Chapter #9

FACTORS INFLUENCING THE PHYSICAL SCIENCES PRE-SERVICE TEACHER'S PEDAGOGICAL ORIENTATIONS IN ONE OF THE UNIVERSITIES IN SOUTH AFRICA

Aviwe Sondlo[1], & Umesh Ramnarain[2]
[1]University of Zululand, South Africa
[2]University of Johannesburg, South Africa

ABSTRACT
To effectively teach sciences, science teachers require content knowledge of the science subject and know how to teach such content better. The purpose of this paper was to determine factors influencing the Physical Science pre-service teachers' pedagogical orientations. Orientations refer to teachers' knowledge and beliefs about teaching science at a particular grade level. Pedagogical orientations are classified into two approaches: direct approaches and inquiry approaches. A mixed-method approach was adopted, where a quantitative method was used to determine Physical Science pre-service teachers' pedagogical orientations and a qualitative method was used to establish factors influencing their pedagogical orientations. A questionnaire of ten items was administered to forty-five final year Physical Sciences pre-service teachers, and they were requested to select the most appropriate pedagogical orientation and then justify their choices. The questionnaire justifications and interviews were used to generate themes. This study's findings indicate that Physical Sciences pre-service teachers' preferred pedagogical orientations were between Direct Active and Guided Inquiry, and factors influencing their pedagogical orientations were: school resources, class size and teaching time.

Keywords: pedagogical orientation, pre-service teachers, inquiry-based learning.

1. INTRODUCTION

South African universities attract most student-teacher cohorts from impoverished schools, mostly in townships or rural areas. In their first year at university, these student teachers bring along images about teaching construed from their previous secondary school teachers. Their images of teaching sciences do not encompass learning through inquiry and are often teacher-centred (Cross & Ndofirepi 2013), while the modern science teaching standards worldwide require teachers to change their ways of teaching to include learner-based activities (National Research Council, 2011). It was found that in-service and pre-service teachers face critical challenges in aligning their classroom practices with the standards of scientific inquiry since such reform-based classroom practices require professional skills, knowledge and pedagogical content knowledge (PCK) (Gess-Newsome, 2015; Harris & Rooks, 2010). Therefore, pre-service teachers at university need to know how to translate such content to benefit learners at school. Furthermore, in-service and pre-service teachers do not always translate their teaching science beliefs into their science teaching practice due to factors influencing their teaching (Friedrichsen & Dana, 2003).

These factors dishearten teachers from teaching sciences using inquiry-based learning methods, which can be grouped into intrinsic and extrinsic factors.

Bronfenbrenner's ecological theory of development (1979) explains the influences of extrinsic and intrinsic factors. Extrinsic factors are contextual aspects comprised of the physical, social and cultural features of immediate settings in which people live. The commonly cited contextual factors include lack of resources, school culture, classroom management and content coverage (Ramnarain, Nampota, & Schuster, 2016; Lewthwaite, 2006). Intrinsic factors represent the individual aspect and are associated with personal attribute factors such as science teaching efficacy, professional science knowledge, science teaching interest and motivation, and teacher content knowledge (Ramnarain et al., 2016; Lewthwaite, 2006). This paper focuses on extrinsic factors influencing the pedagogical orientations of Physical Sciences pre-service teachers since they are perceived as common factors and are easier to diagnose than intrinsic factors. There are various empirical studies about factors influencing in-service teachers. The most cited factors from the literature include teacher's beliefs about learners and learning, prior work experiences, time constraints, classroom context, professional development, class size, availability of resources, teacher competence and confidence, student ability, school culture, parents' expectations and IBL requirements (Ramnarain & Schuster, 2014; Volkman, Abell, & Zgagacz, 2005; Friedrichsen & Dana, 2005). Even though South African teachers grapple with some of the factors mentioned above at school, the newly designed curriculum demands them to adopt learner-centred teaching pedagogies, irrespective of their diverse culture and context.

