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Novice teachers' professional discourse on teaching natural science in the Foundation Phase in the Western Cape, South Africa

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In this article we report on the initial professional discourse on teaching natural science (NS) in the Foundation Phase among a sample of novice teachers in the Western Cape province of South Africa. The sample comprised 7 novice teachers (NTs) with 3 or fewer years of teaching experience. We investigated the NTs preparedness to teach NS, exploring their interpretation of the foundation phase (FP) life skills (LS) curriculum and assessment policy statement (CAPS). We identified and examined gaps in the NTs' understanding and knowledge of teaching NS to formulate an intervention programme (IP), and an 8-week IP integrating theoretical and practical elements was subsequently developed. The data collection instruments included a questionnaire, semi-structured interviews and classroom observations. Inductive and deductive analysis were employed in coding the data, defining common trends and categorising these into themes. The findings highlight the teachers' lack of content knowledge (CK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK) for NS teaching. The study underscores the need for effective approaches to teaching NS, such as a pedagogy of inquiry with specific strategies to foreground learner agency. Instruction in these approaches should be incorporated into teacher training curricula at higher education institutions (HEIs), which is recommended as a topic for future research.

Keywords: content knowledge; foundation phase; inquiry-based teaching; natural science; novice teacher; pedagogical practices; teacher training

Introduction

The *Britannica Dictionary* defines natural science as science which includes the subjects physics, chemistry or biology. Science investigates the physical world or occurrences that occur in the environment. The specific goal of NS is to explore and understand the natural world through the process of scientific inquiry (Worth, 2010). In the teaching of NS, the natural curiosity of the learner is encouraged and enhanced by inculcating scientific process skills to develop scientific knowledge. Encouraging exploration, idea generation and questioning are essential as NS education fosters the ability to critically analyse and use creative problem-solving skills to represent scientific ideas (Worth, 2010). The emphasis on developing critical thinking skills nurtures active investigation, analysis and understanding the world rather than memorising facts.

The importance of integrating inquiry-based learning in early NS schooling is widely acknowledged within educational contexts (National Science Teachers Association [NSTA], 2014). Teaching NS in the Foundation Phase (FP) (encompassing Grades R to 3) is crucial as it not only provides a fundamental knowledge base but nurtures learners' inherent curiosity about the world around them. However, in foundational curricula worldwide, NS is either omitted entirely or lacks explicit articulation within the curricula frameworks (Campbell & Chittleborough, 2014; Hume & Berry, 2018; Orhun & Ozturk, 2021).

Ensuring the provision of quality NS instruction within the FP, including its distinct meta-language, scientific processes and pedagogy, is vital for equipping learners with the necessary skills and knowledge for success in later grades. To ensure quality instruction, FP teachers are expected to possess knowledge in various fields of science, as prescribed by the four NS concepts outlined in the CAPS curriculum. These concepts encompass life and living, energy and change, matter and materials, and planet Earth and beyond (Department of Basic Education [DBE], Republic of South Africa [RSA], 2011:8). A general understanding of the disciplines of biology, astronomy, physics and chemistry is required for effective teaching (Dixon, Flett & Isaac, 2018). Additionally, teachers need to possess the knowledge and ability to implement various pedagogies and strategies to teach effectively (James, Beni & Stears, 2019).

Explicit and precise guidelines for teaching NS are notably absent from the South African FP CAPS document, which covers the initial stage of formal NS education. NS is embedded within the Life Skills (LS) curriculum under the study area of beginning knowledge, which often goes unnoticed by FP teachers (Beni, Stears & James, 2012). Moreover, the CAPS document allocates limited time for NS instruction. Out of the 4 hours assigned to LS per week, only 1 hour for Grades 1 and 2, and 2 hours for Grade 3, are allocated to beginning knowledge (DBE, RSA, 2011). This limited time not only undermines the intended emphasis on scientific inquiry but also has the potential to hinder the holistic development of learners during their formative years (Bosman, 2017). While the CAPS curriculum encourages an integrative approach in FP teaching (DBE, RSA, 2011), the specificity of the NS subject and its pedagogy should not be weakened, compromised or overlooked in the process. The purpose with this article was to answer the research question: What specific gaps in qualifications, content knowledge (CK) and pedagogical strategies hinder novice teachers (NTs) from effectively teaching NS in the FP?

