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Optimising mathematics teaching practice in an ODeL context: A subject-specific supervisor's perspectives

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ABSTRACT

Many student teachers in Open Distance e-Learning (ODeL) contexts struggle to develop strong teaching competencies, partly because supervision is often not subject-specific. This gap limits the quality of feedback needed to address discipline-related misconceptions. The study, therefore, examined how subject-specific supervision can optimise mathematics teaching practice in an ODeL environment. A qualitative, multiple-case study was conducted with five student teachers, three from Mathematics and two from Natural Sciences & Technology, participating in the Mathematics Specialist-Supervisor Pairing Programme (SSPP). Data were generated through classroom observations, lesson analysis, field notes, and reflective feedback meetings, and were thematically analysed using Pedagogical Content Knowledge (PCK) as the guiding framework. Findings showed that subject-specific supervisors were able to identify and correct key misconceptions, including misuse of brackets, misunderstanding the distributive property, misrepresenting geometric fractions, and interpreting chemical equations arithmetically. Targeted probing, modelling, and immediate feedback helped student teachers refine both content knowledge and pedagogical strategies. The study concludes that subject-specific supervision significantly enhances instructional quality in Mathematics and related STEM subjects within ODeL settings. It recommends institutionalising subject-specialist pairing models to strengthen student teachers' PCK, improve feedback quality, and better prepare graduates for effective classroom practice.

INTRODUCTION

In today's complex educational landscape, the quality of teacher education, particularly in mathematics, plays a crucial role in shaping students' academic achievements and future career prospects. Effective mathematics teaching requires both theoretical understanding and practical application. Auslander and Myers (2022) highlight the growing demand for specialized training in mathematics education to ensure the availability of qualified teachers. Jha and Manushi (2022) emphasize that inadequate teaching competencies and foundational knowledge deficiencies can significantly impact educational quality. Additionally, Etim (2023) links these challenges to broader issues of poverty alleviation and equity, reinforcing their importance in maintaining high academic standards. Addressing these concerns, Ekeh and Ramsaroop (2022) stress the necessity of effective subject-specific supervision in optimizing teaching practices and improving student-teacher performance. At the University of South Africa (UNISA), a hybrid assessment model combines in-person and virtual supervision by internal and external supervisors to tackle various challenges in teacher preparation, though it does not guarantee subject-specialized oversight. Mulaudzi et al. (2023) underscore the advantages of hybrid problem-based learning in technology teacher

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preparation, a method that also holds relevance for mathematics education by integrating subject-specific knowledge with pedagogical skills. However, the absence of consistent subject-specific pairing within this model creates a gap in addressing the unique pedagogical challenges faced by student teachers in mathematics, often resulting in limited actionable feedback and overlooked misconceptions.

Research underscores the significance of subject-specific supervision in developing strong pedagogical skills. Abidin and Maizah (2023) argue that structured supervision enhances the teaching capabilities of student teachers by offering guidance, support, and professional development opportunities. In mathematics education, tailored pedagogical strategies and content knowledge provided by expert supervisors can be particularly beneficial, as noted by Mafa-Theledi (2024), who emphasizes the integration of subject matter knowledge with pedagogical content knowledge for effective instruction. However, UNISA's current supervision model, which lacks subject-specific pairing, poses several challenges, including insufficient, actionable feedback crucial for addressing the complexities of teaching mathematics. Despite extensive research on the importance of subject-specific supervision, there remains a gap in understanding its impact within Open Distance e-Learning (ODeL). This study aims to bridge that gap by examining the role of subject-specific supervision in enhancing mathematics teaching practices in the ODeL context. By exploring how pairing student teachers with expert supervisors can improve instructional skills, this research aspires to contribute to better educational outcomes. Despite the recognition of subject-specific supervision as vital in traditional contexts, little empirical research has examined its role and effectiveness in ODeL settings where supervision is mediated by distance and technological constraints. This gap underlines the need to explore how specialist supervisors can enhance mathematics teaching practice in such environments. The study seeks to answer the question: How can subject-specific supervisors optimize mathematics teaching practices within an ODeL context?

Theoretical framework

This study is underpinned by the Pedagogical Content Knowledge (PCK) framework, originally introduced by Shulman (1986), to examine the impact of subject-specific supervision on the development of pedagogical skills and content knowledge among mathematics student teachers. PCK is crucial for understanding the intersection of content knowledge and pedagogical expertise, which enhances teaching effectiveness, particularly in highly specific subjects like mathematics (Shulman, 1986). PCK combines knowledge of the subject with teaching techniques that make learning effective and accessible. This framework is especially relevant to mathematics education, where both the depth of content knowledge and the quality of its delivery are essential (Zubaidah et al., 2023). The framework includes several key components, of which three have been adapted to align with the objectives of this study while remaining closely linked to the original elements. The three relevant tenets for this study are.

Subject-specific knowledge

This includes a comprehensive understanding of mathematics as a subject—its concepts, procedures, and logical underpinnings. According to Quinio and Cuarto (2023), deep subject knowledge in mathematics is crucial for teaching as it informs the instructor about common pitfalls and students' likely misconceptions.

Pedagogical knowledge (PK)

This pertains to the knowledge and skills related to teaching and learning. In mathematics, pedagogical knowledge (PK) involves presenting mathematical concepts understandably and engagingly, adapting instruction to accommodate different learning styles and abilities. Shulman (1986) highlights that PK distinguishes an expert teacher from a mere content expert. This includes explaining complex ideas, designing effective learning sequences, and critically assessing student understanding of mathematics.

