MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2022, 18(10), em2161
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/12426

A South African beginner natural sciences teacher's articulated PCK-in-practice with respect to electric circuits: A case study

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Received 15 April 2022 ▪ Accepted 23 August 2022

Abstract

Literature shows that science teachers' development and practice of PCK have always been a concern in science education research. Globally, national policies have begun to underscore the instruction of science teachers as a great concern. This study is considered worthwhile, as it intended to address this gap by exploring a beginner teacher's PCK knowledge and articulated PCK-in-practice. One participant was purposefully sampled. An exploratory qualitative case study was conducted, and the beginner natural sciences teacher's PCK of teaching grade 9 electric circuits was explored and analysed through an in-depth enquiry. First, the participant was interviewed, then classroom observations were conducted. The observations were video recorded while the topic in question was being taught. The PCK classroom observations schedule was adopted from Barendsen and Henze (2019). A post-classroom observation interview was conducted. Saldaña's (2009) model and Pitjeng's (2014) topic specific PCK rubric were adopted as analytical tools. The findings of this study show that the participant ignored students' contributions and debates because the lessons were teacher centred. The participant highlighted difficulties linking theoretical classroom science concepts with learners' real-life experiences. This study is important, as it shows the interconnections of PCK knowledges and how they play a significant role in a teacher's articulated PCK-in-practice with respect to electric circuits.

Keywords: pedagogical content knowledge (PCK), natural sciences, electric circuits, beginner teacher, science Education

INTRODUCTION: BACKGROUND

The concept of pedagogical content knowledge (PCK) is popular in science education research. Shulman (1986) introduced PCK to describe the knowledge that teachers create by transforming the content they know into a teachable form. To Hijazi and Al-Natour (2019), PCK is teachers' knowledge of how to introduce, illustrate and explain a topic to their learners. According to Jang et al. (2013, p. 28), "[s]cience teachers' classroom practices are determined by their PCK, making PCK a vital component of the knowledge in professional teaching". Little is known about how science teachers develop their PCK, especially when they have never attended any teacher professional development training (Bayram-Jacobs et al., 2019). Globally, national policies have begun to highlight the instruction of science teachers as a great concern (Navy et al., 2018, p. 919). Furthermore, Kind (2015) and Shulman (2015) argue that being an expert or experienced in a particular field do not indicate strong PCK. Science teachers' development and practice of PCK have always been a concern in science education research. Thus, it was considered worthwhile to investigate a beginner teacher's PCK knowledge and articulated PCK-in-practice.

According to Magnusson et al. (1999), PCK comprises five knowledges, namely

1. learner knowledge,
2. curriculum knowledge,
3. assessment knowledge,
4. content knowledge, and
5. pedagogical knowledge.

These five knowledge bases relate to what is referred to as knowledge-on-action (Barendsen & Henze, 2019),

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Contribution to the literature

- This study provides an understanding of how a science teacher's articulated PCK-in-practice can be portrayed in terms of the underlying PCK knowledges.
- This study further provides an outline on how the interconnections of PCK knowledges play a significant role in informing a science teacher's PCK-in-practice.
- This study contributes to literature which bridges between PCK knowledge and practice.

which requires a kind of knowledge called knowledge-in-action (Park & Oliver, 2008). Knowledge-in-action, according to Schön (2017), is both enacted and developed during teaching by reflection-in-action. "To reflect on one's action (i.e., one's practice) is to do so retrospectively–thinking through and critiquing what happened" (Dean, 2021, p. 251). Therefore, there is a need to determine how beginner science teachers' teaching practice is portrayed in terms of Magnusson et al.'s (1999) PCK knowledges (Demirdogen & Uzuntiryaki-Kondakci, 2016).

Barendsen and Henze (2019, p. 1144) claim that "the relationship between teacher PCK and what the teacher does in the classroom is inherently complex since their interplay involves both knowledge-on-action and knowledge-in-action". What informs a teacher's PCK? Literature (Chan & Yung, 2018; Kind, 2009; Magnusson et al., 1999; Pitjeng-Mosabala & Rollnick, 2018; Sickel & Friedrichsen, 2018; Smith & Banilower, 2015) highlights two basic concepts for determining the development of PCK–that is, knowledge and practice. Alonzo et al. (2012) state that the "ability to connect science content to students' own experiences in ways that make the content meaningful is a key component of PCK" (p. 1214). Therefore, while appreciating the complexity surrounding the development of teachers' PCK, this study determined one beginner teacher's PCK-in-practice with respect to electric circuits and how it was portrayed in terms of the five PCK knowledges discussed here.

A Turkish qualitative study by Kutluca (2022) was conducted to examine five elementary school teachers' PCK-in-practice. Kutluca (2022) collected data through lesson plans and interviews before and after a 10-week teaching and learning process. One of the main findings of Kutluca's (2022) study was that beginning teachers were unable to incorporate PCK components during practice in the classroom. A collaborative study by Navy et al. (2018) explored the cycle of instruction of newly hired secondary science teachers in South Africa and the United States (US). The main findings of their study revealed prevailing areas of practice and connections to levels of policy in the instructional cycle phases and that newly hired teachers were susceptible to micro policies and were progressively developing their practice. Said studies (Kutluca, 2020; Navy et al., 2018) highlight the interconnections of PCK knowledges and their role in teachers' articulated PCK during practice in the classroom.

Du Plessis and Sunde (2017) conducted a single large-scale qualitative study with beginner teachers in Australia, Norway, and South Africa to explore their experiences. They collected data through semi-structured interviews and classroom observations. The latter entailed recording all events during the first 10 minutes of a lesson. The results of their study (Du Plessis & Sunde, 2017) showed that beginner teachers in all three countries learnt more about teaching during their first few months at school than during teacher training; they were struggling to cope with teaching demands; they struggled to manage their classrooms; they sometimes argued with learners about the content; they struggled to maintain good relationship with learners due to learners' lack of discipline and respect; and they felt misplaced and unprepared to teach. In addition, some teachers were unqualified for the grade or subjects they taught.