Literature Review

There is consensus among international and national researchers that a strong early science foundation is crucial for a positive and effective science learning experience (Beni, Stears & James, 2017; Bosman, 2017; Dixon et al., 2018). The teaching of NS from Grade R is regarded as essential for promoting scientific literacy and developing critical thinking skills (DBE, RSA, 2011). Teachers play a vital role in understanding what science content should be taught and how it should be taught to establish a solid foundation for learners (Beni et al., 2017).

The conceptualisation of NS in selected contexts

In many developed countries like Finland and Singapore NS education is regarded as a critical component of elementary education because it promotes scientific literacy, problem-solving skills, and critical thinking among elementary school learners (European Commission, 2015; Singapore Ministry of Education, 2019). The education system in Singapore prioritises science and technology from elementary schooling onwards, using the pedagogy of inquiry-based learning and experimentation, with a focus on the application of scientific knowledge to real-world situations (Singapore Ministry of Education, 2019). Finland, renowned for its excellent standards in education, implements an interdisciplinary approach to NS education by combining it with other disciplines such as mathematics and languages (European Commission, 2015). Many other countries actively implement NS in their elementary curriculum. Teachers in Lithuania, for example, employ inquiry-based activities like practical, hands-on demonstrations and experiments to cover topics such as healthy living, environmental protection and ecology (Lamanauskas, 2022). In India, a developing country, play-based, self-paced individual learning in a more social group-based learning pedagogy to teach NS is used (India National Steering Committee, 2023).

However, the NS curriculum in South Africa is not prioritised adequately (Beni et al., 2017). The DBE emphasises mathematics and languages over LS, as these subjects were deemed preferential following the release of the results of the 2022 Progress in International Reading Literacy Study (PIRLS). The PIRLS results highlight the alarming state of Grade 3 learners' reading comprehension, with 81% struggling to read for meaning.

As a result, LS subjects, including NS, appear to have been assigned a lower status than mathematics and languages, undermining their perceived importance in the educational framework. Yet in teaching NS, there can be a deliberate focus on language acquisition, vocabulary development, meaningful discussion, effective questioning, critical thinking, problem-solving and various forms of information recording. This kind of instructional strategy consistently promotes the skills for reading comprehension, as learners actively engage in developing scientific process skills, acquiring CK and understanding key concepts and their application (Riveros, 2020).

NS as formulated in the Curriculum and Assessment Policy Statement (CAPS)

In the South African schooling system, the FP (Grades R to 3) is the initial phase of formal education. The FP curriculum, as set out in the CAPS documents, consists of four subjects, namely home language, first additional language, mathematics and life skills (DBE, RSA, 2011).

LS is divided into four study areas: beginning knowledge, personal and social well-being, creative arts and physical education. Beginning knowledge comprises social sciences (history and geography), NS and technology (DBE, RSA, 2011). The key concepts and skills relating to these disciplines are presented in Table 1.

Table 1 Key concepts and skills relating to beginning knowledge in FP LS (DBE, RSA, 2011:8)

Social science concepts	Conservation, cause and effect, place, adaptation, relationships and interdependence, diversity, and individuality and change.
Natural science concepts	Life and living, energy and change, matter and materials, planet Earth and beyond.
Scientific process skills	The process of enquiry that involves observing, comparing, classifying, measuring, experimenting and communicating.
Technological process skills	Investigate, design, make, evaluate, communicate.

The NS concepts that are foregrounded alongside scientific process skills in elementary science (DBE, RSA, 2011:8) are life and living, energy and change, matter and materials, planet Earth and beyond. These foundational science concepts primarily align with everyday knowledge, potentially diverting teachers from the more intricately interconnected scientific concepts within NS, as conceptualised by scientists (Larkin, 2013).