2. DIVERSE SCHOOLS IN SOUTH AFRICA AND INQUIRY PRACTICE

Since the dawn of democracy in South Africa, the educational system has experienced several changes to redress the previous government's wrongdoings concerning education to promote and provide quality education to all citizens. The school curriculum was changed to make it relevant, address skill shortages, and mirror education that exposes the needs of South African citizens (Mouton, Louw, & Strydom, 2012). However, the changes failed to consider issues of diversity, which contributed to curriculum reform implementation problems, and these disadvantaged schools were situated in the township and rural areas (Rogan & Grayson, 2003). As mentioned before, South Africa is a diverse country in terms of school context and culture compared to other countries worldwide. Some schools are located in the most affluent areas, and these schools have all the resources to aid learning. Some schools are located in the most impoverished areas without proper infrastructure and learning resources. To address the issue of diversity and inequality, the South African Department of Basic Education categorised the schools into five groups, known as quintiles. Public schools in South Africa are grouped under quintile one, two and three, which are comprised of 60% of the schools, while the remaining 40% are the elite schools that fall under quintiles four and five. Quintile one to three schools has a higher teacher-learner ratio than quantile four or five schools. For example, in 2017, quintile five schools had an average teacher to learner ratio of 1:40 in Physical Science class, compared to 1:69 teacher to learner ratio in quintile one to three schools. Quintile one to three schools experience different challenges compared to their elite counterparts since they have limited science resources, large numbers of under-qualified or non-qualified Physical Sciences teachers and overcrowded classes. When adopting inquiry-based learning activities, these factors influence teachers' pedagogical orientations (Ramnarain & Schuster, 2014).

The National Research Council (1996) defines inquiry-based learning (IBL) as activities where learners develop knowledge, understand scientific ideas, and understand how scientists study the natural world in their everyday lives. IBL in a science classroom allows teachers to act as facilitators while learners become more self-directed. Learners are expected to discover new knowledge independently, formulate hypotheses, test the results; therefore, IBL promotes autonomy and encourages learners to construct knowledge (Pedaste, Mäeots, Leijen, & Sarapuu, 2012; Ramnarain & Hobden, 2015). Ramnarain and Schuster (2014) assert that South African science teachers embrace inquiry approach perception as there is a belief that inquiry-based learning can help learners develop practical skills and make science more engaging. Therefore, based on the importance of inquiry-based learning in the new South African science curriculum and the diversity in the schools in which this is implemented, it is important to assess the pedagogical orientations of pre-service teachers towards their classroom teaching and identify factors influencing their pedagogical orientations. In order to establish the pedagogical orientations of pre-service teachers, the following research questions were formulated:

i. What are the preferred pedagogical orientations of Physical Sciences pre-service teachers towards their teaching?

ii. What factors influence the pedagogical orientations of Physical Science pre-service teachers when they are at school?

3. PEDAGOGICAL ORIENTATIONS

The underlying theoretical framework of this study is pedagogical content knowledge (PCK), and the underlying conceptual framework is pedagogical orientations (PO). PCK is a blend of pedagogical and content knowledge that formulates the transformation of the two mentioned knowledge into the most powerful, teachable forms to express the subject and make it comprehensible for learners' understanding (Shulman, 1987). PCK emphasises the significance of representation and understanding of emphasised knowledge. Within PCK, Grossman (1990), Magnusson, Krajcik, and Borko (1999) extended the PCK model by adding a key construct known as teaching orientations. The construct 'orientation' refers to teachers' knowledge and beliefs about the purposes and goals of teaching science at a particular grade level (Magnusson et al., 1999). Anderson and Smith (1987) referred to teaching orientations as various approaches to teaching science and general teachers' behaviours. There are different teaching orientations, ranging from teacher-centred presentation 'Direct Didactic and Direct Active modes' to learner-centred presentation 'Guided Inquiry and Open Inquiry modes' (Cobern, Schuster, Adams, Skjold, Muğaloğlu, Bentz, & Sparks, 2014). Pedagogical orientations as a conceptual framework formed the basis for assessing pedagogical orientations of Physical Science pre-service teachers in this paper. Below is a brief description of each of the four pedagogical orientations used in this paper.