Supervision and feedback

The ongoing mentorship and feedback characterise effective supervision experienced educators provide novices aimed at enhancing their teaching strategies and content delivery.

Robinson and Knight (2019) noted that supervisors with a strong foundation in PCK can give precise, actionable feedback that is instrumental in developing novice teachers' pedagogical responses to student learning needs. Furthermore, the study by Kamruzzaman (2023) highlights the significance of mentorship in teacher development, emphasising the role of expert guidance in fostering effective teaching practices.

Application of PCK to the study

This study specifically examines how supervisors equipped with robust PCK in mathematics influence the pedagogical capabilities of student teachers in South Africa's diverse and challenging ODeL environments. The investigation focuses on evaluating the effects of supervision enriched with Pedagogical Content Knowledge (PCK) on the proficiency of student teachers in presenting mathematical concepts. It employs methods such as classroom observations, evaluations of teaching performance, and feedback discussions to collect insights into the relationship between supervisory practices and teaching effectiveness. Moreover, the study conducts a detailed examination of the teaching results from the student teachers. It qualitatively explores the impact of supervision informed by PCK, emphasising the presence of SSPP versus its absence.

This framework aims to dissect the critical elements of effective mathematics teaching and the role of expert supervision in fostering superior pedagogical outcomes. By rigorously analysing the influence of supervisors' PCK on student teachers, the study hopes to contribute valuable insights into the practices that best support the development of high-quality mathematics instruction. Building on this theoretical foundation, the following literature review evaluates the existing knowledge to offer a broader understanding of how Mathematics teaching practices have been optimised studied in similar contexts.

Literature Review

Optimising mathematics teaching practices in an Open Distance e-learning (ODeL) context, according to Uaiana Prates and Matos (2021), requires an optimal understanding of this educational model's unique challenges and opportunities. The challenges include effective e-learning platform utilisation and emphasising the educator's role in creating tailored materials and fostering interactive and innovative learning experiences to enhance student engagement and assessment. Various studies such as (Livers, 2012; Suwidiyanti, 2020) have evidenced that pairing mathematics student teachers with subject-specific supervisors can significantly enhance instructional skills. The role of subject-specific supervisors is crucial in ensuring quality teaching, particularly in mathematics, where the complexity of the subject matter demands specialized guidance.

Open Distance e-Learning (ODeL) represents a shift from traditional face-to-face education to more flexible and accessible forms of learning, facilitated by digital technology. This shift necessitates a review of supervision approaches to ensure quality teaching and learning outcomes. Supervision in ODeL is multifaceted, involving overseeing instructional practices and providing continuous support and feedback to student teachers. Sethusha (2014) conducted a study at UNISA focusing on the challenges experienced by supervisors in an ODeL environment. She found that the geographical dispersion of students posed a significant challenge, as supervisors had to monitor virtual classrooms, review recorded lessons, and provide feedback through digital communication tools. Sethusha (2014) emphasized the importance of adapting traditional supervision methods to the ODeL context to ensure effective support for student teachers.

Subject-specific supervision refers to pairing student teachers with supervisors with expertise in the subject area being taught. This approach is particularly beneficial in mathematics education, where specialized knowledge is essential for effective teaching. Ngara and Simuforosa (2017) investigated the quality of teaching practice supervision among open-distance students at the Zimbabwe Open University. They found that subject-specific supervisors could provide more targeted feedback and address content-specific challenges more effectively than general supervisors. Their study highlighted the need for supervisors to have in-depth knowledge of the subject matter to offer meaningful guidance and model effective teaching strategies. Additionally, Ekeh and Ramsaroop (2022) highlighted that effective supervision in mathematics is essential for addressing issues such as inadequate resources, overcrowded classrooms, and poor pedagogical content knowledge, which are prevalent in many educational settings. Their research underscores the critical role of subject-specific supervisors in overcoming these challenges and enhancing the quality of mathematics education.

Subject-specific supervisors can offer insights into complex mathematical concepts, suggest effective pedagogical approaches, and identify common student misconceptions. Fatmasari and Suripto (2018) conducted a study at the Indonesian Open University to evaluate the teaching practice program in a distance learning environment. They found that the involvement of subject-specific supervisors was crucial in helping student teachers develop a deeper understanding of the subject matter and improve their teaching techniques. The supervisors' specialized knowledge enabled them to provide constructive feedback and foster a more rigorous professional development experience for student teachers.

Despite the benefits, there are challenges associated with subject-specific supervision in an ODeL context. One major challenge is the geographical dispersion of students and supervisors, making real-time interaction difficult, as observed by Musingafi et al. (2019). Their study also highlighted uneven levels of supervisors and mentors expertise.

Kanapathipillai (2022) explored innovative supervision approaches utilizing platforms like ZOOM for meetings, email for document sharing, and social media for peer support, proving more effective than traditional methods during the COVID-19 pandemic in open education contexts. He found that advancements in digital communication tools had mitigated some challenges and offered more advantages than onsite supervision. Another challenge is the potential lack of immediate feedback due to the nature of asynchronous learning environments, as Canals et al., 2020 found in a study conducted on second language learners and teachers. Jojo (2022) suggested utilizing detailed rubrics and formative assessment techniques to provide timely and specific feedback on student teachers' instructional practices, especially relevant to practice teaching. Establishing regular check-ins and feedback sessions can help maintain a continuous support system for student teachers.

Optimizing mathematics teaching practice in an ODeL context through subject-specific supervision holds significant promise for enhancing instructional skills among student teachers. By leveraging the expertise of subject-specific supervisors, student teachers can receive tailored support that addresses content and pedagogical needs. Despite the challenges inherent in ODeL supervision, innovative approaches and technological tools can help bridge the gaps and ensure effective supervision practices, ultimately leading to improved educational outcomes.