The scientific process skills highlighted in the CAPS encompass the process of inquiry – observing, comparing, classifying, measuring, experimenting and communicating (DBE, RSA, 2011:8). However, no reference is made to the term "scientific literacy" (SL). Yet SL is a crucial concept in NS education that empowers learners to become scientifically literate and socially responsible citizens (King, Shumow & Lietz, 2014). SL is essential as it equips individuals with the tools to understand various scientific concepts and use scientific information to identify scientific questions and draw evidence-based conclusions (King et al., 2014). The curriculum omits scientific attitudes such as curiosity, honesty, open-mindedness, scepticism, flexibility, perseverance and creativity, which are crucial for NS learning. Teaching learners scientific attitudes and fostering a positive mindset among young scientists are elements in early education (Prachagool & Arsaiboon, 2021).

The CAPS curriculum for LS additionally fails to provide explicit instructions for FP teachers on how to teach NS. According to Dixon et al. (2018), LS is a dense and complex curriculum. Although the LS CAPS document contains the topics to be taught for NS, it does not explicate the topics, nor provide any clarification about terminology, concepts or activities. The absence of explicit scientific definitions and clear guidance on scientific pedagogy appears to encourage FP teachers to translate the curriculum according to their own knowledge of NS (Morris, 2016). This deficit in educational guidance can lead to frustration and misdirection among teachers, who are expected to be generalists and teach across all the disciplines in the FP (Beni et al., 2017).

Teachers as effective facilitators of NS learning

The quality of the initial training of FP teachers has a substantial impact on how qualified they are to teach NS in FP classes (Beni et al., 2017). Higher education institutions (HEIs) in South Africa train FP teachers to teach Grades R to 3 learners as generalists capable of teaching all the subjects listed in the CAPS.

Qualified FP teachers should possess subject expertise, which includes the ability to interpret the curriculum, understand the pedagogy and comprehend the age and stage of the learners' development (South African Qualifications Authority [SAQA], 2006). Qualified FP teachers should be skilled in the application of knowledge and in creative and critical thinking. They should have a degree of self-awareness and emotional intelligence and be able to maintain a high level of professionalism. HEIs frequently emphasise the teaching of literacy and numeracy while neglecting the teaching of the LS curriculum (Arasomwan & Mashiya, 2018). This is especially evident in FP teachers' interpretation of the FP LS curriculum and their preparedness to teach NS as part of LS (Beni et al., 2017). Life skills, which includes NS, is covered during one semester in the third or fourth year of teacher training at HEIs. Practice in teaching NS is limited to the students' teaching practicum at schools (Arasomwan & Mashiya, 2018). The student teachers experience difficulties in implementing NS instruction because of their limited knowledge of the subject (Mkhasibe, Maphalala & Nzima, 2018). For teachers to develop learners' conceptual understanding, they need more in-depth training in NS that emphasises the subject's core skills, knowledge and attitudes (Dixon et al., 2018).

According to Palmer (2006), primary school teachers face the possible challenge of a lack of the necessary skills and subject knowledge to help learners develop their own skills and knowledge. Many FP teachers are unable to identify the NS component in LS and neglect to teach the subject; or if they are able to identify the NS component, they cannot teach the subject effectively because they lack sufficient knowledge of science (Meiring, 2019). This can be attributed to most FP teachers not choosing science as an elective subject at high-school level (Beni et al., 2017). Teachers with limitations in their knowledge of content, pedagogy and scientific process skills will lack self-efficacy and the ability to teach science meaningfully (Meiring, 2019).

This lack of self-efficacy in respect of teaching NS in the FP may translate into negative attitudes towards the subject. Teachers' attitudes, beliefs, thoughts and feelings affect how they teach science and will manifest in their learners too (Osborne & Dillon, 2008; Tai, Qi Liu, Maltese & Fan, 2006; Turner & Ireson, 2010). Teachers play a crucial role in determining the attitudes of their learners towards science because it is in the FP that learners' curiosity is optimal (Osborne & Dillon, 2008; Osborne, Simon & Collins, 2003).

Theoretical Framework

The theoretical framework that underpins this study is Shulman's (1986, 1987) pedagogical content knowledge (PCK) framework, which reflects a comprehensive understanding of the intricate interplay between subject matter knowledge or CK and pedagogical knowledge (PK) in teaching. PCK goes beyond a mere combination of CK and pedagogical strategies; it delves into a profound understanding of how to teach specific content in ways that foster meaningful learning experiences for learners. It encompasses the nuanced knowledge and expertise that develop over time, enabling teachers to navigate the complexities of classroom practice, address diverse learner needs and facilitate understanding and engagement.