i. **Direct Didactic:** a teacher presents and explains the science concept or principle directly to the students and illustrates with examples and demonstrations. Students apply this knowledge to questions and problems. There are few student practical activities in this method, but there are usually discussions and problems with the content.

ii. **Direct Active:** similarly entails direct teacher exposition, but this is followed by a student activity based on the presented science content, for example, hands-on practical verification of a law.

iii. **Guided inquiry:** the teacher plans an activity where students explore a phenomenon or idea, and from this, the teacher guides them to develop the desired science concept or principle.

iv. **Open inquiry:** students explore a phenomenon or idea on their own, devising ways of doing so, minimally guided, after which they report what they did and found. The teacher facilitates the student activity but does not intervene more than necessary.

The first two orientations are direct approaches, referred to as teacher-centred, and the last two orientations are inquiry approaches, referred to as learner-centred. The four orientations were used to establish Physical Sciences pre-service teachers' pedagogical orientations through a questionnaire comprised of POSTT items. Figure 1 shows an example of the POSTT item used in this study (Cobern et al., 2014).

Figure 1.
Example of the POSTT item.

Finding the density of a mystery substance

Mr. Cobb's 8th grade students have learned the concept of density, through examples of solid objects whose mass and volume could be measured. Mr. Cobb next sets students an 'application' experiment where they have to *apply* their knowledge of density. He provides a 'mystery element' in granular form as shown. The students' challenge is to devise a method of finding the volume of this substance, take the necessary data, calculate density, and hence suggest what the mystery element might be. (They will have to use a water displacement method to measure volume since there are air spaces between granules).

Thinking about how you might teach, which one of the following approaches would you suggest that Mr. Cobb use for this lab activity?

A. Provide students with lab worksheets giving the experimental method and procedural steps. Students follow this and enter their experimental data in blank tables on the worksheet. They then calculate density and give their result and conclusion.

B. Provide students with an instruction sheet which outlines the experimental method. Students follow this and record data in a way of their choosing in their lab notebooks. They then calculate density and give their result and conclusion.

C. Do not provide method or instructions but have students first propose and develop a method they intend to use. Before going ahead they discuss this with Mr. Cobb, get feedback, revise if necessary, and then go ahead with their experiment, calculations and result.

D. Leave students to their own devices as much as possible; they should figure out a method on their own and decide what measurements to take and how. They then do their experiment their own way, and write up their method, result and conclusion.

Give reasons for your preference, and say why you did not choose the other options.

Figure one illustrates the nature of the POSTT item, and all the items have the same format, namely, vignette, pedagogy question and four options. However, they involve different facets of science and science instruction. Even though the items had different facets of science, the commonalities, like the pedagogy response options, were the same. The question structure was based on instructional scenarios allowing the pre-service teachers to make decisions and provide possible pedagogical reasons (Ladachart, 2019; Cobern et al., 2014).