METHODS

This study employed an interpretivist paradigm, aligning with a qualitative research approach to understand and interpret how student teachers conduct their lessons. The interpretivist paradigm was chosen because Sekar and Bhuvaneswari (2024) assert that it allows an in-depth exploration of the participants' experiences and perspectives.

Research design

This study adopted a qualitative multi-case study design, as recommended by Mohamed et al. (2024) for inquiries seeking to understand complex teaching and supervision practices within naturalistic settings. Such a design allowed an in-depth exploration of how subject-specific supervision shapes student teachers' Pedagogical Content Knowledge (PCK), as framed by Shulman (1986).

Participants

Participants consisted of five student teachers purposively selected from a cohort of 46 within the Mathematics Specialist-Supervisor Pairing Programme (SSPP). Purposive sampling was appropriate because, as Tongco (2007) argue, it enables researchers to select individuals who can provide rich, relevant, and information-laden cases. Three participants were studying Intermediate Phase Mathematics, and two were specialising in Natural Sciences and Technology (Grade 9), all of whom displayed initial conceptual or pedagogical difficulties pertinent to PCK development.

Instruments and validation

Data were collected using a lesson observation schedule, a post-lesson feedback guide, field notes, and reflective supervisory memos. These instruments were explicitly aligned with the PCK components proposed by Shulman (1986). To ensure content validity, two mathematics education specialists reviewed the instruments for coherence, alignment, and clarity, following validation procedures recommended by Nurcahyono et al., 2020.

Data collection procedures

Classroom observations formed the primary data source, enabling close examination of instructional sequences, students' responses, and emerging misconceptions, consistent with Nahouli et al. (2023) emphasis on gathering data in real-world contexts. Structured post-lesson feedback discussions supported clarification and elaboration of observed practices. Supplementary artefacts including lesson plans, worksheets, and WhatsApp reflections were collected to provide additional triangulation and contextual grounding.

Trustworthiness of the data

Aquilar Solano (2020) framework guided the establishment of trustworthiness where credibility was enhanced through triangulation of observations, field notes, and reflective discussions. To erify interpretations with participants, researchers conducted member checking during post-lesson feedback sessions. Peer debriefing with fellow SSPP supervisors strengthened interpretive depth, while a maintained audit trail of memos and dated reflections supported dependability and confirmability.

Data analysis

The data were analysed using thematic analysis, selected for its flexibility and capacity to produce rich and complex insights (Fuchs, 2023). Initial themes were guided by the study's theoretical framework subject-specific knowledge, PK, and supervision and feedback while additional themes, particularly misconceptions, were incorporated as they emerged from the data, consistent with Schmidt et al. (2020).

Coding began immediately after each post-supervision session, with the first author identifying potential cases and sharing them with co-researchers via WhatsApp for collaborative discussion. These early codes were refined and classified as either theoretically grounded or emergent, and were subsequently organised into cases that informed the final thematic structure.the development of themes.

The researchers obtained ethical clearance from the university where they are employed, and a clearance certificate was issued with the reference number 2021/11/10/90194969/41/AM. Beckmann (2017) stresses that obtaining ethical clearance from the university signifies that human participants are protected from harm. Confidentiality and anonymity of all participants were strictly upheld throughout the research process, as acclaimed by Nii Laryeafio and Ogbewe (2023) ensuring that any information that could reveal personal and sensitive information was protected.

FINDINGS

The following presentations highlight key misconceptions observed during the supervision of 46 students, as shown in Figure 1. This figure provides essential information on the first five students, including their province, district, and town, while maintaining confidentiality. The findings are organized according to the cases discussed in the methodology section, with summaries of the supervisor's feedback provided for each student. These summaries emphasize areas for improvement and recommend strategies to enhance teaching practices.

Case one: Mathematics student teachers

Student 1

In her lesson, Student 1 was teaching Grade 4 Addition by breaking down numbers. Below is how the student worked out an example:

$$251 + 133 \tag{1}$$
$$= (200 + 50 + 1)(100 + 30 + 3) \tag{2}$$
$$= 200 + 100 + 50 + 30 + 1 + 3 \tag{3}$$
$$= 384 \tag{4}$$