In the central region of Ghana, Boakye and Ampiah (2017) conducted a qualitative study with five newly qualified science teachers who taught junior high school at the time to investigate the challenges they faced. Their data collection methods involved semi-structured interviews, classroom observations, and content analysis. The findings of their study showed that these teachers experienced the following challenges: time management; inadequate content knowledge; inadequate teaching and learning strategies and resources; following lessons as planned; learners' lack of discipline; classroom management; promoting learners' interest in science; and a heavy workload.

In Midwestern and Southwestern US, Nixon et al. (2017) investigated the PCK of 15 beginner secondary science teachers over their first five years of teaching. The findings of their study revealed that beginner teachers' PCK does not change significantly.

The South African Context

South Africa has experienced three curriculum shifts–outcome-based education (OBE), curriculum 2005; the revised national curriculum statement (RNCS); and the national curriculum statement grades R–12, referred to as the curriculum assessment policy statement (CAPS)–since its first democratic elections in 1994 (Russell et al., 2019). However, the country continues to perform poorly in science (Govender, 2018;

Naidoo & Sibanda, 2020). Although Trends in International Mathematics and Science Study (TIMSS) reports (Reddy et al., 2015, 2019) show that, generally, in South Africa, grade 9 learners' performance in science has improved, the latest TIMSS report (Reddy et al., 2019) shows that the North-West province–one of nine provinces in the country–is one of the six provinces which has performed lower than the national benchmark. Reddy et al. (2019) further posit that "learners in no-fee schools come from lower income households, live in poorer communities, attend schools with fewer resources, and are largely taught by teachers with less specialist knowledge" (p. 7). The North-West province is dominated by no-fee schools in poor communities, and beginner teachers mostly teach in these communities.

In this study, a beginner natural sciences teacher was defined as a teacher with teaching experience of five or fewer years and relevant teaching qualifications such as a Bachelor of education (BEd) and a post-graduate certificate in education (PGCE) (Luft & Dubois, 2015; Sebatana & Dudu, 2022). The researchers in this study operated from the same premise as Chaaban and Du (2017): teachers with five or fewer years of teaching experience lack PCK and innovative teaching and learning strategies to sufficiently interrogate topics they teach. In the current study, the topic in question was *electric circuits*. Nkanyani and Mudau (2019) argue that there is a need for well-qualified and prepared teachers to prepare learners for subsequent disciplines of specialisation subjects post-natural sciences. Malinga and Jita (2020, p. 232) state that, "[i]n the South African context, Natural Science lays the foundation for at least four high school subjects, that is, physical sciences, life sciences, geography, and agricultural sciences". According to Toerien (2013), a successful education system is critically dependant on the quality of teachers' PCK.

PCK is highly regarded as the superior knowledge used during teaching and learning that helps learners to better understand specific concepts (Gess-Newsome, 1999). Teachers' PCK is closely related to learners' understanding of science content (Akerson et al., 2000). Most beginner teachers have some relatively good content knowledge (Kaptan & Timurlenk, 2012). However, they struggle to transform the content knowledge they have into a teachable form, referred to as PCK (Rollnick et al., 2017). PCK is the knowledge that teachers develop for practice with experience, which is difficult to measure but can and must be measured to help them improve in a specific discipline (Rollnick & Mavhunga, 2014). Therefore, this study focussed on exploring a beginner natural sciences teacher's PCK of teaching grade 9 *electric circuits*.

In the South African curriculum–CAPS (Department of Basic Education (South Africa) [DBE], 2011) of grade 9 natural sciences–the topic *electric circuits* falls under the knowledge strand of energy and change in the physics discipline. Natural sciences comprises three other knowledge strands, namely:

1. Life and living,
2. Matter and materials, and
3. Planet earth and beyond.

However, the aforementioned knowledge strands (1-3) were not the focus of the current study. DBE (2015, 2016) reports on the annual national assessment indicate poor performance in the topic *electric circuits* at the grade 9 level. According to Nkopane et al. (2011), teachers contribute to learners' poor performance, as they themselves have misconceptions. Gunstone et al. (2009) posit that, when teaching *electric circuits*, most teachers put more emphasis on calculations than on practical work and conceptual understanding. Teaching learners basic electric circuit functions is one of the difficult pedagogical challenges, according to some researchers (Hart, 2002; Jaakkola et al., 2011; Morrison & Lederman, 2003).

Dudu (2014) conducted a qualitative study in the same site as the current study (North-West province, South Africa), but in a different educational district, with 40 grade 8 and 9 natural science teachers. In the study (Dudu, 2014), the researchers generated data through a questionnaire, structured interviews, and classroom observations. Their pre-classroom observation results showed that most of the teachers used at least two different learner-centred teaching strategies when teaching natural sciences. Although this was impressive and gratifying, the lesson observation data were contradictory, since all lessons observed showed that the "*telling*" *(traditional) method*, which is largely teacher-centred, was always hogging the limelight. The results of the study also showed that natural sciences teachers use different forms of assessment, such as homework, assignments, classwork, demonstrations, projects, experiments, investigations, and case studies.

In South Africa, Mavhunga and Van der Merwe (2020) conducted a study on developing final-year pre-service teachers' topic-specific PCK in the core topics of chemistry and physics taught in CAPS. They followed their study participants to secondary schools during their teaching practice, where data were collected through lesson plans, two video-recorded lessons, and self-reflection reports. The main findings of their study showed a structural format change of teachers' topic-specific PCK in planning practice settings due to reflection-for-action, reflection-on-action and learner understanding, while original lesson intentions were intact.