4. PRE-SERVICE TEACHERS' PEDAGOGICAL ORIENTATIONS IN PRACTICE

The review is based on empirical studies that employed pedagogical orientation as a conceptual framework and used POSTT items to investigate pre-service teachers' pedagogical orientations. Sahingoz and Cobern (2020) used POSTT to gain insight into how taking a science methodology course correlates with pre-service science teachers' science teaching pedagogical preferences. Education students enrolled in American public university were used as participants, some of whom had completed a science methods course, and some were not. The findings indicate that many pre-service teachers' orientations were towards inquiry science teaching orientation even if they did not take a methodology course. However, their reasons often varied where pre-service teachers who took a methodology course think more broadly about factors that should influence choices of instructional practice (e.g. grade level, prior knowledge, interest areas) than those who did not. Ladachart (2019), Güven, Muğaloğlu, Doğança-Kücük, and Cobern (2019) studies revealed that fresh-man pre-service science teachers' orientations leaned towards Guided Inquiry and were not influenced by their earlier science learning experiences. Their orientations were largely related to their conceptions about the roles of teachers and students, students' grades and nature of subject matter rather than their immediate experiences as learners. Nyirenda (2019) examined Zambian pre-service science teachers' pedagogical orientations and factors influencing their pedagogical orientations. The findings show that Guided Inquiry was the preferred pedagogical orientation. Factors influencing their pedagogical orientations include curricula, time constraints, resource availability, and educational background (Nyirenda, 2019). The review based on pre-service teachers' pedagogical orientations and POSTT items indicate pre-service teachers preferred Guided Inquiry orientation, and the results were similar irrespective of context.

5. RESEARCH APPROACH

This study employed a sequential explanatory mixed methods design, and this design enabled the researchers to collect quantitative and qualitative data, then merge the data, and use the results best to understand the research problem (Creswell, 2005). A quantitative method was used to determine the pedagogical orientations of the Physical Sciences pre-service teachers, and a qualitative method was used to establish factors influencing their pedagogical orientations. The questionnaire comprised ten POSTT items developed at the Western Michigan University by Schuster et al. (2007) and Cobern et al. (2014). The POSTT item portrays an actual teaching scenario for a particular Physical Science concept, and the pre-service teachers were required to select the most appropriate teaching approach

from the four options given and justify their selection. Eight pre-service teachers were purposefully selected for interviews based on the quantitative results.

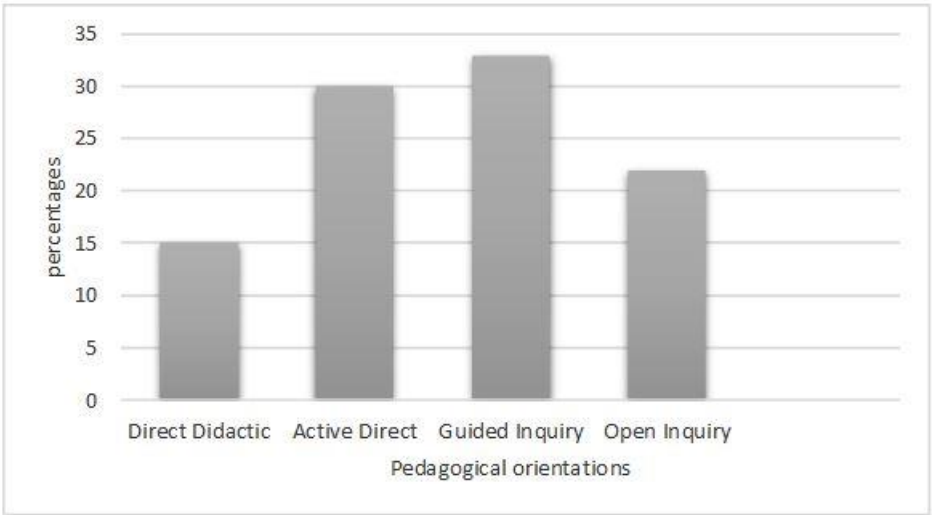
The data were analysed at different stages; for quantitative data, a similar data analysis method used by Ladachart (2019), Ramnarain and Schuster (2014), Ramnarain et al. (2016), Cobern et al. (2014) and Schuster et al. (2007) was adopted in this paper. The data analysis is based on a scoring system, where 1 point was given for each option representing a Direct Didactic, 2 points for Direct Active, 3 points for Guided Inquiry and 4 points for Open Inquiry. A Cronbach's alpha reliability was calculated to prove the reliability of the scoring system, and the result was 0.62, which can be considered low compared to the normal standard in educational research (≥ 0.7). This instrument also yielded weak inter-item correlations in the study conducted by Cobern et al. (2014). Therefore, this value should not be considered the result of a poor instrument.