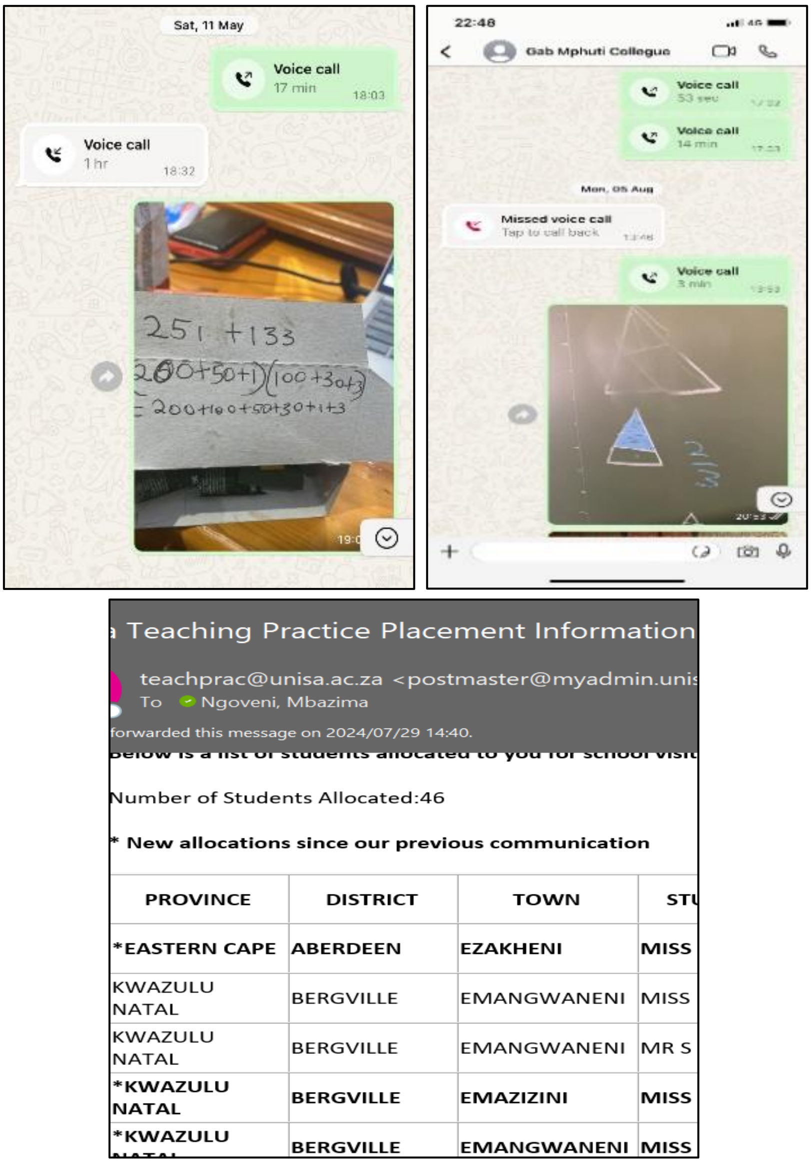

Figure 1. Student Teacher Allocation by Teaching Practice Office

In the first step an incorrect operation used. Instead of adding the numbers 251 and 133, the student wrote the expression to indicate multiplication. The original statement was written as: $251 + 133 = (200 + 50 + 1) \times (100 + 30 + 3)$, which is not $251 + 133$. I put multiplication sign between the two brackets to emphasise that the brackets mean multiplication.

After the lesson presentation, the supervisor probed the student-teacher to find out if the first step, where the student introduced the brackets, was an error or misunderstanding/misconception on the student's side. This happened in the presence of the mentor teacher. The student said that was her understanding *("Sir, I do not see anything wrong with the step")*. The supervisor asked the mentor-teacher if she also agreed that nothing was wrong. The mentor teacher confirmed that there was nothing wrong with the step. She added, "*This is how we teach this, sir*."

The supervisor went on to ask both the student and the mentor teacher if they understood the meaning of the brackets, and both confirmed that they did. It was followed up with the question of what it means. Both confirmed that it means multiplication. The next question was, "*If brackets mean multiplication, what do we get after multiplying the brackets?*" Here, they were allowed to use a calculator, and they confirmed that the answer was 33383. The next discussion was why their answer differs from the one in the calculator. After they insisted that this was how they taught this section and were unsure why the answers differed, the researcher rewrote the step with a plus sign between the brackets and asked them to use their calculators to calculate the answer. They found 384. This is how the researcher convinced the student and mentor teachers that adding an addition between the two brackets is important. The mentor teacher appreciated the explanation and conceded that she had been teaching this concept for many years and did not notice anything wrong. She promised to correct misconceptions among the learners and their fellow teachers.

Summary of supervisor's feedback on teaching strategies

Student 1 primarily relied on a teacher-centred approach, focusing on direct instruction with minimal student interaction. This method limited opportunities for students to actively engage with the content or participate in discussions. To improve this teaching practice, the supervisor emphasised the importance of reinforcing a solid understanding of mathematical operations, particularly the correct use of brackets in addition. Since brackets usually denote multiplication, they must be correctly separated by a plus sign when used in addition to prevent confusion. The supervisor recommended adopting a more interactive approach, such as having students work in pairs to solve similar problems. This strategy promotes active engagement and enables the teacher to identify and correct any misconceptions in real-time. Shifting away from a teacher-centred approach and integrating these interactive techniques will create a more dynamic and effective learning environment, helping students gain a clearer and more accurate understanding of mathematical concepts.

Student 2

The second student taught multiplication by breaking down the terms and treating the expression as follows, where in brackets is the explanation from the student.

215×12	
$= (200 + 10 + 5)(2 \times 2 \times 3)$	(*Breaking down the numbers*)
$= (400 + 20 + 10)(2 \times 3)$	(*Using the first 2 in the second bracket to multiply the first bracket*)
$= 1200 + 60 + 30$	(*We cannot use 2 in the second bracket to multiply the first bracket because we used it already. We must, therefore, ignore the 2 and use 3 to multiply the first bracket). [The student said so while deleting the second 2*].
$= 1290$	(*Adding the three numbers together*)

The student correctly wrote 215 as $200 + 10 + 5$ in the first bracket and 12 as $2 \times 2 \times 3$. The student multiplied 2 in the second bracket with what is in the first bracket to obtain $(400 + 20 + 10)(2 \times 3)$. The problem was when the student moved to the next step, where she said, "Because we have multiplied the first bracket with 2 already, we cannot repeat multiplying the first bracket by another 2, meaning we must ignore the second 2 and proceed to multiply 3 by the first bracket to get $1200 + 60 + 30$." Adding the three numbers results in 1290.

