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Pedagogical issues of Senior Phase teachers when teaching the matter and materials strand of natural sciences

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The study reported on here was a qualitative interpretative case study. We explored the pedagogical issues of Senior Phase natural sciences teachers when teaching the matter and materials strand in some of the schools in the Siyabuswa circuit. This study was motivated by the concerted focus on the Fourth Industrial Revolution in developing countries with a particular focus on science, technology, engineering and mathematics (STEM) subjects, fast-tracked by the coronavirus disease (COVID-19) pandemic. The following question guided the study: What are the classroom practices of teachers when teaching the matter and materials strand in the Senior Phase? Semi-structured interviews and observations were used to collect data from 2 purposefully sampled participants. The findings show that some natural sciences teachers are frustrated with the teaching of natural sciences as they are teaching out of their fields of expertise. Furthermore, they are not qualified to teach the subject and the workshops presented are not capacitating them to teach the strand. Their limited content knowledge (CK) and weak subject matter knowledge (SMK) result in misconceptions, which could be transferred to their learners. Moreover, the lack of CK and SMK also impacts on their choice of instructional strategies as they still prefer traditional methods of teaching, which promotes memorisation. In the study, even the teacher who was qualified to teach the subject still lacked content knowledge and instructional strategies like the unqualified one. The challenge is that the core resource in increasing interest and uptake in the STEM subjects, the teacher, is lacking knowledge and instructional strategies. It is, therefore, prudent to recommend tailor-made content enrichment workshops on the matter and materials strand. These workshops should also be intertwined with pedagogical issues. We also recommend studies on specific topics in the matter and materials strand as this study focused only on a broad overview of the strand.

Keywords: matter and materials strand; natural sciences; pedagogical issues; subject matter

Introduction

The COVID-19 pandemic has motivated the urgency in many countries to fast-track towards the Fourth Industrial Revolution as opposed to what would normally have happened (Mnguni & Mokiwa, 2020). This is clear from the number of countries that drastically began to incorporate online teaching and learning in their education system, as well as a concerted effort to integrate STEM education, as in the United Kingdom (UK) and the United States of America (USA), or increase the focus on STEM education (Aykan & Yıldırım, 2022). In developing countries with developing economies, a nuanced focus on STEM subjects has been the intention, however, with slow implementation for some time (Adesugba, 2018). Thus, in spite of the COVID-19 pandemic being devastating in terms of human lives, it has indirectly fast-tracked the focus on STEM subjects.

It is also the vision of the South African government to increase the number of learners taking subjects in the science, technology, engineering and mathematics (STEM) field (Mudau & Nkopodi, 2015) like in many developing and even developed countries (Mnguni & Mokiwa, 2020). In some developing countries schools and industries cooperate in an effort to integrate STEM and stimulate interest in these subjects (Kim, 2021). However, many developing economies like South Africa lag behind in integrating or increasing the numbers of learners in STEM subjects because of the teachers they have (Yıldırım, 2021). Jamil, Linder and Stegelin (2018) indicate that teachers who have little knowledge in these subjects will have less interest in them and this will also translate to their practice in the classroom. Even in South Africa this is not a foreign phenomenon. Teachers’ incompetence in teaching some of the STEM subjects such as natural sciences is one of the constraints to effective and meaningful science teaching and learning (Netshivhumbe & Mudau, 2021; Nkanyani & Mudau, 2019; Semeon & Mutekwe, 2021). The focus on natural science is of paramount importance as it is the gateway to subjects such as physical science and life science (Nkanyani, 2017). It is also imperative to note that there has been a decrease in the number of learners taking physical science (Ogegbo, Gaigher & Salagram, 2019) in the Further Education and Training Phase (FET), which directly affects the numbers envisaged by the government in the STEM field (Sedibe, Maema, Fourie & Peter, 2014).

Kola (2013) indicates that natural science teachers are important in the teaching and learning of sciences and that there cannot be progress in science education in any country without considering the teachers’ contribution in the education system. Wang and Fwu (2007) further argue that there is no good education without good quality teachers. In science education, there is a necessity for qualified and specialised science teachers to teach the subject. This will not only ensure content accuracy and the use of appropriate instructional strategies, but also aid to increase the motivation and interest of learners. The studies conducted by Dudu (2013) and Makgato and Mji (2006) show a trending challenge in the South African science education system, which is the lack of specialised science teachers. Apart from the above, Taylor and Moyana (2005) also observed a similar trend – they revealed that these teachers also lacked adequate CK.