Research Questions

The research question was, as follows:

1. How can a beginner teacher's articulated PCK-in-practice with respect to Electric Circuits be

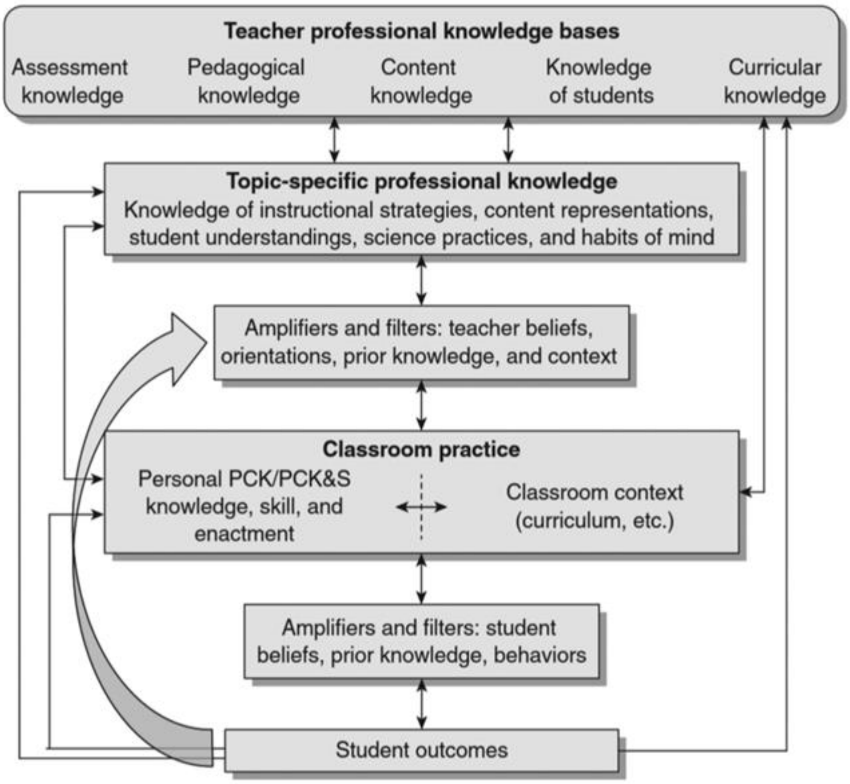

Figure 1. Gess-Newsome's (2015) PCK theoretical framework

portrayed in terms of the underlying PCK knowledges (pedagogical, assessment, curriculum, content, and students) and their interconnections?

Theoretical Framework

This study was founded on the theoretical construct of PCK to answer the research question. Literature on the teaching and learning of electricity, challenges experienced by beginner science teachers, and PCK is reviewed. As mentioned earlier, PCK is a theoretical construct originally coined by Shulman (1986). Specifically, this study adopted Gess-Newsome's (2015) theoretical construct of PCK (see **Figure 1**), as "it interfaces between PCK knowledge and practice" (Pitjeng-Mosabala & Rollnick, 2018, p. 744). Gess-Newsome's (2015) model interfaces PCK in terms of knowledge and practice by the construct of topic-specific professional knowledge (TSPK), which can be identified as a collective PCK.

As authors, we view the theoretical framework based on Magnusson et al. (1999), which feeds into the five knowledge bases in Gess-Newsome's (2015) consensus model, as follows: the five knowledge bases in Gess-Newsome's (2015) consensus model may influence TSPK, which may influence amplifiers and filters, namely, teacher beliefs, orientations, prior knowledge, and context. Amplifiers and filters may, in turn, influence classroom practice, and vice versa. Gess-Newsome's (2015) consensus model was deemed more relevant for this study due to its five knowledge bases, which were used as themes for data analyses and presentation, linking findings to the theoretical framework. Other PCK frameworks–such as Shulman's (1986, 1987) with seven knowledges, and Park's (2007) six knowledges–would have made it difficult to make this link, hence they were not chosen. In this study, one beginner natural sciences teacher's PCK and classroom practice were salient and, therefore, these were explored in the teaching and learning of grade 9 electric circuits.

According to this framework (**Figure 1**), a teacher may develop TSPK by drawing on teacher professional knowledge base (TPKB) construct. The TPKB construct comprises assessment knowledge, pedagogical knowledge, content knowledge, curricular knowledge, and knowledge of students. TSPK–such as instructional strategies and content representation, to name but two–are directly linked to classroom practice through a series of amplifiers and filters, which, in turn, link to learner outcomes, again through a series of contextual filters. These filters may assist a teacher to make selections from their knowledge base for use during the teaching and learning situation. This framework's dynamic and recursive nature interfaces between PCK knowledge and practice, outlining how all three constructs (TPKB, TSPK, and classroom practice) feed back into each other, accounting for teacher learning through practice and interaction with learners. Thus, teachers may acquire PCK as a skill during the teaching and learning situation in the classroom context.

METHODOLOGY

Research Design

An exploratory qualitative case study approach was adopted in this study. An exploratory research design entails an investigation that intends to achieve new insights on a case with little to no research knowledge available (Rizvi & Bhardwaj, 2019), thus, making it appropriate for the current study. According to Yin (2018), a case study is an in-depth inquiry used to explore and analyse a contemporary situation such as a phenomenon, a person and a community, or an institution and event within its real-world context, aimed at generalising across several units. In this study, an exploratory qualitative case study research design was employed to capture the required in-depth data to answer the research question.