During the post-supervision, the researcher engaged the student to understand the rationale for ignoring the second 2 when multiplying, and the student maintained that we cannot repeat it because we used it already. The researcher drove the student to use a calculator to verify if the answer was 1290. The student found the answer from the calculator to be 2580. Together with the researcher, they recalculated the same problem by including the 2 that were ignored, only to find that the answer was the same as the one from the calculator.

Summary of supervisor's feedback on teaching strategies

Student 2 primarily used a teacher-centred approach, focusing more on delivering content than engaging students in the learning process, which limited opportunities for student interaction. The supervisor recommended shifting to a more learner-centred strategy by incorporating techniques like think-pair-share, where students first consider a problem individually and then discuss it with a partner before sharing it with the larger group. This approach encourages students to articulate their understanding and learn collaboratively. Additionally, using visual aids or manipulatives was suggested to make abstract concepts more tangible and engaging for learners.

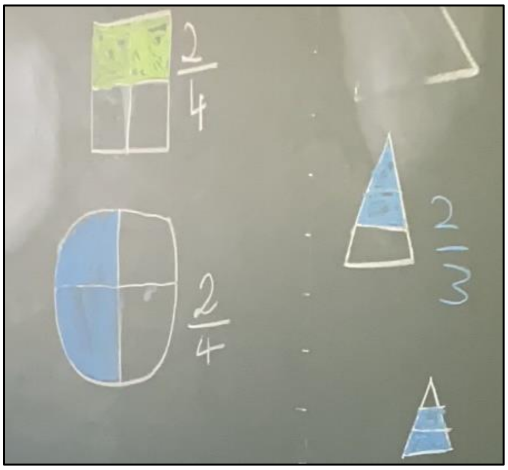

Figure 2. Division of a triangle

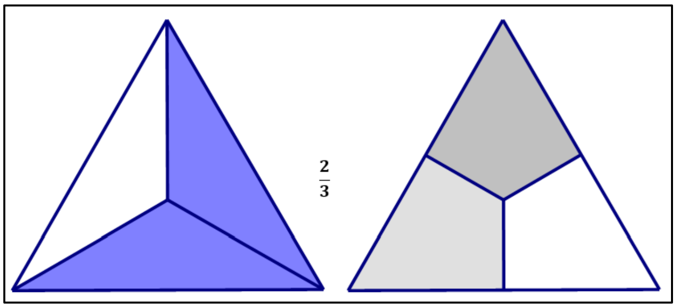

Figure 3. The triangle divided into three equal parts

To further enhance the teaching of the distributive property, it is essential to revisit and solidify your understanding of this concept. Practice applying the distributive property in various contexts to build confidence. Moving away from a lecture-based format, integrating visual aids and hands-on activities can make abstract mathematical concepts more concrete, helping students better grasp and retain the material. This shift to a more interactive and engaging teaching style will foster a deeper understanding and active participation among students.

Student 3

Student 3 taught Grade 3 mathematics under the topic as "Fractions - Share and group things equally." In this lesson, she taught the division of various geometric shapes such as circles, squares, triangles, etc. Even though the shapes were not drawn accurately, the student successfully illustrated how to divide a circle, square, and other figures. The challenge in this regard was when the student was supposed to divide a triangle into three equal parts, as illustrated in Figure 2.

According to the student, the two triangles illustrated on the right-hand side illustrate the division of a triangle into three equal parts, where the colouring indicates the fraction $\frac{2}{3}$. This misconception is passed on to the learners, as it can also be seen in the learners' workbooks. However, since the supervisor in this scenario was a mathematics specialist, he was able to probe the student teacher to understand if this was indeed a misunderstanding, during the post-supervision session. The student confirmed this misconception. Figure 3 shows the triangle that is divided into three equal parts.

Following the supervisory session, the supervisor clarified to the student that in such instances, it is recommended to utilize an equilateral triangle. The student should identify the triangle's centre and subsequently draw lines from the centre to the corners or to the midpoints of the sides in order to divide it into three equal parts.

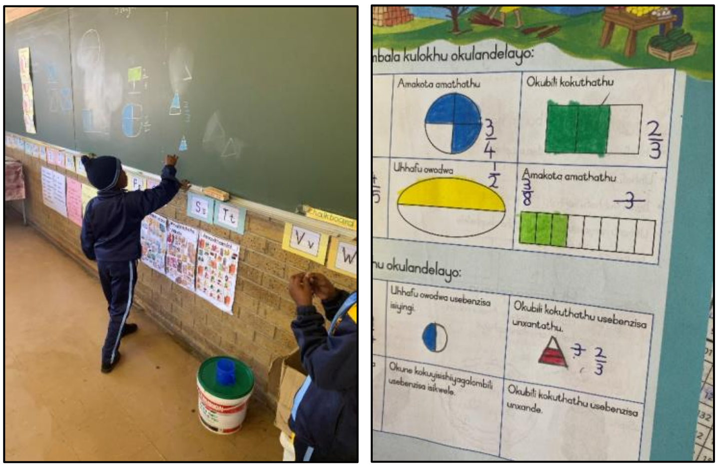

Figure 4. Learners' activities

Summary of supervisor's feedback on teaching strategies

Student 3's lesson revealed a common misconception in the geometric division of triangles, particularly in accurately dividing them into equal parts. However, the student effectively employed a learner-centred teaching strategy, utilizing charts and encouraging students to work individually, in pairs, and present their answers on the board, which promoted active participation. This was clearly reflected in the learners' workbooks. To enhance this approach further, the supervisor advised focusing on the precise use of geometric tools and techniques, such as drawing lines from the centre to the vertices to ensure correct division. In addition, to deepen engagement, assigning different roles during group activities, like scribe, presenter, or discussion leader, was recommended to rotate these roles to ensure active participation from all students. This strategy will reinforce understanding through peer teaching and promote a more comprehensive grasp of geometric concepts. Moreover, incorporating models when teaching could significantly enhance students' understanding of fractions and related concepts. Figure 4 represent the involvement of learners by Student 3 and one learner's workbook indicating that learners actively participated in the lesson.