Muwanga-Zake (2001) highlights that there is a lack of qualified natural science teachers and that in some instances the subject is taught by teachers who may not have adequate qualifications to teach it. Mudau and Tabane (2015) agree with the above and indicate that the lack of knowledge and skills in science teaching by misplaced teachers is problematic. Moreover, Netshivhumbe (2018) claims that teachers teaching natural sciences in the Senior Phase are also faced with a lack of resources and the learners' lack of interest in learning natural science. Although the South African education system has endured a series of curriculum reforms to address the injustices and inequalities caused by apartheid policies (Bantwini, 2010; Jansen, 1998), human resources remain challenging. The effectiveness of the reforms will only materialise when the subject is taught by effective, qualified teachers (Bantwini, 2010). Even Aykan and Yıldırım (2022) indicate that for the effective integration of STEM subjects teachers should develop competencies in these subjects. Thus, the call on the integration of STEM subjects without improving the competencies of teachers is a futile exercise.

In making a contribution to address the challenges that teachers face it is imperative for us to focus on the human resources and their readiness in the concerted focus on STEM subjects in South Africa. The findings in our study were not too dissimilar to those found in other developing, and to a certain extent, developed countries. As a Senior Phase natural science teacher, one of the researchers observed some of the natural sciences teachers' struggles in teaching the matter and materials strand. Moreover, after attending several content workshops, the researcher observed teachers venting their frustrations about how they struggled with the content, especially the matter and materials strand, as it requires science CK which some of them did not have due to a lack of specialisation in the subject. When completing the attendance register for workshops, teachers are required to complete their teaching qualifications as well, from which it was evident why they were frustrated. Most of them were not specialists in natural science because they specialised, among others, in life orientation, geography or history, therefore they did not have adequate qualifications to teach the subject. At the specific workshop more than 20 of 44 teachers (close to 50%) attending did not hold natural science qualifications. The anecdotal observations at these content workshops made us realise that, especially with regard to the matter and materials strand, further research the teaching of the strand was warranted. Even though numerous studies (Bantwini & Feza, 2017; Netshivhumbe, 2018; Nkanyani, 2017; Sedibe et al., 2014) have been conducted on natural sciences in the Senior Phase, none of them specifically investigated teachers' classroom practices when teaching the matter and materials strand.

In this article we focus on natural sciences teachers' pedagogical issues, which entail CK, SMK and instructional strategies. According to Kleickmann, Richter, Kunter, Elsner, Besser, Krauss and Baumert (2013), CK is a key component of teacher competence that affects learners' progress. CK is the amount and organisation of the teacher's SMK (Mudau, 2013).

In this article instructional strategies entail epistemological perspectives, explanatory frameworks, and activities. According to Mudau (2013), epistemological perspectives refer to how knowledge is demonstrated to learners, whether rational or empirical. Empiricism is the gaining of knowledge through experiences, while rationalism is the gaining of knowledge through reasoning. Explanatory frameworks are the analogies, models and/or illustrations that teachers use to make learning accessible for learners. The problems, demonstrations, simulations, investigations, or experiments that teachers use to help learners understand the subject matter are called activities. The choice of instructional strategies is greatly influenced by the teacher's CK and SMK (Kuzniak & Rauscher, 2011), which means that a teacher who lacks SMK and CK will not find it easy to choose appropriate instructional strategies, and hence the teacher will resort to rote learning. This implies that a teachers' teacher knowledge and instructional strategies are dependent on each other.

Method

The research approach used in this study was qualitative in nature, which is considered a method of inquiry by making sense of central phenomena in studying participants in their context. In this case the phenomenon was the practical experiences of natural science teachers when teaching the matter and materials strand. A multiple case-study design was used because we were more interested in obtaining in-depth details of what was being explored (Njie & Asimiran, 2014). Furthermore, we used a multiple case study design as the cases were treated as individual cases which were not compared, although we reflected on findings from both at the end. This design allowed us to understand the contextual factors underlying teachers' actions and allowed us to treat each case differently as the participants had different backgrounds and teaching experiences.