A Saldana (2009) coding method was adopted to analyse the qualitative data to gain insights into the quantitative results. The qualitative data from the questionnaire was based on the Physical Sciences pre-service teachers' reasons behind their choices, and the conducted interviews formed part of the qualitative data. The qualitative data were first transcribed, coded and analysed using basic techniques for thematic analysis. In the process of thematic analysis, both deductive and inductive reasoning approaches were used to establish factors influencing their pedagogical orientations.

6. RESEARCH FINDINGS: QUANTITATIVE

The analysis of quantitative data collected through the questionnaire is presented below, together with the qualitative findings, enabled understanding factors influencing the pre-service teachers' orientations. The overall Physical Sciences pre-service teachers' most appropriate pedagogical orientations results are presented in figure 2.

Figure 2.
The overall preferred pedagogical orientations of Physical Sciences pre-service teachers in percentages (%).



The results show that Guided Inquiry (33%) was selected as the appropriate pedagogical orientation followed by Direct Active (30%). The overall mean score, 'an average score for items', was 2.61 (i.e. responses were centred between Direct Active and Guided Inquiry) with a standard deviation of 0.8 'spread of the mean scores'. The figure above also reveals that the pre-service teachers' had multiple pedagogical orientations ranging from Direct Didactic to Open Inquiry. A One-Way ANOVA was used to compare the relationship between the four overall mean scores, and there was a significant difference between the mean scores of the most appropriate pedagogical orientations where [$F(2.340, 102.976) = 15.917$ $p<0.000$, $\eta p2 = 0.266$] (equal variances are not assumed).

7. QUALITATIVE FINDINGS

The questionnaire responses were recorded, transcribed, coded, analysed using Saldana (2009) coding method, and codes were assigned to different statements. After the coding process, codes that shared similar characteristics were grouped to develop categories, then different assertions emerged from different categories and themes were generated. The factors influencing the Physical Sciences pre-service teachers are presented below.

7.1. Theme one: Resources at school influenced the preferred Physical Sciences pre-service teachers' pedagogical orientations

The availability of resources and many learners per class emerged as factors influencing the Physical Sciences pre-service teachers' pedagogical orientations since these factors had an impact on the teachers' autonomy to adopt a learner-centred teaching approach. These factors often led the pre-service teachers to opt for a teacher-centred orientation. A teacher who adopts a traditional orientation believes in conducting a whole-class demonstration or direct teaching method where learners cannot work independently in small groups. One of the Physical Sciences pre-service teachers, Mr Motsapi, mentioned there was a laboratory with few resources to conduct experiments at his school that was why he preferred a traditional teaching method. In one of the POSTT items responses, 'A lesson on force and motion', Mr Motsapi mentioned he would prefer a teacher demonstration. In this lesson, a teacher prepares an experiment where she/he plans to introduce learners to the relationship between force and motion. He/she used a small loaded cart to pull a force, and the force can be applied to teach the concept where a net force will either cause an object to speed up or slow down (Newton's 2nd Law).

> *The school had a laboratory, but it did not have many resources, for example, the station wagon. So, as a teacher, I will bring a homemade wagon and load it with books to show the whole class.*

Mr Motsapi indicated few resources at a school where he was placed during teaching practicum, which led him to opt for teacher-centred lessons or class demonstrations. Another pre-service teacher, Ms Faltein, also indicated that there were no science laboratories in her school, and she opted for teacher-centred methods.

> *They did not have resources or laboratories for sciences in my school, and there were so many learners in all my classes*.

The lack of laboratory resources and many learners per class led Ms Faltein to opt for teacher-centred orientations. She further elaborates even though there were no laboratories at her school, she was willing to adopt a learner-centred method, but she usually reverts to a teacher-centred approach. In summary, the lack of laboratory resources and many learners per class influenced the Physical Sciences pre-service teachers' preference for a teacher-centred pedagogical orientation.