Case Two: Natural sciences and technology (Students 4 and 5)

Student 4 and Student 5 were grouped because their misconceptions were closely related. These students chose to teach "balancing equations" in their lessons, a Natural Sciences and Technology section, both of them in Grade 9. Even though this topic does not fall under mathematics, it applies the knowledge of mathematics. We believe the errors discovered in these lessons are directly linked to the phenomena under investigation and helped strengthen our argument.

According to Student 4, two hydrogen atoms react with one oxygen atom to form water, as represented in Figure 5. Our focus in this regard is on the students' belief that H_2O results from adding one oxygen atom and two hydrogen atoms, as seen in Figure 4, which will become more evident with Student 5. The student understands $H + H = H_2$; hence, we have H_2O after the chemical reaction, this misunderstanding was confirmed by the student in the post-supervision discussion. The researcher engaged the student in understanding that the chemical reaction should not be confused with addition in mathematics. Moreover, $H + H = 2H$, not H_2, as the student explained it to the students.

The researcher involved in this supervision is a mathematics specialist and could not thoroughly explain the chemical reaction to the student. However, the researcher sought the intervention of a Physical Science teacher, who was also a mathematics teacher, in the absence of the mentor teacher on the day. The Physical Science teacher clarified this chemical reaction and confirmed that it should not be confused with adding terms in mathematics. The in-service teacher explained that there is confusion among students and some teachers who do not fully understand the distinction between atoms and molecules. In its most stable form, oxygen is diatomic (O_2), meaning it exists as a molecule consisting of two oxygen atoms. Hydrogen also exists as a diatomic molecule (H_2). The Physical Science teacher explained further about the chemical reaction and the balancing

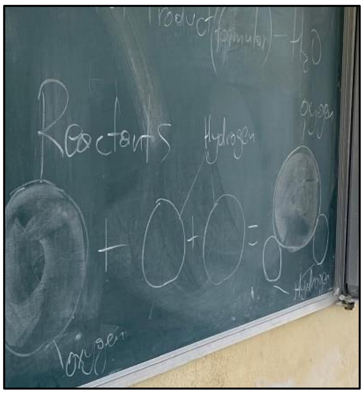

Figure 5. Student 4's representation of reactants and products in a chemical reaction

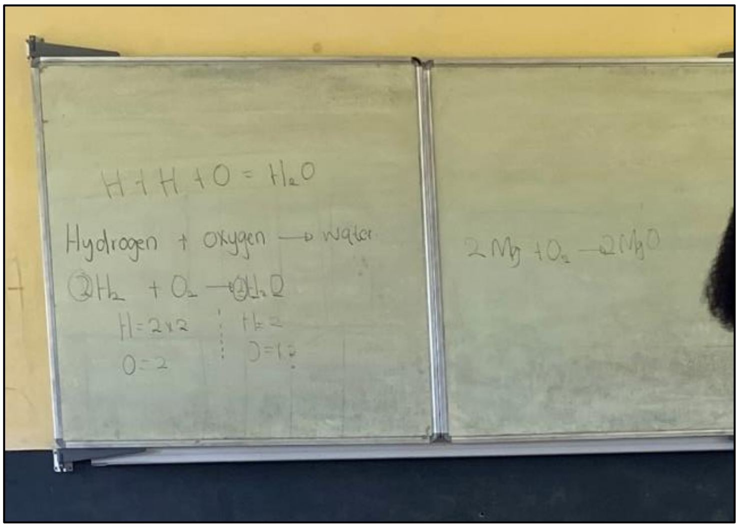

Figure 6. Student 5's representation of reactants and products in a chemical reaction

of the equations to the student teacher and the supervisor. Figure 6 depicts how Student 5 presented her understanding of the chemical reaction, which is equivalent to the one committed by Student 4.

Student 5 repeated the error that was committed by Student 4 (see Figure 5). This time, clearly confirming the misconception that Student 4 had as displayed in Figure 6: $H + H + O = H_2O$. After the lesson, the researcher probed the student to verify if the misconception was the same as that of Student 4. It was discovered that the student believed that adding H and H results in H_2, as we see on the right-hand side of the equation. Empowered by the previous supervision of Student 4 and the explanation from the Physical Science teacher, the researcher managed to clarify to the student that in the equation $H_2 + O_2 \rightarrow H_2O$, one molecule of hydrogen gas (H_2) reacts with one molecule of oxygen gas (O_2) to form one molecule of water (H_2O).

Summary of supervisor's feedback on teaching strategies

Even though Student 4 & 5 displayed similar misconceptions, especially when it comes to the interpretation of the chemical reaction, their teaching approaches were completely different.

Figure 7. Student illustration of the balancing scale

Student 4

Student 4, like Students 1 and 2, primarily relied on a teacher-centred approach with limited student interaction, delivering the lesson with minimal input from the learners. This method significantly reduced opportunities for active engagement, as the student teacher did not ask any questions to involve the learners during the presentation. The supervisor advised that to enhance understanding, particularly in concepts like balancing equations, Student 4 could have posed open-ended questions and encouraged group work. This strategy would have allowed students to hypothesize answers before discussing them as a class, fostering critical thinking and collaboration.