In this study, the PCK framework served as a valuable lens for investigating the CK and PK of novice teachers teaching NS. The framework enabled us to explore various aspects, including NTs' understanding of NS and their comprehension of the FP LS CAPS curriculum. A qualified FP teacher is expected to possess subject expertise, which includes the ability to interpret the curriculum (Department of Higher Education and Training [DHET], RSA, 2015). The CK for NS embraces four key concepts: life and living, energy and change, matter and materials and planet Earth and beyond (DBE, RSA, 2011). The PK covers the teaching principles and strategies to be used in the teaching of NS (Shulman, 2004); that is, the theoretical and practical knowledge concerning the activity of teaching and the process of learning that teachers require to teach effectively. It includes the development of learning and teaching support materials, classroom management, learning habits, problem-solving, methodology, strategies and assessment. The teachers' ability to effectively integrate and transform their CK and PK determines their capacity to address different learners' abilities and backgrounds for effective classroom practice and learner achievement. In short, a combination of CK and PK is essential for the professional development of teachers (Shulman, 2004). In this study, the NTs' integration of CK and PK was analysed by employing the PCK framework to determine how they designed effective practices for the diverse needs of individual learners (Shulman, 2004). We investigated the connection between the NTs' experience, pedagogical practice and the content they taught, that is, how they employed their CK and PK to improve their NS teaching practice and meet learners' requirements.

Methodology

For this study we employed a qualitative interpretivist design in order to collect rich information relating to NTs' readiness to teach NS, teaching practice and abilities (Creswell & Creswell, 2018). The approach enabled us to capture the depth and intricacy of NTs' perspectives (Cohen, Manion & Morrison, 2017). This was achieved by exploring each NT's personal experience, opinions and beliefs about NS in their immediate context (Patton, 2015). Information was also obtained about the NTs' initial teacher education (ITE) training at each of their HEIs, with a view to changing factors adversely impacting their preparedness and practice. The NTs' subjective perspectives and authentic voices offered comprehensive insight into the complexities of their social contexts, including relevant socio-cultural factors (Ezzy, 2002; Smith, 2018). A multiple case study methodology was chosen to afford us a holistic understanding of the NTs' qualifications, training and readiness, their knowledge of the subject, and their implementation of CAPS and PK. The approach allowed for a thorough examination of the interconnected variables, perspectives and contextual factors (Yin, 2018) that shaped the NTs' teaching practices in NS.

The study was performed at three public primary schools in the urban Metro Central Education district (MCED) in the Western Cape province of South Africa. The schools were selected by convenience sampling, being close to each other and to the researchers' location, with English as their medium of instruction (Yin, 2018). The proximity facilitated easy access and convenience for research purposes (Creswell & Creswell, 2018).

The following criteria were then purposively invoked to select the sample of seven NTs for the study: all the participants had to have been teaching for 3 years or less, in English, in the FP. While the objectives of the study were diligently pursued, the findings may be limited by the small sample size, participant withdrawal for personal reasons, timing constraints, limited interaction, and remote data collection methods.

The data collection methods for this multiple case study included a short questionnaire, semi-structured interviews, classroom observations and document analysis. The participants' biographical details were collected using the questionnaire (Clough & Nutbrown, 2012:159). We encountered limitations arising from the coronavirus disease (COVID-19) pandemic, which impacted the data collection process. Educational disruptions and restrictions on face-to-face sessions necessitated remote methods such as video-conferencing interviews and video-recorded classroom observations, which may well have limited the capture of non-verbal cues.

Although they were time-consuming and resource-intensive, semi-structured interviews offered direct interaction with the participants and in-depth data capture regarding their understanding, knowledge and thoughts about NS teaching. The direct interaction allowed us to probe and ask follow-up, open-ended questions, leading to more in-depth data (Kvale, 1996). All the interviews were audio recorded and transcribed verbatim to form the raw data for analysis. This process ensured accuracy and facilitated subsequent examination of the data during data analysis.