7.2. Theme two: Insufficient teaching time influenced the preferred Physical Sciences pre-service teachers' pedagogical orientations

The Physical Sciences pre-service teachers' responses revealed that time was another factor that precludes them from conducting practical work or engaging in a learner-centred approach, which led them to opt for teacher-centred approaches. At the secondary school level, to come up with the school timetable is the responsibility of the School Management Team (SMT). The school curriculum guides schools when it comes to time per subject a week, Physical Sciences as a subject is assigned four hours per week, and the school has the prerogative to allocate the four hours in a way they think would be appropriate for their school. Some schools in South Africa prefer a double period for Physical Sciences lessons at least once a week, and each period is either forty-five minutes or one-hour long. The four hours per week are for the actual teaching and laboratory experiments. Therefore, limited time was another factor influencing pre-service teachers' pedagogical orientations. For example, Ms Sibeko, in one of the POSTT item responses, the 'Volumes and displacement' item, preferred a Direct Didactic orientation. She claims that there was inadequate time to teach using learner-centred approaches at her school. The volume and displacement POSTT item is based on the teaching scenario where the teacher plans to teach Volume and displacement. In the lesson, a part involves using a graduated cylinder partially filled with water to determine the Volume of small irregular objects. Below is Ms Sibeko POSTT item response, where she indicates the influence of time on her practice.

> *Most of the inquiry lessons are time-consuming because other learners may not find the correct equipment or resources to conduct experiments on their own, and it might seem impossible to find another way of measuring the Volume of objects without measuring the objects themselves.*

Her response suggests inquiry approaches or letting learners conduct a practical themselves have a negative impact on the lessons since they are time-consuming. In the interviews, she further explains:

> *The reason is that other options are time-consuming require more skills from the teacher. There is nothing wrong with using a direct teaching approach to ensure effective teaching and learning.*

The issue of skills or exposure to inquiry approaches surfaced in the interview because the pre-service teachers were reluctant to adopt learner-based activities due to their limited skills of handling learner-centred lessons. Ms Sibeko claims inquiry approaches are time-consuming and time specification in the curriculum played a role in limiting her teaching styles. Mr Jacobs shared similar sentiments as Ms Sibeko, and he argued that time to teach Physical Sciences subjects was not enough.

> *The time given to Physical Sciences lessons is not enough to follow the learner-centred approach in class. Therefore, I used my teaching method because we are expected to cover so much content with little time*.

Mr Jacobs also complained about the limited time given to teaching Physical Sciences, and his assertion is similar to Ms Sibeko's. They both claim that insufficient time for Physical Sciences lessons influenced their pedagogical orientations. In summary, the results show that contextual factors such as resources, class size and teaching time at school influenced the preferred pedagogical orientations of Physical Sciences pre-service teachers to opt for a teacher-centred approach.

8. DISCUSSION

This study used a questionnaire comprised of adapted POSTT version and interviews to establish factors influencing the Physical Sciences pre-service teachers' pedagogical orientations in one of the universities in South Africa. The Physical Sciences pre-service teachers' overall results for the most selected appropriate pedagogical orientations were in the following descending order: Guided Inquiry (33%), Direct Active (30%), Open Inquiry (22%) and Direct Didactic (15%). Therefore, their pedagogical orientations varied from Direct Didactic to Open Inquiry. The overall mean score was 2.61 (i.e. responses were centred between Direct Active and Guided Inquiry). The findings of this study resonate well with other studies both locally and internationally; for example, Ladachart (2019) and Nyirenda (2019) indicate pre-service teachers preferred Guided Inquiry compared to other orientations in their respective countries. Ramnarain et al. (2016) compared the Malawian and South African Physical Sciences teacher's pedagogical orientations, and the collective responses from both countries lean towards inquiry compared to direct instruction, which means they preferred a Guided Inquiry approach.