Additionally, the lesson presented a fundamental misunderstanding of chemical reactions, equating them with mathematical addition. To improve, it is crucial for Student 4 to strengthen his understanding of chemical reactions and how they differ from mathematical operations. Collaborating with science educators or mentor teacher could provide valuable insights and help clarify these concepts. Furthermore, shifting towards a more interactive teaching style, incorporating open-ended questions and group discussions, would significantly enhance student engagement and deepen their understanding of the material. By adopting these strategies, Student 4 can create a more dynamic and effective learning environment that promotes critical thinking and active participation.

Student 5

Student 5 demonstrated strong engagement with her students through a well-executed mix of interactive activities and discussions. She began the lesson by probing the learners' understanding of balancing, using a balancing scale in small groups to illustrate the concept. Student 5 effectively maintained student involvement throughout the lesson by posing questions for individual answers or group discussions and encouraging learners to balance equations in their workbooks.

The supervisor praised this interactive approach but advised further enhancement by introducing more challenging questions to push students' critical thinking and deepen their understanding of chemical equations. To improve further, it is recommended that Student 5 consult with science educators to solidify her understanding of chemical equations, ensuring that the concepts are taught accurately. By continuing to use interactive strategies and incorporating more complex problems, Student 5 can ensure that her students engage with the material and apply the concepts correctly in various contexts, leading to a more effective and comprehensive learning experience.

In Figure 7, the student teacher demonstrated the concept of a balanced equation using a balancing scale to the learners. By employing this model, the student teacher illustrates the fundamental principle that for an equation to be balanced, both sides must be equal in value, similar to how the arms of a scale remain level when the weights on either side are equivalent. This demonstration serves as an intuitive and concrete method to convey the abstract idea of balance in equations, helping to reinforce the mathematical concept that any operation performed on one side must be mirrored on the other to maintain equality. Through this hands-on approach, the student teacher effectively supports learners' understanding of balancing equations by symbolically linking mathematical expressions to physical balance, thereby making the concept more accessible and meaningful. The findings presented in this section are interpreted in the next section by integrating them with the reviewed literature and theoretical framework underpinning this study.

Summary of similarities and differences across the case studies

Across the five cases, both Mathematics and Natural Sciences & Technology student teachers demonstrated conceptual and pedagogical gaps that affected the clarity and accuracy of their instruction. A key similarity was that all participants exhibited discipline-specific misconceptions—for example, the misuse of brackets, incorrect application of the distributive property, and misunderstanding of fractional geometry in Mathematics, as well as interpreting chemical equations arithmetically in Natural Sciences. These misconceptions indicated limitations in subject-specific knowledge, a central component of PCK. Another similarity was that all student teachers showed improvement when provided with probing questions, modelling, and targeted subject-specific feedback. This promotess the value of specialist supervision in correcting misconceptions and strengthening pedagogical reasoning.

Differences emerged in the nature of the conceptual errors. Mathematics students tended to struggle with operational and representational concepts (brackets, fractions, geometric interpretation), whereas Natural Sciences students' challenges centred on conceptual translation, such as distinguishing symbolic representations in chemical equations from arithmetic operations. Additionally, Mathematics student teachers appeared more dependent on procedural steps, while Natural Sciences students struggled more with the conceptual underpinnings of scientific symbols.

Cross-case analysis

These patterns suggest that misconceptions are prevalent across subjects but manifest differently depending on the disciplinary context. Mathematics errors were largely procedural or representational, while Natural Sciences errors were conceptual and symbolic. Despite these differences, the consistent positive response to subject-specific supervisory interventions across all cases reinforces the conclusion that specialist supervisors are better positioned to identify, interpret, and remediate discipline-related misconceptions. Overall, the cross-case analysis highlights that while the subjects differ in content demands, subject-specific supervision enhances both content knowledge and pedagogical competence across STEM domains supporting the effectiveness of the SSPP model in ODeL environments.

DISCUSSION

This discussion integrates the Pedagogical Content Knowledge (PCK) framework with emergent themes identified from the data, offering a significant analysis of the misconceptions observed in student teachers' mathematics and science instruction. The focus is on how the Specialist-Supervisor Pairing Program (SSPP) intervention has influenced teaching effectiveness within an Open Distance e-Learning (ODeL) environment.

Mathematical misconceptions

The study revealed critical misunderstandings in fundamental mathematical operations among student teachers, particularly concerning the misuse of brackets and the distributive property. Student 1's incorrect application of brackets as symbols for addition mirrors the findings of Das (2020), who emphasizes that such errors can lead to significant computational mistakes and hinder students' progression to more complex mathematical concepts. The SSPP intervention provided corrective feedback that not only addressed the immediate errors but also contributed to a deeper understanding of mathematical notation, a foundational element crucial for students' future success in algebra and arithmetic.

In a similar vein, Student 2's misapplication of the distributive property underscores the importance of multiplicative thinking in mathematics education, as argued by Hurst and Huntley (2020). They contend that a conceptual understanding of multiplication is vital for students to grasp the interconnected nature of mathematical operations. The intervention's focus on reinforcing these concepts through targeted instruction demonstrates the effectiveness of specialized supervision in mitigating such widespread misconceptions.

Geometric misconceptions

Student 3's lesson on dividing triangles into equal parts revealed what Maurice-Ventouris et al. (2021) identify as a common visuospatial misunderstanding. The student incorrectly divided the triangle, failing to apply accurate geometric principles. Using diagrams, while powerful for visualising geometric concepts, according to Saracco (2023) can lead to errors if not properly understood and applied. The supervisor's feedback emphasised the importance of accurate geometric tool usage, such as drawing lines from the triangle's centre to its vertices, to ensure correct division.