Classroom observations complemented the interview data by providing first-hand evidence of the NTs' CK and instructional practices. Although it was a time-consuming undertaking, we compared insights gleaned from the questionnaires, interviews and observations to arrive at a comprehensive overview of NTs' knowledge, understanding and preparedness to teach NS (Bhattacherjee, 2012).

Document analysis was also deemed critical to explore and interpret the textual discourse of the FP LS CAPS document (O'Connor, 2019). The aim was to determine the aims, principles, subject knowledge, pedagogy and allocated time for teaching NS. Jääsaari (2007) recommends policy documents as trustworthy resources, and evaluation of the LS CAPS curriculum document proved a non-invasive and rich source of information in the study. However, we had to guard against interpretative bias during the process.

The data analysis process included both deductive and inductive reasoning (Creswell & Creswell, 2018). Through deductive analysis we used the CAPS curriculum and theory as an initial framework to derive certain conclusions from the data gathered (Patton, 2015). Conversely, through the inductive analysis we applied an iterative approach focused on the identification of recurrent patterns within the data, which were then coded, categorised and incorporated into dominant themes. Colour and descriptive coding were employed to identify meaningful segments and group distinct concepts for categorising into themes (Creswell & Creswell, 2018; Henning, Van Rensburg & Smit, 2004). The following themes were generated: i) qualifications and experience to teach NS; ii) CK; and iii) pedagogical practices and willingness to learn.

Methodical interpretation of the coded data yielded meaningful insights and a deeper understanding of the NTs' beliefs, knowledge and instructional strategies, effectively addressing the research question. By taking the NTs' experiences and points of view into account, a contextually relevant, comprehensive and tailored intervention programme (IP) for their professional development was produced.

Validity, reliability and triangulation (Cohen, Manion & Morrison, 2000; Kumar, 2018) can help ensure the trustworthiness of research. The validity of this study derived from the continuous verification and interpretation of the findings to guarantee the quality of the data generated using the instruments (Kvale, 1996). Member checking was used to ensure the accuracy of data interpretation (Henning et al., 2004). Multiple research instruments were employed to multiply perspectives, triangulate the data (Creswell & Creswell, 2018) and enhance its richness (Cohen et al., 2017).

Ethical clearance was obtained from the Cape Peninsula University of Technology (CPUT) and the Western Cape Education Department (Creswell & Creswell, 2018; Yin, 2018). The NTs were provided with information about the research, its purpose, what it entailed, and their rights (including their option to withdraw from the study). Consent forms were signed by the principals and the seven participating NTs. Pseudonyms were used to refer to the participants in order to ensure confidentiality and anonymity.

Findings and Discussion

In this study we used Shulman's (2004) PCK framework to interpret the data collected through one questionnaire, seven semi-structured interviews and five observations of lessons presented by NTs 1, 4, 5, 6 and 7. The data were organised into thematic categories, namely: i) qualifications and experiences to teach NS; ii) CK; and iii) pedagogical practice.

Qualifications and Experience to Teach NS

A qualified FP teacher is an individual who possesses the necessary qualification to teach all subjects in this phase (SAQA, 2006). Typically, a FP teacher holds a 4-year bachelor's degree in education (B.Ed.) for the FP as recognised by the SAQA (2006) and the national qualifications framework (NQF). In this section we provide an overview of the qualifications held by the seven NTs, highlighting their diverse educational backgrounds and areas of specialisation (see Table 2 for further details).

Table 2 Teachers' qualifications and experience with NS as a subject

	NT 1	NT 2	NT 3	NT 4	NT 5	NT 6	NT 7
A Grade 12 certificate with science as a subject	X	X				X	X
A Grade 12 certificate without science as a subject			X	X	X		
Bachelor of Arts (BA) 3-year degree	BA specialisation psychology and linguistics (HEI A)	BA specialisation psychology and linguistics (HEI A)					
Post Graduate Certificate in Education (PGCE) 3-year degree + 1 year = 4 years	PGCE FP (HEI A)	PGCE FP (HEI A)					
Bachelor of Education (B.Ed.) 4-year degree FP or Intermediate and Senior phase (Intersen)			B.Ed. FP specialising in music (HEI B)	B.Ed. FP (HEI C)	B.Ed. FP (HEI C)	B.Ed. FP (HEI B)	Intersen B.Ed. Specialising in mathematics and English (HEI D)