In the responses and interviews, the pre-service teachers tend to select a teacher-centred approach due to numerous factors, including school resources, the number of learners per class, and teaching time. Therefore, the pre-service teachers at township schools tend to select either Direct Active or Guided Inquiry approaches in the POSTT because of the many learners per class and the lack of resources in those schools. Schools in impoverished areas experienced difficulties in pedagogy compared to their counterparts in urban or semi-urban areas due to limited science resources, a limited number of qualified Physical Sciences teachers, and overcrowded classes (Ramnarain & Schuster, 2014, Makgatho & Mji, 2006). Nyirenda (2019) and Ramnarain and Schuster (2014) studies mentioned that the lack of resources, large number of learners per class, and limited teaching time influenced in-service and pre-service teachers' pedagogical orientations in their countries. In order to respond to research question two, the Physical Sciences pre-service teachers' pedagogical orientations were influenced by several factors such as school resources, teaching time and class size.

9. FUTURE RESEARCH DIRECTIONS

This study sheds light on the nature of pedagogical orientations and factors influencing the pedagogical orientations of Physical Sciences pre-service teachers, where the questionnaire and interviews were used to collect data to address the research questions. The questionnaire comprised POSTT items in standardised multiple-choice questions

whose options were restricted to only four pedagogical orientations. I recommend future studies to use open-ended questions so that pre-service science teachers can give the pedagogical orientations. The results of this study reveal that science pre-service teachers are inclined towards Guided Inquiry pedagogical orientations. However, the study did not determine whether the Physical Sciences pre-service teachers project the same pedagogical orientations in practice. Therefore, future studies must consider following pre-service teachers into the classroom for observations to determine whether their pedagogical orientations in the questionnaire aligned with their classroom practices.

10. CONCLUSION

With science education reforms in South Africa and worldwide, inquiry-based learning has been recommended to promote scientific literacy among school learners. However, it was found that science teachers face challenges in aligning their classroom practices with the standards of inquiry-based learning (Harris & Rooks, 2010) since such reform-based classroom practices require high levels of professional skills and knowledge (Gess-Newsome, 2015). The purpose of this explanatory sequential mixed-method study was to establish the pedagogical orientations of sciences pre-service teachers towards their instructional approaches and to determine factors influencing their pedagogical orientations. The findings of this study indicate the Physical Sciences pre-service teachers' preferred pedagogical orientations were between Direct Active and Guided Inquiry, while factors influencing their pedagogical orientations were contextual: school resources, class size, and teaching time. Based on the findings presented, this study's significant contribution is that pedagogical orientations are a dynamic construct, and context plays an important role in influencing teachers' PCK and pedagogical orientations.

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AUTHORS' INFORMATION

Full name: Aviwe Sondlo
Institutional affiliation: University of Zululand
Institutional address: NE 309 Postal Address: Private Bag X1001, KwaDlangezwa 3886
Short biographical sketch: Mr Aviwe Sondlo is a Physical Sciences lecturer in the Department of Mathematics, Science and Technology Education, University of Zululand. His research interest includes pre-service teachers' pedagogical content knowledge (PKC), pre-service teachers' pedagogical orientations and inquiry-based learning in the 21st century. He is a PhD candidate and his dissertation title: The Pedagogical Orientations of Pre-Service Sciences Teachers towards Instructional Approaches. He presented his work both at the international and national conferences.

Full name: Umesh Ramnarain
Institutional affiliation: University of Johannesburg
Institutional address: B-Ring 420, Faculty of Education, University of Johannesburg, Auckland part, Johannesburg 2006
Short biographical sketch: Prof Umesh Ramnarain research focus is mainly inquiry-based learning. His research is on inquiry teaching and learning, and its uptake in South African classrooms characterised by diversity and complexity in intrinsic and extrinsic or environmental factors. The knowledge base he has built has important implications at both the national and international levels, especially in terms of inquiry teaching in underprivileged schools.