Case analysis: misconceptions in natural sciences and technology

Scientific misconceptions

Students 4 and 5 demonstrated significant misconceptions about the interpretation of chemical reactions, conflating them with mathematical operations. This issue, where chemical equations were misinterpreted as algebraic equations, is consistent with findings by Hamerská et al. (2024), who noted that students often confuse the plus sign in chemical equations with its mathematical equivalent. This misunderstanding can lead to a fundamental misrepresentation of chemical bonding and reactions, as theorised by Febriana Sari and Agustini (2024) thereby severely limiting students' ability to engage meaningfully with scientific concepts.

In the case of Student 4, the misconception was compounded by a teacher-centred approach that offered little opportunity for student interaction or clarification. The SSPP intervention addressed this by recommending a shift towards a more interactive teaching style, incorporating open-ended questions and group discussions. This strategy aligns with the recommendations of Lumpkin (2022), who emphasise the importance of student engagement and the use of formative assessment techniques to correct misunderstandings in real-time.

Student 5, although exhibiting a similar misunderstanding, effectively engaged students through interactive activities and discussions. However, the SSPP intervention identified the need for deeper content knowledge and more challenging problems to further push students' critical thinking. The integration of science educators in the intervention process as confirmed by Potvin et al. (2024) also underscores the importance of interdisciplinary collaboration in correcting scientific misconceptions.

Application of the PCK framework with SSPP intervention

Subject-specific knowledge

The observed misconceptions across both mathematics and science instruction highlight the critical need for robust subject-specific knowledge. Research by Quinio and Cuarto (2023) has consistently shown that deep content knowledge is essential for identifying and correcting instructional errors. The SSPP intervention demonstrated that subject-specific supervision, rooted in content expertise, is crucial for improving instructional quality and ensuring that student teachers are well-prepared to convey accurate and comprehensive content knowledge to their students.

Pedagogical knowledge

The intervention also underscored the importance of integrating effective pedagogical strategies with content knowledge, particularly in an ODeL context. Shulman (1986) posited that the ability to convey complex ideas clearly is a hallmark of expert teaching, a notion supported by Leach et al. (2024), who emphasised the role of targeted interventions such as metacognitive teaching in addressing specific student misunderstandings. The SSPP's approach, which included guided questioning, the use of visual aids, and collaborative learning activities, demonstrated how tailored pedagogical interventions can effectively address and correct misconceptions in both mathematics and science instruction.

Supervision and feedback

The role of feedback in the SSPP intervention was pivotal in enhancing the instructional practices of student teachers. Robinson and Knight (2019) assert that precise and actionable feedback is critical for developing novice teachers. The feedback provided during post-supervision sessions in this study was instrumental in helping student teachers recognise and rectify their misconceptions, thereby enhancing their overall teaching effectiveness. This process aligns with Ackerman and Horn's (2021) findings on the impact of high-quality feedback on learning outcomes, further reinforcing the value of specialised supervision in teacher education.

Study's contribution

This study contributes to the importance of subject-specific supervision in enhancing the instructional skills of student teachers in an ODeL context. It provides empirical evidence supporting the implementation of the SSPP to address pedagogical challenges and improve teaching effectiveness. Furthermore, it offers practical insights into the development and application of targeted feedback and interdisciplinary teaching approaches, underscoring the critical role of expert supervision in the professional growth of student teachers. This study also revealed various misconceptions held by students, not only in mathematics but also in Natural Sciences and Technology.

Study limitations

This study did not comprehensively account for contextual factors such as institutional culture, school environment, and teacher support, which could influence the effectiveness of the SSPP. The reliance on a small purposive sample restricts the generalisability of the findings, and the absence of quantitative performance data limits the ability to evaluate the direct impact of supervision on student achievement. In addition, the positionality of the lead researcher as both observer and evaluator may have introduced bias. While subject-specific supervision was shown to address critical misconceptions, the findings should be interpreted within these constraints and situated alongside broader systemic considerations.

CONCLUSION

In conclusion, the study demonstrates that subject-specific supervision plays a pivotal role in strengthening student teachers' Pedagogical Content Knowledge (PCK) in an ODeL environment. By enabling supervisors to identify and address discipline-specific misconceptions, the Mathematics Specialist-Supervisor Pairing Programme (SSPP) contributed to clearer explanations, improved lesson structure, and more accurate conceptual representations across both Mathematics and Natural Sciences. These findings highlight the need for ODeL institutions to institutionalise subject-specific supervision models, ensuring that student teachers consistently receive expert feedback aligned to the demands of their subject. The results suggest the importance of ongoing professional development for supervisors, particularly in deepening their PCK and understanding of common learner misconceptions. Schools and mentoring teachers are also encouraged to collaborate more actively with specialist supervisors, reinforcing feedback and modelling sound pedagogy during teaching practice. This study points to the value of strengthening reflective practices, encouraging student teachers to engage deeply with feedback and use reflection as a tool for correcting misconceptions and improving instructional decisions. Collectively, these recommendations support more effective teaching practice and better preparation of future educators within ODeL contexts.

Recommendations for future research

Future studies should expand the sample to include student teachers across multiple regions and ODeL institutions, thereby increasing generalisability and testing the applicability of SSPP in varied contexts. Mixed-methods designs could be used to combine qualitative supervisory insights with quantitative student performance data, offering stronger evidence of impact. Longitudinal studies could also track the sustained influence of subject-specific supervision on student teachers' classroom practices once they enter the profession. Finally, research could explore cost-effective models of implementing subject-specific supervision at scale, such as leveraging digital platforms for remote specialist input while maintaining the depth of feedback observed in this study.

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