The seven NTs obtained their ITE at four different HEIs in South Africa, resulting in diverse educational backgrounds. Four NTs (NTs 1, 2, 6 and 7) had prior exposure to NS content at Grade 12 level, while three NTs (3, 4 and 5) had not. Their qualifications shed light on their preparedness to teach NS in the FP, while their practical teaching experience varied among them. The data in Table 3 includes the utterances of the NTs during the interviews about their experiences with NS, answering the following question: "Can you describe your experience teaching NS?"

Table 3 NTs' experience with NS

NT 1:	*... I was figuring things out ... I would usually use inquiry-based learning....*
NT 4:	*... Actually, I've never taught it as a subject....*
NT 5:	*... It's foreign to me ... We were not taught how to teach NS....*
NT 6:	*... I feel like we never had enough training....*
NT 7:	*... I was not really aware that there was, um, there was natural science for FP.... We do not teach science as a subject.*

These narratives highlight the limitations of the NTs who were required to teach NS without adequate qualifications, training or subject exposure, placing them in an "out-of-field" teaching position with limited instructional strategies (Faulkner, Kenny, Campbell & Crisan, 2019:4) or, as Childs and McNicholl (2007:14) describe it, "teaching outside subject specialism." NTs lacking subject knowledge face challenges in understanding and effectively teaching the science curriculum. The absence of essential components such as disciplinary, pedagogical, practical, fundamental and situational learning, further underscores the difficulties that NTs face in acquiring the necessary skills and competencies for effective teaching (DHET, RSA, 2015). Overall, the combination of qualifications and subject exposure significantly impacts the readiness and preparedness of NTs to teach NS in the FP.

Content Knowledge

The NTs exhibited limited CK about the four fundamental scientific concepts encompassed in the FP NS curriculum. The NTs' comments reflected their lack of familiarity with and comprehension of the NS content stipulated in the CAPS (DBE, RSA, 2011:8). This deficiency in CK holds significant implications for effective teaching and learning, as underscored by Shulman (2004). The NTs' responses to the question, How familiar are you with NS requirements in the CAPS document?, are presented in Table 4.

Table 4 The NTs' comments about teaching NS

NT 1:	*... I wouldn't say I am very familiar with it*.
NT 2:	*... I'm not really familiar with that, the CAPS requirements for NS*.
NT 3:	*... There's NS in the CAPS? I didn't know that*.
NT 4:	*... Not that great, to be honest*.
NT 5:	*... Do I know ... don't I know ... I just know enough*.
NT 6:	*... I did not familiarise myself with that ... do not have much knowledge of CAPS....*
NT 7:	*... I would say not say very familiar....*

The NTs' comments reflected their lack of familiarity with and comprehension of the NS content as stipulated in the CAPS (DBE, RSA, 2011:8). A comprehensive analysis of the NTs' statements (see Table 5), highlights a common theme of knowledge gaps, feelings of uncertainty and inadequacy (NTs 1, 2, 3, 4, 5, 6 and 7). The findings are concerning, especially in the light of the professional expectations prescribed in the *Norms and Standards* (Department of Education [DoE], RSA, 2000:15). The norms and standards document advocates a strong foundation in the knowledge, skills and principles relevant to the subject. In this study, the observed lack of sufficient CK among the NTs resonates with Shulman's (1986:6) notion of the "missing paradigm", highlighting its indispensable role in enabling effective teaching and learning. Shulman (2004) emphasises the importance of teachers' CK for their teaching practice. The NTs' insufficient CK not only hampered their own knowledge base but also impacted their ability to effectively interpret, understand and implement CAPS NS content during instruction.

Consequently, the quality of their teaching is likely to be compromised and render them in need of continuous professional development. Inadequacy of CK typically leads to teacher-centred instruction, potentially weakening learner interest and academic performance (Cofré, González-Weil, Vergara, Santibáñez, Ahumada, Furman, Podesta, Camacho, Gallego & Pérez, 2015; Fitzgerald, Dawson & Hackling, 2013). The observed lack of CK is a critical area of concern, as it directly reflects teachers' inability to meet the standards outlined in the *Norms and Standards for Educators* (DoE, RSA, 2000).