Purposive sampling was used to select two participants for this study. Sampling was done based on the following criteria: all participants were required to have taught natural sciences in the Senior Phase in schools in the Siyabuswa circuit for a minimum of 2 years; participants had at least one recognised teaching qualification, e.g., Senior Teachers Diploma (STD), Senior Primary Teachers

Diploma (SPTD), et cetera. Only participants who were willing to participate in the study were considered.

Qualitative data were collected in two ways. In the first instance, one-on-one semi-structured interviews with a set of pre-determined questions (Lombaard, 2015) were conducted with two natural science teachers from two selected schools. Even though interviews are considered to be time-consuming and costly (Creswell, 2007), this technique has been determined to be the most relevant to collect data from a small number of participants and because of the personalised nature of the interview data. It is through the interviews that sufficient and relevant information was gathered (Frels & Onwuegbuzie, 2013; Hancock & Algozzine, 2011). Interviews also provide a richer source of descriptive information than other data collection instruments such as questionnaires (Bertram & Christiansen, 2014). Participants were interviewed for a period of no more than 30 minutes during their free time and after school. The interview responses were recorded on tape. Post-interview questions were prepared after classroom observations had been done.

The second strategy, classroom observation, served as a useful strategy for data collection as we wanted to gain an in-depth understanding of classroom practices of natural science teachers when teaching the matter and materials strand. One class of learners from each selected school was observed. Observations were conducted after the interviews. The type of observation most suited for this study was the observer as a non-participant because we remained uninvolved and did not influence the dynamics of the setting. The two strategies also assisted in data triangulation. We corroborated participants' responses from the interviews with the classroom observations to confirm the findings.

A typological approach was used for data analysis wherein the themes and categories were developed from the research questions, the literature review, and personal experiences (Hatch, 2002). The collected data from the two cases were analysed and interpreted separately as no two cases are similar. When analysing data, teacher knowledge entailed content, context and learners' understanding. CK refers to the amount of knowledge that the teacher has on the subject matter and its organisation. Context knowledge refers to other factors that influence teaching and learning of the subject matter such as resources and curriculum. Learners' understanding refers to how the teacher links learners' prior knowledge to the new concepts and how they identify and rectify any misconceptions displayed by learners. Instructional strategies entail the teaching methods that teachers use to mediate the CK for meaningful learning.

The classroom practice diagnostics framework (CPDF) by Mudau (2016) was considered as framework for this study as it focusses on teachers' teacher knowledge, instructional strategies and interaction, and discourse as the proponents of classroom practices.

Results

In this section we present the results of the study. Each case is presented separately as a comparison was not the focus of the study.

Case 1: Kate

According to the natural science curriculum and assessment policy statement (NS CAPS) for Grades 7 to 9 (Department of Basic Education [DBE], 2011), the natural sciences curriculum consists of four knowledge strands, namely: life and living, matter and materials, energy and change and planet Earth and beyond. Since this study is based on one of the four strands, matter and materials, all of the observations and interviews were focused on this particular strand. During the pre-interview, Kate indicated that she would teach metals, non-metals and semi-metals as part of the matter and materials strand according to the NS CAPS for Grades 7 to 9 (DBE, 2011). From the onset Kate displayed a limited CK as she failed to explain the concepts she was going to teach during her lesson:

> Kate: *Non-metals are found on the periodic table, from our left-hand side those are the materials that cannot make a steel, example a wall. And semi-metals are found not exactly in the middle of the periodic table, we find them after the non-metals, and they can be a liquid or a metal. They are in between the metals and non-metals.*

From the above it is clear that she could not explain what non-metals were but only indicating where they appeared on the periodic table. She did the same with metals and semi-metals, only describing their positions on the periodic table. This indicates that Kate did not know what these aspects entailed, and shows that she had limited comprehension of those aspects.