Sampling Technique, Sample, and Site Selection

Purposive sampling was employed to select one (a) beginner natural sciences teacher from one rural secondary school in one of the four educational districts (Bojanala educational district) of the North-West province, South Africa. This study is part of a larger project that focussed on the PCK of natural sciences teachers in the Bojanala educational district. The participant was purposefully selected, since he was the only participant teaching in a rural secondary school. Rural secondary schools are generally remote, relatively under-developed, they usually receive delayed information, communication technology and support, are far from towns and cities, and experience severe socio-economic deprivation (Du Plessis & Mestry, 2019; Myende & Maifala, 2020). These factors usually negatively affect the quality of education. The researchers in the current study were aware that "the context of the classroom might play a role in the action in the classroom, making it difficult to attribute to a given action the implementation of a given PCK" (Cross & Lepareur, 2015, p. 3). To ensure anonymity, the participant in this study was given a pseudonym (i.e., Francois, 28-year-old male). Francois held a BSc degree, specialising in physics and electronics, a PGCE, and had four years' teaching experience at the time.

Data-Generation Instruments

A semi-structured interview and classroom observations were employed to collect data. The PCK classroom observation form of Barendsen and Henze (2019) (**Appendix A**) was adapted as an observation tool. Moreover, a self-developed semi-structured interview schedule with some questions from Pitjeng's (2014) topic-specific PCK rubric (**Appendix B**)–which is aligned with Gess-Newsome's (2015) PCK theoretical framework–was used in this study. The semi-structured interview was conducted prior to the classroom observations to investigate Francois' PCK for *electric circuits*, offering insights into his pedagogical reasoning in the context. It is worth mentioning that a semi-structured interview was also conducted after the classroom observations to clarify some of the classroom activities so that the researchers could confirm that they had captured the lesson accordingly–more or less following the principles of an audit trail. An example of a self-developed interview question that was asked prior to the classroom observation is "[h]ave you attended any professional development intervention on this topic?" An example of an interview question adapted from Pitjeng's (2014) rubric is "[h]ow do you find (easy or difficult) teaching and explaining the electricity concept to your learners?" Finally, an example of the post-interview question is "[w]hat knowledge about learner thinking influenced your teaching of this topic, and kindly give an example from the lesson you taught?"

The PCK classroom observation form consisted of five categories, namely: time, lesson content, instructional method, control, and check. The *time category* referred to time intervals in minutes, capturing all other categories based on the length of the lesson that were taught. The *lesson content category* involved three observational items–knowledge, skill, and attitude; however, the knowledge observational item encompassed science concept, personal life, society, and epistemology. *Epistemology* in this study referred to what Hofer (2001) defines as classroom learning which leads to lifelong learning for science content knowledge and the application of that knowledge outside of the school. The *instructional method category* entailed nine observational items, such as lecturing, interactive instruction, demo, students' work without teacher assistance, students' work with teacher assistance, conclusion of students' work, debate, and others. The *control category* referred to either the teacher or students being in control during the lesson. Finally, the *check category* referred to checking if the lesson went well, which could be done through various items such as question, assignment, and others. The completed PCK classroom observation form for both lessons is attached as **Appendix A**.

Research Methods

A beginner teacher-participant, Francois, was interviewed face-to-face for 30 minutes on 30 August 2021. The first classroom observation was conducted the day after Francois was interviewed. Observing a teacher's PCK from self-reported data, such as an interview, is the best way to gain a broad understanding and a complete portrayal of a teacher's personal PCK or PCK knowledge (Cross & Lepareur, 2015). It is worth mentioning that the interview was conducted only once–before the first classroom observation; no interview was conducted prior to the second classroom observation which took place on 02 September 2021. Since "classroom observations would not reveal why a teacher chose to use some examples while avoiding others" (Baxter & Lederman, 1999, p. 148), it was deemed necessary to conduct a post-classroom observation interview to address the latter. The post-classroom observation interview took place on 3 September 2021.

During the two classroom observations, data were captured using the PCK-related observation form (**Appendix A**). Two video-recordings were captured. The duration of each period in the school was 45 minutes; however, the videos were recorded for classroom observations on the days Francois had a double slot, in which case each session was 90 minutes. The total minutes of the two sessions amounted to 180 minutes. The video recordings were coded, assigning applicable categories on the PCK-related observation form (**Appendix A**). Sometimes, time intervals overlapped with more than one category. For example, while Francois gave instructions on building an electric circuit, he also demonstrated using components of the electric circuits. The aforementioned activities are part of the *instructional method* category, and they overlapped with the *lesson content* category, since Francois also discussed science concepts.

Data Analysis

Saldaña's (2009) model and Pitjeng's (2014) topic specific PCK rubric (**Appendix B**) were adopted as analytical tools for both the semi-structured interview and classroom observations. First, coding was done. According to Stuckey (2015), coding is preparatory work for higher-order thinking about the study; moreover, coding is in itself analysis. In this study, categorised data transcribed from the semi-structured interview were used for coding. To Thomas (2006), coding entails a process of reading; identifying texts relating to and answering the research question(s); categorising those texts to reduce overlaps; and incorporating important categories to create a small number of summarising categories. Usually, a summarising phrase, name, or label for a segment of data is assigned and accounts for each stretch of data. As in many studies, these labels are placed at the beginning of the data analysis. This is exactly what was done in this study. The researchers read through the transcribed data (interviews and observations), attached labels line by line, and after open coding, the data were reassembled through axial coding. Determining dominant themes and patterns in this research was the primary purpose of axial coding, then reducing and reorganising the data. The result of axial coding was a list of categories–for example, "lesson content" and "instructional method". Themes–for example, "knowledge of the science curriculum" and "knowledge of students' misconceptions"–were then generated from these categories. Before drawing conclusions, the results were fully explicated and discussed during and after corroborating the interview and classroom observation data.