Pedagogical Practice

In primary education, the significance of pedagogical practices in teaching NS cannot be understated (Feyfant, 2011). Shulman's PCK framework emphasises the importance of teachers knowing how to implement specific teaching practices that promote learners' comprehension of science concepts (Durden, 2016). This section draws from five semi-structured interviews and five classroom observations to offer insights into the primary pedagogical practices used by the five NTs (two NTs withdrew from the research before the classroom observations). Valuable information was nevertheless obtained from the NS lessons presented by the five remaining NTs.

The comments in Table 5 are the NTs' interview responses to the question, "What pedagogical practices and strategies do you use to teach NS lessons?"

Table 5 The most common pedagogical practices used by the NTs

NT 1: *... I would usually use inquiry-based learning … getting the learners to talk to each other, build on their knowledge and each other's knowledge … I would try to bring in the concrete … I would start off by showing the learners a video … we would do the practical planting bean.*

NT 4: *... the method we would do is group work … they touched it physically. The trunk of the tree, roots, leaves etc. We also planting our bean.*

NT 5: *... It was gathering of all the soil … types.*

NT 6: *… I just know it's about experiments … I did a float and sink experiment. When we do plan … go outside and check the types of plants.*

NT 7: *... I do enjoy taking them out … to engage practically.*

The findings from the interviews indicate that the NTs used various strategies, including inquiry-based learning, hands-on experiences, the use of information and communication technology (ICT), collaboration, practical demonstrations and group work in their instructional practice. They emphasised the use of concrete materials, observation and discussion to actively engage learners. However, variations in their understanding and practices suggest a need for further support to enable them to implement these strategies effectively. The four most prevalent pedagogical practices used by the NTs during the classroom observations are indicated in Table 6.

Table 6 The most common pedagogical practices of the NTs during classroom observations

Pedagogical practices used by five NTs	NT 1	NT 4	NT 5	NT 6	NT 7
Question-and-answer pedagogical approach (Q&A)	X	X	X	X	X
Direct instruction (DI)	X	X	X	X	X
Scientific process skills/Inquiry-based teaching (IBT)				X	
Group work/Collaborative learning	X				

The information in Table 6 shows that all the NTs focused mainly on teacher-centred strategies, including Q&A and DI, with only two NTs attempting more learner-centred strategies, group work and IBT. The contrast between their verbal reports (in the interviews) and their actual practice (from classroom observations) shows the NTs' lack of understanding of appropriate PK and PCK for teaching NS. There is a clear disjunction between their professed knowledge of how NS should be taught and their actual knowledge of the fundamental scientific process skills and concepts that should form the foundation of NS learning. The gaps in the NTs' CK and PK restricted the agency of learners and limited their ability to articulate understanding and pose questions (Shulman, 2004). The NTs' interview responses regarding their PK and use of science concepts and scientific process skills to teach NS lessons are presented in Table 7.

Table 7 NTs' comments on pedagogical knowledge, concepts and inquiry

NT 1: *... I mostly did it with discussions … like more concrete things like planting … I wouldn't say I am very familiar with it …* [NS process skills and concepts] *I would usually inquiry-based learning … learners to talk to each other, build on their knowledge and each other's knowledge … we would do the practical planting beans*.

NT 4: *... Actually, I've never taught it* [NS] *… don't know* [process skills and concepts] … *The trunk of the tree, roots, leaves, etc. They touched it* [trees] *physically. We also planting our bean.*

NT 5: *... I was so invested in soil … It was probably one of my best lessons … It* [the lesson] *gathering of all the soil … I am not … familiar with NS process skills*.

NT 6: *... the float and sink experiment and I did the plants … I did not familiarise myself with that* [NS process skills and concepts] *… I just know* [NS] *about experiments … I send two learners to check how's the weather*.

NT 7: *... No, we do not teach science as a subject … not very familiar* [NS process skills and concepts] *… I do enjoy taking them out … to engage practically*.

