emphasized the need for teachers to further their studies in physical science content. In-service training for CTPD was also instituted to enhance deeper understanding of the science topics. However, McDermott (2006) assert that teachers must have PCK in order to be effective in helping their students understand and learn.

This is appropriate as even the teachers who were produced from the universities fail to make the physical science content a teachable content. So it cannot be the notion of lack of content knowledge only nor the pedagogy but the PCK is also vital. In the South African context in teacher development more emphasis has been and is still on the improvement of teacher qualification and content knowledge in the FET phase. The DBE (2009) indicates that many teachers registered for qualifications which are not in the sciences. Hence physical science centres for example the SCI-Bono which enhance physical science teachers' content knowledge as well as the achievements of students were initiated. The districts of education where also tasked with ensuring that teachers are equipped in terms of the content knowledge in physical science through workshops. How the teacher presents the content in the classroom or how it should be presented is not catered for. The teacher's expertise in the classroom is not focused on. Even the growth of the teacher in the profession is largely based on the qualification which the teacher has and not on his expertise in the classroom.

Studies do confirm a positive significant relationship between the teacher with high content knowledge and student achievement (Kaplan and Owings, 2001). But Magnusson *et al.* (1999) did indicate that it is not guaranteed that strong content knowledge of the teacher will result in better student achievement, as the teacher might not have the best methods of representing that knowledge. This is further emphasized by Haycock (1998) and Kaplan & Owings (2001:68) who indicated that "professional development can be a useful tool for improving teaching quality and student achievement when teacher learning activities are closely tied to actual classroom practices". Hence according to Kaplan and Owings (2001) a focus on developing the content of teachers is desirable but it is also essential to focus on the professional development of the teacher if the student achievements have to be improved. In this case, referring to the actual teacher practices in the classroom.

McDermott (2006) also indicates that the ability to solve quantitative problems is not an indication of strong command of concepts and representational skills. Emphasis should be on reasoning required in the development and application of concepts (McDermott, 2001 and 2006). According to Gess-Newsome (1999), the SMK of what she calls the *knowledgeable teacher* (KT) is organised whilst that of the *unknowledgeable teacher* (UT) is unorganised. It is further indicated that KTs plan a lesson from the perspective of students' understanding whilst the UT relies on textbooks. Kalman (2009) also indicates that when science teachers rely heavily on textbooks it does not help students to develop a scientific mindset, thus creating difficulties in comprehending the science content. Moreover, the KT involves students actively in the lesson and can deal with students' misconceptions and alternative ideas whilst the UT's teaching style is algorithmic and s/he tends to teach in such a way that only questions that are up to their level are asked and they are dismissive of alternative answers

To avert the challenges in the teaching of physical science many higher institutions of education (HEI) in South Africa adopted a system wherein pre-service students are taught physics content in the physics department or by lecturers who are knowledgeable in the physical science content. Yet, McDermott (2006) cautioned that in-depth study of basic topics is more useful than superficial coverage of advanced topics and choice of topics should be guided by grade 12 curriculum even though not limited to that. What the HEIs are doing is not an absolute solution to the challenges in the teaching of physical science. This is so because McDermott, Heron, Shaffer and Stetzer (2006) indicate that there is a gap between what is taught in high schools to what is in the materials at the universities. As such McDermott (2006) posit that materials in those courses must prepare teachers such that they teach science to students as a process of active inquiry and not as a body of information which they must memorize. This point emphasise the relevance of the need to focus on the teacher's perspective on the nature of science and the purpose of teaching it.

Gunstone et al. (2009) and Schwartz and Lederman (2008) indicate also that the nature of the content itself can cause challenges in the teaching of the subject because some concepts are abstract and teachers fail to use explanatory frameworks that will enable students to learn. So, teachers resort to traditional methods of transmitting information. According to Mulhall and Gunstone (2012) these traditional methods put forward the use of mathematics to represent science ideas above conceptual understanding. According to Magnusson et al. (1999) some challenges result from the concepts of science such as projectile motion and quantum mechanics lacking any connection with the students' common experiences. Magnusson et al. (1999) further indicate that some challenges result from the nature of the instruction. That is where the instruction should be problem solving whereas the teacher is not knowledgeable about such modes of instruction. So, Physics can be challenging to teach depending either on how the teacher teaches it, how he was prepared, how he is in serviced or because of the nature of the content itself. However, Gunstone et al. (2009) indicate that a teacher with a more informed view of learning tends to appreciate the teaching difficulties of a topic and uses instructional strategies that facilitate understanding by the students. A point also emphasised by McDermott (2006) when she said that a teacher with a deeper and broader content knowledge and PCK should help students to learn meaningfully

4. The Art of Teaching

Teaching as explicated in a model of pedagogical reasoning and action (Shulman, 1997) is an art which involves the compression of the subject matter and pedagogical reasoning. According to the model teaching involves the exchange of ideas. That is the teacher grasps an idea and understands it as well as try to see many sides of it. The idea is then shaped so that it can be comprehended by students. It follows then that it is not only about grasping the subject matter but also involves its ways of effective delivery. Hence, the saying by Shulman (1986:14) that "those who can do; those who understand, teach". Therefore, the quality of teaching mirrors the comprehension of what is to be taught and henceforth the transformation and reflection thereof of what is to be taught which is called reasoning (Shulman, 1997). Furthermore, using the ideas of Kaplan and Owings (2001), teaching quality is what the teacher does in the classroom to promote learning amongst the students. This includes the type of instructional strategies he/she chooses to advance learning and create a positive learning environment. So the teacher's teaching quality should be judged from how his/her classroom practices such as instructional strategies, interactions and discourse advance meaningful learning, misconception dissonance and the development of inquiry and problem solving skills (Abd-El-Khalick & Akerson, 2009).