The topic specific PCK rubric (**Appendix B**) contained the "pedagogical knowledges", which were divided into five categories, namely: category A (*learners' prior knowledge*); category B (*curriculum saliency*); category C (*what makes the topic difficult to understand*); category D (*representations/models*); and category E (*teaching strategies*). The five categories mentioned in the rubric also related to the theoretical framework as indicated in **Figure 1**. The five categories in the topic-specific PCK rubric were evaluated on a four-point scale as follows: 1 (limited); 2 (basic); 3 (developing); and 4 (exemplary). It is worth noting that only 1 (limited) and 2 (basic) evaluations are described for all five categories, as they were used. However, others can be perused in the rubric attached as **Appendix B**. Regarding learners' prior knowledge and misconceptions, *limited* evaluation suggests that a teacher did not identify, acknowledge, or consider learners' prior knowledge or misconceptions. *Basic* evaluation denotes that a teacher identified misconceptions or prior knowledge, providing standardised knowledge as definition without expanding it, or providing incorrect explanations. Regarding curricular knowledge or saliency, *limited* evaluation informs that a teacher identified relevant content, mixing it with content being taught in the current topic, and/or reasons given for the importance of the topic were limited to generic benefit of education, and/or mixed sequencing of concepts (making series and parallel circuits) was taught. *Basic* evaluation suggests that a teacher's sequencing had one or two illogical placing of big concepts (electric current, voltage, and resistance) of the content taught.

Shifting focus to what makes the topic difficult, *limited* evaluation is given if a teacher identified broad topics without specifying the actual sub-concepts that were problematic and did not give any reasons during teaching and learning. On the other hand, *basic* evaluation means that a teacher identified specific concepts but provided broad generic reasons such as "abstract". Looking at the content representation category, *limited* evaluation indicates that a teacher was limited to the use of only macroscopic analogies, demos, and representations, with no explanation of specific links to the concepts represented. *Basic* evaluation means that a teacher identified macroscopic representation (analogies, demos, etc.) and used sub-microscopic representation for different aspects of a concept without enforcing a specific aspect. Finally, regarding the conceptual teaching strategies category *limited* evaluation, there was no evidence of acknowledgement of student prior knowledge and misconceptions, lack of aspects of curriculum saliency, limited use of representations, macroscopic or symbolic scientific representation with no linking explanatory notes–

mostly teacher-centred activities. *Basic* evaluation means that a teacher acknowledged student misconceptions verbally, with no corresponding confrontation strategy, lacking aspects of curriculum saliency, used macroscopic and symbolic representations without linking explanatory notes, and limited learner involvement.

Each author carried out the coding independently. Thereafter, the three authors compared their coding results. There was a slight difference in interview coding results for the teacher-participant in this study. Inter-rater reliability was found to be 0.93, which was taken to signify consensus amongst the three authors. For classroom observations, each author completed the PCK-related observation form independently. Finally, all three authors compared their observation results, and inter-rated reliability of 0.91 was found, also signifying consensus.

Positionality

"Positionality is the practice of a researcher delineating his or her own position in relation to the study, with the implication that this position may influence aspect of the study, such as the data collected or the way in which it is interpreted" (Qin, 2016, p. 1). For this study, Holmes' (2020) principles of positionality were followed, which is normally identified by locating the researcher(s) in three areas:

1. the subject under investigation,
2. the research participants, and
3. the research context and process.

Regarding the subject under investigation, despite a plethora of research on PCK, there is a dearth of studies on how science teachers develop their PCK without having attended any teacher professional development training. Therefore, the authors intended to address this gap. With regard to the research participant, the authors included a subject education specialist (who supervised effective curriculum implementation) and two university teacher educators. The participant was a teacher at a rural secondary school as defined under the methodology section. It is worth mentioning that the participant worked directly under the supervision of the subject education specialist. Therefore, to avoid power relations, the other two authors interacted with the participant as independent individuals, since they did not know the participant. With regard to the research context, this study acknowledged principles by Cross and Lepareur (2015) mentioned under the methodology section. The authors of this paper met to draft the semi-structured interviews questions based on the components of PCK, which eventually became the themes. It is important to note that the findings are presented according to emerging themes which are related to the components of PCK which were informed by the theoretical framework of this study, the PCK classroom observation form, and the topic specific PCK rubric.

Trustworthiness

According to Connelly (2016), credibility, confirmability, dependability, and transferability can be used to ascertain trustworthiness in a qualitative study. This study adopted the same principles to enhance the audit trail in order to draw conclusions and answer the research question (Connelly, 2016). In this study, the researchers undertook a prolonged immersion in the field and checked their interpretations with the participants to ensure *credibility* (Yilmaz, 2013). For *dependability*, the researchers reported detailed data generation (interview and classroom observations) and data analysis processes (Paskevicius, 2018; Schwandt, 2015). Regarding *confirmability*, as stated by Liamputtong (2013), this study attempted to show that the findings reported and the interpretations made were not from the imagination or emotions of the researchers but were clearly linked to generated data by applying a theoretical framework, reporting data verbatim, and attaching the PCK classroom observation form as Appendix A. *Transferability* refers to the application of the research to other contexts and settings to ensure that the results are related and helpful to understand the studied phenomenon in other contexts (Paskevicius, 2018). A sufficient rich description is provided for the reader to compare their own social context with the social setting of this research.

RESULTS PRESENTATION AND DISCUSSION

This section presents and discusses the results of this study to answer the research question. It is important to note that the findings are presented according to emerged themes as described under the methodology section. It is worth mentioning that some of the participant's responses represented more than one theme. The identified themes are presented next.