Overall, the NTs' comments indicate that they were not familiar with the scientific process skills and science concepts that are fundamental to engaging learners in scientific inquiry. These skills develop higher-order thinking skills and problem-solving and include the rubrics observe, compare, classify, measure, experiment and communicate. The science concepts of life and living, energy and change, planet Earth and beyond sum up the scientific knowledge encapsulated in each of them. They are the core foundational concepts for more complex scientific ideas to be introduced in later grades.

Shulman (2004) emphasises the importance of knowledgeable teachers who provide hands-on and minds-on experiences for learners' holistic development. The findings suggest that NTs should increase their CK and PK and widen their pedagogical practices, particularly by effectively using scientific process skills and IBT strategies. A diversity of pedagogical practices and the incorporation of scientific process skills can foster active engagement, social interaction and the exploration of various perspectives, ultimately promoting meaningful learner engagement in FP classes (Johnson & Johnson, 2014; Shulman, 2004; Vygotsky, 1978). The range of pedagogical practices employed by the five participating NTs reflects both strengths and limitations. By addressing the areas in need of improvement, the NTs can better meet the challenges of teaching NS in the FP and create more effective and engaging learning environments for their learners.

Conclusion

With this study we aimed to identify the gaps in the NTs' qualifications, CK and pedagogical strategies, which hindered them from effectively teaching NS in the FP. The results show that qualifications, CK and pedagogical practices collectively influenced NTs' effective teaching of NS.

Despite attending four different HEIs, the seven NTs agreed that inadequate training and limited practical experience contributed to their unpreparedness to teach NS in the FP. Insufficient exposure to the NS curriculum and the lack of a repertoire of effective pedagogical practices that might have been developed in their training compounded the NTs' inability to comprehend the nature of NS and resulted in their not having acquired the necessary competencies to teach NS. According to James et al. (2019), FP teachers' roles are fundamental. They need to possess the knowledge to enable them to teach NS effectively, developing the appropriate NS skills.

This study showed the considerable impact of inadequate CK exposure and comprehension among NTs. The NTs' inability to extract, understand and employ the NS concepts and scientific process skills from CAPS limited their capacity to create NS lessons. The minimum requirements for teacher education qualifications ([MRTEQ] DHET, RSA, 2015:11) emphasises disciplinary learning, CK, as crucial for effective NS teaching. A deficit here impacts the teachers' ability to explain concepts, answer questions, dispel misconceptions and facilitate inquiry. A lack of CK may well result in predominantly teacher-centred lessons which could stifle learner creativity and curiosity (Cofré et al., 2015).

The NTs' comprehension of pedagogical practices, particularly inquiry-based practices, for the effective teaching of NS, was found to be notably deficient. Inadequate facilitation of active learner engagement underscored gaps in the teachers' preparedness and execution and exposed their continued reliance on outdated practices. The deficit has dire implications for the development of critical thinking, problem-solving and 21st-century skills among learners.

Consistent with the research objectives, a compelling necessity for targeted intervention to address the dearth of effective teaching strategies emerged (Baxen & Botha, 2016). These strategies assume a crucial role in fostering stimulating and impactful science education in the FP.

Based on the study findings, the following recommendations are proposed to enhance the development of NTs' teaching of NS. Teacher education programmes should be prioritised to focus on developing NTs' CK expertise and integrating IBT practices. This should be coupled with practical training to develop scientific process skills for improved teaching efficacy. There is an urgent need for policymakers to re-evaluate the NS curriculum. The proposed guidelines should provide explicit instruction to enhance the understanding of NS content and promote explication of the nature of science, scientific process skills, explanations of concepts and scientific attitudes (Baxen & Botha, 2016). Careful guidance can ensure a holistic approach to teaching NS to FP learners. Future research endeavours could include a longitudinal study on the development of a comprehensive, subject-specific professional development programme for FP NS, focusing on the practices of reflection, inquiry and ongoing refinement of expertise (Darling-Hammond, 2017).

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Authors' Contributions

EJF was the original researcher and wrote the manuscript. JC was the supervisor for this study. AC supported the initial process of writing a research paper and CM reviewed the manuscript during the writing process. HNP and JC reviewed the final manuscript for publication.

Declaration of Interest

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Notes

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