Moreover, Shulman (1987:7) indicates that "teaching necessarily begins with a teacher's understanding of what is to be learned and how it is to be taught". A teacher is that person who knows something not understood by others, usually students, and the teacher then transforms and reorganises that which is to be understood (Shulman, 1987). Reorganisation of the subject matter is very important so that it can become teachable content to be understood by the students. Even though the subject matter knowledge is very important in the Pedagogical Content Knowledge theory (PCK) as espoused by Rollnick et al. (2008), its representation and instructional strategies for student consumption are also very important (Magnusson et al. 1999). Within the pedagogical reasoning and action model, comprehended ideas by the teacher need to be transformed so that they are teachable to the students (Shulman, 1997). The transformation process encompasses instructional selections which involves instructional strategies. Magnusson et al. (1999) categorised instruction into two strategies namely: the subject-specific strategy as well as the topic specific strategy (Magnusson et al., 1999). Topic specific instructional strategies and explanatory frameworks are shaped by teacher knowledge (Mudau, 2013). Magnusson et al. (1999) considered explanatory frameworks as part of topic specific instructional strategies, which the researcher found plausible. This was so because the researcher found it illogical to consider explanatory frameworks independently of topic specific instructional strategies. Magnusson et al. (1999) further indicate that subject specific strategies are broad teaching strategies which are mostly based on the teacher's belief system. Amongst others they include the process, didactic, discovery, activity driven, inquiry and conceptual change strategies.

The topic specific strategies can be differentiated into two categories, namely explanatory frameworks and activities. Explanatory frameworks can be illustrations, examples, models or analogies, for instance using the flow of water through pipes as an analogy to explain the concept of electricity. Activities are used to help students comprehend specific concepts. Hollon, Roth and Anderson (1991) indicate that instructional strategies should engage students in such a way that they are able to think and also realise that their thinking is important. The choice of the instructional strategy by the teacher is important as it influences the comprehension of the subject matter by students (Kaplan & Owings, 2001). According to Kuzniak and Rauscher (2011), the epistemological perspective of the teacher has an inherent influence on the choice of instructional strategies. What is more, students struggle to understand abstract science due to "….instructional strategies that do not lead students to grasp the meaning of the learning task" (Ward & Wandersee, 2002:575). In actual fact the use of explanatory frameworks should help students comprehend the targeted concepts (Childs & McNicholl, 2007). Additionally, Childs and McNicholl (2007:1633) indicate that "the main reason for teachers using analogy and metaphor is to make scientific ideas accessible to young people, in other words to simplify them". However, it is also important to note that instructional strategies are intertwined with content knowledge. This is so because according to Childs and McNicholl (2007) when teachers' subject content is insecure their ability to use appropriate instructional strategies for science teaching explanations in the classroom is limited. The teacher's ability to use explanatory frameworks is a very important aspect of the teacher's pedagogical content knowledge.

In the art of teaching, the quality of the teacher depends on the teaching qualification which the teacher has and this is called teacher quality as well as what he does in the classroom which is called teaching quality (Kaplan and Owings 2001). Teacher quality refers to what the teacher brings to the classroom, the qualifications and professional preparation. The teaching quality refers to what the teacher does in the classroom to promote learning amongst the students. This includes the type of instructional strategies he/she chooses to advance learning and create a positive learning environment. Kaplan and Owings (2001) also indicate that the teacher's expertise in the classroom is an important factor in student comprehension and achievement. Hence, the focus cannot be solely on equipping the teacher with the content knowledge but the teaching of the content too. A point raised by McDermott.

How knowledge can be demonstrated, which is the teacher's epistemological perspective (Mason, 2002), has an inherent influence too, on the art of teaching (Kuzniak & Rauscher, 2011 and Kalman, 2009). There are many epistemological perspectives, some of which are rationalism and empiricism (Boeree, 1999). Rationalism is the gaining of knowledge through reasoning, whereas from the empirical perspective knowledge is gained through experience. It was also imperative for the purposes of this study to note that studies such as Childs and McNicholl (2007), Nott and Smith (1995), as well as Dagher and Cossman (1992) indicate that in the art of teaching, a teacher whose content knowledge is adequate and who has the ability to represent it to his/her students engages in class activities that facilitate students' learning. However, teachers whose art of teaching is deficient, for example from the lack of adequate subject matter knowledge, lack confidence and this has implications for how they plan and teach the subject matter. Thus the teacher's art of teaching should help students to make meaning out of what is being taught so that they can gain knowledge and achieve expected goals (Wayne & Youngs, 2003).

5. Conclusion

This paper has presented the possible influence of the teacher's perspectives on the nature of science, the teaching purpose and teaching challenges. It also elucidated on the teaching of science as an art. It is envisaged that the logical reasoning of the art of teaching being a complex activity founded on the teacher's perspectives of the nature of science and its teaching has been expounded. Furthermore, the teaching challenges which should also shape the art of teaching science were also discussed. The review conducted should form a basis for micro fundamental resources for in-service training with a focus on teaching as an art influenced by many facets of which some of them were elaborated in this paper. Henceforth, it is imperative to engage on empirical studies that will focus on how the facets discussed shape the practice as well as how to intervene to assist or nature the teacher's art of teaching science.

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