Knowledge of the Science Curriculum and Content Representation

This section combines two themes: *knowledge of the science curriculum* and *content representation*. *Knowledge of the science curriculum* refers to a teacher's knowledge of the goals and objectives for students in the subject(s) they are teaching; knowledge about the elements of the science curriculum; variety of instructional tools presented in the science curriculum and how to use them; and knowledge about the topic at hand. On the other hand, *content representation* refers to identification of analogies; macroscopic and sub-microscopic representational levels; enforcing a particular aspect or concept, which, in this study, was electric circuits. During the pre-classroom observations, Francois was asked: How do you find (easy or difficult) teaching and explaining the electricity concept, particularly electric circuits, to your learners? He responded by saying, "[a]lthough I know this subject like I know my name, I struggle to convey the information to the students in an appealing and comprehensive manner that instils enjoyment in their learning, I am frustrated". Francois' response analogy of him knowing his name and relating it to the subject matter of electric circuits elucidated his confidence in content knowledge. This might be interpreted as him having a relatively good content knowledge of electric circuits. However, the second part of the response gives the idea that Francois struggled to put it in an understandable manner for learners, as he explicitly said he was frustrated conveying the information to the students in an appealing and comprehensive manner. This finding is consistent with that of Kaptan and Timurlenk (2012), who argued that most beginner teachers have some relatively good content knowledge of the subject they teach. However, this finding contradicts Boakye and Ampiah (2017) in Ghana, who found that beginner teachers have inadequate content knowledge of the subject they teach. This finding further corroborates the assertion by Rollnick et al. (2017) that most beginner science teachers struggle transforming the content knowledge they have into a teachable form referred to as PCK. Evaluating this finding with Pitjeng's (2014) topic specific PCK rubric, the researchers in the current study argue that Francois' PCK knowledge about content representation was *limited*. Further evaluating this finding using Pitjeng's (2014) topic specific PCK on the category of what makes electric circuits difficult to teach, Francois' broad generic reason was considered as *basic*. There are similarities between the findings of this study and those described by Boakye and Ampiah (2017) in Ghana and Nixon et al. (2017) in the USA, who found that beginner teachers are challenged with promoting learners' interest in science and having inadequate PCK which does not change significantly during the first five years of practice.

During the pre-classroom interview, Francois was asked the question: Have you attended any professional development intervention on this topic? If yes, what effect did it have on your conceptual knowledge? Francois' response was as follows:

> Yes, every year we attend workshops on this topic at the beginning of term 3 arranged by the senior subject specialist, but the time is never enough. It is only for five hours, and that includes administrative work and moderation of a teacher's files for school-based assessment activities. I cannot outrightly and frankly say that I have gained anything from the workshop.

This finding shows that Francois attended four professional development activities on the teaching and learning of electric circuits for the four years he had been practising. In reviewing literature, Bayram-Jacobs et al. (2019) and Navy et al. (2018) suggested that attending professional development activities may result in better or developed PCK, which, unfortunately, was not the case with Francois. However, for Francois, PCK might have developed more slowly than it should have, as professional development, when conducted, is coupled with administrative work. However, given that Francois taught in a rural school, far from cities, the senior education specialist might have had challenges calling teachers more often.

Knowledge of Students' Prior Knowledge and Misconceptions

Knowledge of students' prior knowledge and misconceptions refers to the type of difficulty students' encounter when learning topic areas or concepts in which their prior knowledge is contrary to the targeted scientific concepts known as *misconceptions*. These concepts can be difficult to learn, as misconceptions are coherent with students' everyday life experiences and, therefore, typically favoured over scientific knowledge. After the classroom PCK observation, one of the researchers asked the following: What knowledge about learner thinking influenced your teaching of this topic, and kindly give an example from the lesson you taught? Also indicate the learners' typical misconception(s) on this topic you have identified. Francois responded, as follows:

> These learners can have pretty good ideas and still get some of these wrong because they are connecting it [sic] to certain kind of personal experiences which may be a misconception. I keep telling them that we do not charge a non-rechargeable battery, but they keep on saying that–that's what they know to be true, that's what everyone at home says.

Francois was further asked a follow-up question based on the observations, clarifying his previous response as to why he did not seem to try to acknowledge, identify or consider students' prior knowledge and misconceptions. He highlighted that it was not easy to convince the learners without conducting the experiments with them and realising theoretical classroom science concepts in real-life experiences. This finding shows that, although Francois saw himself as the master of knowledge, he "just poured" knowledge passively into the learners; his PCK was at the novice level, and he lacked planning. It is difficult to explain this finding; however, this finding corroborates with his response prior to the classroom observation under the *knowledge of the science curriculum* and *content representation* themes where he mentioned that he was sometimes frustrated. Evaluating this observation and response, utilising Pitjeng's (2014) topic specific PCK, showed that Francois was limited in this category. Although this study produced findings that contradict those by Mavhunga and Van der Merwe (2020), they corroborated some of the findings of previous work in this field, such as that of Du Plessis and Sunde (2017) conducted with beginner teachers in Australia, Norway, and South Africa, which showed that beginner teachers in all three countries struggled to cope with teaching demands and felt misplaced and unprepared to teach.

From the observation form, **Table 1** presents the frequency analysis on the cumulative scores (across all recordings). As stated by the instrument developers Barendsen and Henze (2019):

> … the numbers within each item do not always add up to the length of the segment in minutes (e.g., 3+9≠15 in lesson content in video 1). There can be two possible causes for this. The first reason is the occurrence of multiple categories in the same one-minute interval mentioned above. The second is that no category was assigned to a one-minute interval, because a specific item was not visible (e.g., lesson content during student work) (p. 1156).

The analysis findings of patterns in each of the observational items, as well as patterns between observational items, are presented **Table 1**.

Table 1 outlines all the categories that were found in the PCK-related observation sheet (**Appendix A**) in a more analytic form. A lesson was 45 minutes; however, the teacher was observed for a double period, making it a 90-minute lesson. Observational items that were not observed, are not included. It is worth mentioning that observational items are not discussed discretely or in isolation from their categories. This is because, as mentioned earlier in this section, sometimes, time intervals overlap with more than one category. These findings are discussed next in the order of the categories.