Her limited CK was also evident during the classroom observation when she was interacting with the learners. The following was observed:

> Kate: *Non-metals are found on the right-hand side of the periodic table* (reading from the textbook).
> Kate: *How many non-metals do we find on the right-hand side?*
> Thulani: *16.*
> Kate: *No they are not 16. They are 16 on the right-hand side plus one that is up on the left-hand side which sums up to 17.*

In her answer to the learner, Kate only told the learners that there were 17 non-metals on the periodic table but did not explain why one (hydrogen) was located on the left-hand side of the periodic table and why it was classified as a non-metal. This could have been a learning opportunity that could have benefited not only the learner in question but the rest of the class as well. This was one of Kate's shortcomings and a clear indication of her lacking SMK and CK.

Keeley (2012) defines prior knowledge as pre-conceived ideas that learners have and bring to the classroom about science topics and concepts. Prior knowledge is regarded as a foundation to meaningful learning (Ausubel & Fitzgerald, 1961). In order for meaningful learning to take place, both the learner and the teacher must play their part. Learners have pre-conceived ideas and concepts about science and the teacher uses these pre-conceived ideas to build and link new knowledge. Kate indicated that in the last lesson the learners had learned about the properties of metals, hence she started off by doing revision and asking learners questions on the work previously learned before proceeding to the new topic. However, she did that to show the link between the previously learned concepts and the one to be introduced. Furthermore she did not check how much the learners knew about the new concept to make that the focus of her lesson. Mesa, Pringle and King (2014) assert that concepts are built from known to unknown content. As she was checking the learners' prior knowledge at the start of the lesson, there was some misunderstanding where learners confused silicone and silicon.

Kate was observed battling to address this misconception, probably due to a lack of CK and poor SMK. Instead she created more misconceptions for learners (Van Driel & Verloop, 2002). She could not explain the difference between silicone, which is a man-made, synthetic product that the learners were referring to and silicon (Si), the natural chemical element she was referring to. Kate knew that metals, non-metals and semi-metals were found on the periodic table but she did not know their exact positions as she was observed confusing their positions. This could be evidence that she has limited CK. To her silicone and silicon were one and the same thing. This is an indication that not only did her learners have misconceptions, but she had the same and by not being able to clarify these, the teacher exacerbated the problem and even transferred misconceptions to her learners. This is an example of Bayraktar's (2009) claim that misconceptions held by teachers are likely to be transferred to the learners.

Case 2: Rose

According to Kind (2009), the level of SMK greatly influences how a subject is taught. Rose demonstrated inadequate SMK as she failed to explain the content she was going to teach. During the interview, Rose said: "*Everything is an element, all matters are made up of elements, for an example: salt that we use at home in the kitchen is an element*." This is a clear indication that Rose's SMK was inadequate and that it was quite possible that she might not be confident in teaching the subject (Harlen & Holroyd, 1997). Rose not only displayed inadequate SMK for the better part of the lesson, but she also displayed poor CK. This was confirmed by her referring to salt as an element and not a compound. She had indicated that she would be teaching elements, however she was observed teaching compounds instead: "*If an element has two element on it, it is no longer an element but a compound because why, it has two elements in one at the same time*." As she continued teaching irrelevant content, she showed the following misconceptions: "*What is this HO_2, it is hydrogen from our elements. We have hydrogen* (Rose wrote hydrogen on the board). *Look at it, I have given you hydrogen.*"

From Rose's teaching of irrelevant content (compounds) in Grade 7, it was evident that she was not familiar with the NS CAPS (DBE, 2011). The CAPS clearly states that elements are to be taught in Grade 7 and that learners must know the names and symbols of the first 20 elements on the periodic table. Sanders, Borko and Lockard (1993) describe misconceptions as the result of everyday usage of unscientific language, which leads to the formation of incorrect concepts, which reflect informal learning. Rose did not only teach irrelevant content, but she transferred misconceptions to learners as well when she was trying to explain what a compound was using water as an example (Bayraktar, 2009).

Rose was observed using question and answer method of teaching as she said:

Rose: *Who created the periodic table?*
Learners: *Dmitri Mendeleev*
Rose: *Lets us all talk, Dmitri Mendeleev*
Learners: *Dmitri Mendeleev*
Rose: *Again*
Learners: *Dmitri Mendeleev*
Rose: *Again*

The above teaching method she employed is regarded by (Lombaard, 2015) as a traditional method and is criticised by the CAPS NS curriculum (DBE, 2011), as it does not promote any critical thinking, and rather leads learners to become shallow thinkers as they repeat after the teacher (Kaddoura, 2011).