Table 1. Cumulative score of lesson observation

Video		1	2	Total
	Number	1	2	Total
	Length (45×2)	90	90	180
Lesson content				
	Science concept	30	40	70
	Personal life	4	6	10
	Society	3		3
	Skill	5		5
Instruction model				
	Lecturing	15	25	40
	Interactive instruction	3	3	6
	Demo	3		3
	Instruction students' work	8		8
	Students work without teacher assistance	13	13	26
	Students work with teacher assistance	4	4	8
	Conclusion of students' work	3	5	8
	Debate	4		4
Control				
	Teacher	35	35	70
	Student	16	6	22
Check				
	Question	5	10	15
	Answer	2	19	21

Lesson Content Patterns

Francois expressed a mix of science concepts (i.e., electric current) and contextual (i.e., personal life, society, and communication and collaborative skills) knowledge content, in which science content knowledge was prevalent for 140 of 180 minutes of the observations. Moreover, personal life contexts appeared more frequently, followed by skills, then society. Skills were addressed only a few times, possibly because Francois' teaching and learning approach was more teacher centred. Moreover, this might also be because the lesson was taking place in the classroom rather than in the laboratory which the school did not have. Learners' attitudes towards the learning of electric circuits were never addressed, which corroborates pre-classroom observation results where Francois stated that, although he knew and understood this science concept, he struggled to convey the information to the learners in an appealing and comprehensive manner that instilled enjoyment in the learners' learning. Epistemological content was not observed at all, possibly because, before the classroom observation, Francois mentioned that sometimes he got frustrated with teaching, resulting in him teaching passively.

Instructional Method Patterns

The results of this study show that Francois was mostly lecturing 80 of the 90 minutes during the lessons. Francois' instructional methods were mostly teacher-centred, with little influence from the students. As mentioned earlier, the lessons were mainly concerned with physics concepts which belong to the knowledge strand *energy and change*. Moreover, electricity is taught in grade 8 technology–it is an issue in South Africa, as the country experiences unprecedented power cuts, load shedding, and illegal power connections (DBE, 2013). Therefore, it is surprising that related contexts during teaching and learning appeared less frequent. On the other hand, the researchers found it appealing when a demonstration of components of the electric circuits was conducted for students. Observational item *students work without a teacher's assistance* shows that students were interacting cooperatively. In both observations, for a short while, Francois started with interactive teaching but would shift to lecturing. Francois was possibly more comfortable with being the centre of attention during his lessons. Another possible explanation is that Francois felt more confident lecturing than using interactive teaching. The researchers observed that Francois did not assess students' prior knowledge and misconceptions.

Control Patterns

The data that emerged from the classroom observation form show that Francois was mostly in control of the teaching and learning for 140 minutes of both lessons observed. The results of this study show that he ignored students' contributions and debates because he was not interacting with them. This resulted in Francois not being in charge, continuing with the lesson without addressing any concerns students were arguing about.

Check Patterns

Verifications of students' understanding were relatively enough for 72 of 180 minutes in both lessons observed. The study findings show that Francois checked students' understanding; however, the time between a checked question and discussing the answer was often shorter than assignments. Francois put more responsibility on the students during assessment time only. Furthermore, keeping track of the content of (guided or unguided) students' work on the note sheets revealed that Francois presented questions and other class-activities which he did not always follow up on after completion by the students. The few checked questions and other class activities occurred mostly during instruction for students' work, a little during interaction, and less during lecturing.

The main findings from the classroom observation are that Francois employed a more teacher-centred instructional approach which dominated the teaching and learning, control patterns and assessment, and he used assignments to check learners' knowledge. These findings corroborate those of Dudu (2014), who, through lesson observations, showed Natural Sciences teachers use the "*telling*" *(traditional) method*, which is largely teacher-centred and is always hogging the limelight, as assessments are done through assignments and demonstrations, to name but a few. Moreover, it is interesting how these findings agree, since both studies were conducted within the same context of the North-West province of South Africa.

The findings of this study show that a beginner teacher's articulated PCK-in-practice with respect to electric circuits can be portrayed in terms of the underlying PCK knowledges (pedagogical, assessment, curriculum, content, and students). The findings corroborate those of Kutluca (2020), which showed that beginner teachers are unable to incorporate PCK components during practice in the classroom. Moreover, the findings of this study also showed a visible yet complex relationship between a teacher's PCK and what a teacher does in the classroom. This study is important, as it shows the interconnections of PCK knowledges and how they play a significant role in a teacher's articulated PCK-in-practice with respect to electric circuits. The researchers in this study appreciate the argument by Kind (2015) and Shulman (2015) that being an expert or experienced in a particular field do not indicate a strong PCK; rather, the findings of this study showed poor PCK throughout the study. An experienced teacher–say a teacher with 10 years' teaching experience–might have a significantly better PCK than a beginner teacher, such as Francois in this study. We wondered *what informs a teacher's PCK*. Here, the interconnections of PCK knowledges might play a significant role because the participant clearly treated instructional method separately from the type of students or content or context, while they actually inform one another.

Limitations of this study

The limitation of this study is that the participant lacked lesson planning skills, which made it difficult for him to know when to check learners' prior knowledge and perform experiments and/or practicals relating to the electric circuits topic. Thus, the teacher's articulated PCK, which was found to generally be at the novice level, might have been as a result of this limitation.

CONCLUSION & RECOMMENDATIONS

This study sought to answer the following research question: "How can a beginner teacher's articulated PCK-in-practice with respect to electric circuits be portrayed in terms of the underlying PCK knowledges (pedagogical, assessment, curriculum, content, and students) and their interconnections?" This question was answered by showing how a beginner teacher's articulated PCK-in-practice with respect to electric circuits can be portrayed in terms of the underlying PCK knowledges. This study also showed that the interconnections of PCK knowledges play a significant role because they actually inform one another. For data analysis, components of PCK were utilised to generate themes which are related to the theoretical framework, PCK classroom observation form and topic specific PCK rubric used in this study. It is recommended that the interconnections of PCK knowledges and how they play a significant role in a teacher's articulated PCK-in-practice should be explored in various contexts, different disciplines, and grade levels.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: The study was approved by the Human Resources Research Ethics Committee (HRREC) on November 14, 2017 (NWU-HS-2017-0223).

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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APPENDIX A: PCK RELATED OBSERVATION FORM

Table A. PCK related observation form

Time	Lesson content						Instructional method									Control		Check		
	Knowledge																			
Interval (minute)	Science concept	Personal life	Society	Epistemology	Skill	Attitude	Lecturing	Interactive instruction	Demo	Instruction students work	Students work without teacher assistance	Students work with teacher assistance	Conclusion of students ' work	Debate	Other	Teacher	Student	Question	Assignment	Other
2							X									X				
5	X		X							X		X				X				
10	X	X	X						X	X		X				X				
13	X	X									X						X	X		X
16	X				X						X						X	X		X
20	X				X						X			X			X	X		X
22	X				X						X			X			X			X
24	X							X			X			X			X			X
25	X							X			X					X	X			X
26	X						X	X			X	X				X	X			X
27	X						X					X				X				
28	X						X					X				X				
29	X						X					X				X				
30	X						X									X				
31	X						X									X				
33	X						X									X				
34	X						X									X				
35	X						X									X				
36	X						X									X				
37	X						X									X	X			
38	X						X									X	X			
39	X						X									X	X			
40	X						X									X				
41							X									X				X
42							X						X			X				X

APPENDIX B: TOPIC-SPECIFIC PCK RUBRIC

Topic Specific PCK Categories	Limited(1)	(2) Basic	(3) Developing	Exemplary (4)
Learner Prior Knowledge including misconceptions	No identification/No acknowledgement/No consideration of student prior knowledge or misconceptions	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Repeats standard definition with no expansion or with incorrect explanation	• Identifies misconception or prior knowledge • Provide standardized knowledge as definition • Expands and re-phrase explanation correctly	• Identifies misconception or prior knowledge • Provide standardized knowledge as definition • Expands and re-phrases explanation correctly • Confronts misconceptions/confirms accurate understanding
Curricular Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas • Identified subordinate ideas are a mix with those of other topics or no subordinates provided • Identified post-concepts are a mix with those to be taught in current topic • Sequencing no value due to mixed concepts • Reasons given for importance of topic limited to generic benefit of education	• Identifies at least 3 Big Ideas • Not all 3 Big ideas have subordinate concepts identified however those identified are correct • Sequencing has one or two illogical placing of main concepts (Big Ideas) • Identified post-concepts are far from the current topic, they refer to concepts basic to the subject. • Reasons given for importance of topic exclude conceptual considerations such as scaffolding or sequential development for other topics in the subject.	• Identifies at least 3 Big Ideas • Identifies correct subordinate ideas and shows links to Big ideas with no additional explanations • Provides logical sequence of concepts of all three Big Ideas. • Identified post-concepts includes those needed for the current topic • Reasons given for importance of topic include reference to conceptual scaffolding/sequential development of understanding of other topics in the subject however without specifying the topics	• Identifies at least 3 Big Ideas • Identifies correct subordinate ideas and explains links to Big Ideas • Provides logical sequence of all three Big Ideas • Identified post-concepts include those needed in discussing the introductory definitions and those sequentially needed in the next Big Ideas of the current topic. • Reasons given for importance of topic include conceptual scaffolding/sequential development of understanding for specified subsequent topics in the subject.
What makes topic difficult	• Identifies broad topics without specifying the actual sub-concepts that are problematic • Reasons not given	• Identifies specific concepts but provides broad generic reasons such as 'abstract'	• Identifies specific concepts with reasons related to specified prior knowledge of students or common misconceptions	• Identifies specific concepts with reasons related to prior knowledge of specified students or common misconceptions • Provides reasons linking to specific gate keeping concepts that when not fully understood adds to the difficulty of a concept regarded as difficult
Representations	• Limited to use of only macroscopic analogies, demos, etc.) representation with no explanation of specific links to the concepts represented	• Identification of macroscopic representation (analogies, demos, etc.) • Use of sub-microscopic representation for different aspects of a concept not enforcing a specific aspect	• Identification of macroscopic representation (analogies, demos, etc.) • Use of sub-microscopic representation for different aspects of a concept not enforcing one specific aspect of a concept	• Use of macroscopic representation (analogies, demos, etc.) • Use of sub-microscopic representation for different aspects of a concept not enforcing at least two specific aspects of a concept
Conceptual Teaching Strategies	• No evidence of acknowledgement of student prior knowledge and misconceptions • Lacks aspects of curriculum saliency • Use of representations limited to macroscopic or symbolic scientific representation with no linking explanatory notes • Suggested activities are largely teacher centred	• Acknowledges student misconceptions verbally with no corresponding confrontation strategy • Lacks aspects of curriculum saliency • Use of macroscopic and symbolic representations for With no linking explanatory notes • Limited involvement of learners	• Overall, strategy workable • Considers confirmation/confrontation of student prior knowledge and/or misconceptions • Considers at least one aspect related to curriculum saliency: sequencing or what not to discuss yet or emphasis of important concepts • Uses at least two different levels of representations to enforce an aspect of a concept with explanations • There is evidence of encouraged learner involvement	• Overall , excellent strategy to teach required concept • Considers confirmation/confrontation of student prior knowledge and/or common misconceptions • Considers at least two aspects related to curriculum saliency: sequencing, what not to discuss yet, emphasis of important conceptual aspects, etc. • Uses either the macroscopic or symbolic representation with sub-microscopic representation to enforce a singular aspect of a concept. • Highly learner centred lesson