Rose was observed asking learners to narrate the answers in a repeated manner, something that she confirmed during the interview when she said that she asked questions repeatedly. From this it was clear that she wanted the learners to memorise the answers which lead to them being shallow thinkers instead of constructing new knowledge (Kaddoura, 2011).

Discussion

Previous studies (Dudu, 2013; Makgato & Mji, 2006; Mudau, 2013; Netshivhumbe, 2018;

Nkanyani, 2017; Taylor & Moyana, 2005) have been conducted on classroom practices in natural sciences, however, none have investigated the teaching of the matter and materials strand in particular. These studies revealed that natural sciences teachers had limited CK, which lead to them choosing inappropriate instructional strategies, resulting in learners becoming shallow thinkers. The findings of our study support the findings of these studies as they reveal that the participating natural sciences teachers had limited CK and weak SMK as a result of these teachers teaching out of their specialisation (Ingersoll & Gruber, 1996). Our study further reveals that, irrespective of the content workshops provided by the DBE and whether the teachers were qualified to teach natural sciences or not, they still lacked SMK and had weak CK.

Kate held the qualification to teach natural sciences but her SMK and CK were inadequate. Her teaching was dominated by misconceptions and she was unable the correct her learners' confusion about silicon and silicone. Rose, who was not qualified to teach natural sciences, displayed weak SMK and disorganised CK. She taught irrelevant content (compounds) which is not a part of the Grade 7 curriculum. She also displayed misconceptions which she transferred to the learners. She wrote the formula of water as "HO_2" instead of "H_2O." This is a clear indication of disorganised CK, misconceptions and poor planning. The teaching of both participants was dominated by misconceptions which were transferred to the learners.

Our study reveals that natural science teachers still struggled to choose appropriate instructional strategies and relevant approaches when teaching matter and materials. They still use traditional, teacher-centred teaching methods which promote rote-learning. An example was when Rose instructed her learners to narrate the same answer repeatedly. The instructional methods that she employed did not promote active learning, but rather created learners who did not learn to think, but were passive recipients instead, memorising what they were told without understanding. These teachers still used traditional methods of teaching, which do not promote any of the skills or specific aims, but only rote learning.

Conclusion

The purpose of this study was to explore teachers' pedagogical issues when teaching matter and materials in natural sciences. Many unqualified teachers indicated that they had challenges in teaching the subject and that the workshops they had attended did not assist them in doing so. The classroom practices of two participants in the study, one qualified and the other not, were similar. Kate held the qualification to teach natural sciences as this was her field of specialisation, however she still experienced challenges in teaching this strand. Her challenges were similar to those experienced by Rose, who was teaching out of specialisation as mathematics was her specialisation. Their limited CK and them teaching out of specialisation hindered their choice of appropriate instructional strategies resulting in them resorting to the use of traditional teaching methods. Aykan and Yıldırım (2022) raise concern that teachers using instructional strategies that do not advance meaningful learning hinder learners' interest in STEM subjects – which is the ultimate goal. Knowing that these teachers attended workshops that were designed to but failed to assist them with SMK is a matter of great concern. How will the increase and interest in STEM subjects take place when some teachers do not know how to teach the subject meaningfully? It shows that Ogegbo et al.'s (2019) comments about the lack of increasing numbers of learners taking STEM subjects in the FET phase persists. Even though this was an instantaneous study in that it was not longitudinal and had only two participants, the sample was representing of the concerns which were observed at the workshops. The findings may also be relevant to other developing economies. We, therefore, recommend that tailor-made needs-analysis workshops for small groups are designed for all teachers irrespective of whether they are teaching out of specialisation or not, as all teachers might have similar challenges in teaching this strand. Although the focus of these workshops should be on the topics to be taught in the matters and materials strand, instructional methods of how the topics should be taught should also be included.

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Authors' Contributions

TGN wrote the manuscript and provided the data, AVM analysed the collected data. Both authors reviewed the final manuscript.

Notes

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