

DOI: <https://doi.org/10.5281/zenodo.20062127>

## FROM INTERNATIONAL PROFESSIONAL DEVELOPMENT TO CLASSROOM PRACTICE: TEACHERS' REFLECTIONS ON IMPLEMENTING THE 5E INSTRUCTIONAL MODEL IN SCIENCE TEACHING

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### ABSTRACT

Developing science teachers' pedagogical knowledge for effective teaching remains a central goal of teacher education. This study explores in-service science teachers' reflections on implementing 5E Instructional Model following the researcher's exposure to the approach through the Third Country Training Programme (TCTP) held in Malaysia and supported by the Japan International Cooperation Agency (JICA). After participating in the programme, the model was introduced to in-service teachers enrolled in a Science Education Honours programme in a rural university in South Africa. Teachers were required to design and implement lessons using the 5E model and reflect on their experiences. Guided by the framework of Topic-Specific Pedagogical Content Knowledge (TSPCK), the study analysed how teachers' reflections revealed aspects of pedagogical reasoning related to teaching specific science topics. Data was collected through reports and analysed using thematic analysis. Findings indicate that implementing 5E model supported teachers in developing several components of TSPCK particularly in recognising learners' prior knowledge, selecting appropriate representations and adopting conceptual teaching strategies that promote inquiry-based learning. However, challenges such as time constraints, limited resources and curriculum coverage pressures constrained full implementation. The study highlights how reflective practice combined with inquiry-based instructional models can support the development of topic-specific pedagogical knowledge among science teachers. Implications are discussed for science teacher education and professional development programmes seeking to strengthen inquiry-based teaching practices.

**Keywords:** 5E Instructional Model; Inquiry-Based Science Education; Reflective Practice in Science Teaching; Science Teacher Professional Development; Topic-Specific Pedagogical Content Knowledge

### 1. INTRODUCTION

Improving the quality of science teaching remains a central concern in science education globally. Across many education systems, there is increasing recognition that meaningful science learning depends not only on the curriculum but also on teachers' capacity to present scientific ideas in ways that promote conceptual understanding, inquiry and critical thinking. Contemporary science education reforms emphasise learner-centred pedagogies that encourage investigation, reasoning and engagement with real-world scientific problems. However, achieving these goals requires teachers to possess sophisticated forms of professional knowledge that enable them to translate abstract scientific concepts into forms that learners can understand and apply. As a result, strengthening teachers' pedagogical

knowledge has become a key priority in science teacher education and professional development (Darling-Hammond et al., 2020; Opfer & Pedder, 2011). Effective science teaching requires teachers to possess not only strong subject matter knowledge but also the pedagogical knowledge needed to transform scientific concepts into accessible learning experiences. This specialized knowledge was conceptualised by Lee Shulman as Pedagogical Content Knowledge (PCK). PCK refers to the blending of subject matter knowledge and pedagogy that enables teachers to represent subject content in ways that make it understandable to learners (Shulman, 1986; 1987). It involves understanding what makes specific concepts easy or difficult for learners, selecting appropriate teaching strategies, and using representations such as analogies, models, and demonstrations to support learning. Over the past three decades, PCK has become one of the most influential frameworks in teacher education research, particularly in science education where conceptual understanding is central to effective teaching (Gess-Newsome, 2015; Kind, 2019).

Building on Shulman's foundational work, science education researchers have argued that pedagogical knowledge must also be topic-specific, because the challenges involved in teaching different scientific concepts vary considerably. For example, teaching abstract topics such as reaction rates, electricity, or waves requires different teaching strategies than teaching observable phenomena such as motion or ecosystems. In response to this need, Edwin Mavhunga and Marissa Rollnick developed the Topic-Specific Pedagogical Content Knowledge (TSPCK) framework. TSPCK focuses on the knowledge teachers require to teach particular science topics effectively and emphasises the pedagogical reasoning involved in transforming disciplinary knowledge into teachable forms (Mavhunga & Rollnick, 2013).

The TSPCK framework identifies five key components that influence effective science teaching. These include teachers' understanding of learners' prior knowledge, awareness of curricular saliency (knowing which concepts are most important within a topic), knowledge of what makes a topic difficult to teach or learn, the use of appropriate representations, and the selection of conceptual teaching strategies that support meaningful understanding. These components work together to guide teachers' pedagogical decisions when planning and implementing lessons. Research has shown that when teachers develop stronger topic-specific pedagogical knowledge, they are better able to anticipate learners' misconceptions, design effective explanations, and promote deeper conceptual understanding in science classrooms (Kind, 2019; Rollnick & Mavhunga, 2014).

Developing such specialized pedagogical knowledge is not a simple process. Teachers often require sustained opportunities to reflect on their teaching practices, experiment with new teaching approaches, and engage with professional learning communities. Consequently, professional development programmes play an important role in supporting teachers to strengthen their pedagogical knowledge and teaching practices. Effective professional development initiatives typically emphasise active learning, collaboration, reflection, and opportunities to connect theory with classroom practice (Darling-Hammond et al., 2020; Desimone & Garet, 2015). Research on science teacher professional development indicates that professional development programmes which emphasise inquiry-based teaching practices can enhance teachers' pedagogical knowledge and teaching practices and are associated with improved learner engagement and learning opportunities (Ramnarain et al., 2022; Tsaliki et al., 2024). For example, long-term professional development designed to familiarize science

teachers with inquiry approaches has been shown to positively influence teachers' views and classroom practices related to inquiry teaching well after participation in the programme, suggesting sustained gains in pedagogical understanding and teaching innovation (Tsaliki et al., 2024). Furthermore, syntheses of teacher professional development literature highlight that programmes which integrate inquiry-focused content, active learning, and reflective practice contribute to both teachers' professional competence and improvements in learners' learning outcomes (Darling-Hammond et al., 2017; Ventista & Brown, 2023).

International training initiatives provide particularly valuable opportunities for teachers to engage in innovative teaching approaches and share experiences across different educational contexts. Such programmes expose teachers to diverse pedagogical practices, encourage cross-cultural collaboration, and foster professional networks that can support ongoing learning. One example is the Third Country Training Programme (TCTP) hosted in Malaysia and supported by the Japan International Cooperation Agency. The programme brings together educators from different African countries to participate in capacity-building workshops focused on curriculum development and innovative teaching strategies in science and mathematics education reform. As the Third Country Training Programme (TCTP) ended, participants had the exciting opportunity to put their learning into practice at a local school in Malaysia. They designed and delivered a lesson on pulleys in real classroom settings, bringing theory to life, as shown in Figure 1.



**Figure 1: Application of the 5E instructional model in a science classroom in Malaysia**

After teaching, participants engaged in thoughtful reflection on their experiences, discussing insights gained and strategizing how to share and implement these new skills and knowledge in their own countries.

A central pedagogical approach introduced during the programme was the 5E Instructional Model, which structures science learning into five phases: Engage, Explore, Explain, Elaborate, and Evaluate. The model is grounded in constructivist learning theory and emphasises the active role of learners in constructing knowledge through inquiry and investigation. During the Engage phase, teachers stimulate learners' interest and activate prior knowledge. The Explore phase provides opportunities for learners to investigate

phenomena and develop tentative explanations. In the Explain phase, learners articulate their ideas while teachers introduce scientific concepts and clarify misunderstandings. The Elaborate phase allows learners to apply and extend their understanding to new contexts, while the Evaluate phase focuses on assessing learners' conceptual development. Research has shown that the 5E model can support deeper conceptual learning, promote learner engagement, and facilitate inquiry-based science teaching (Bybee, 2015; Duran et al., 2014). Following participation in the programme, the model was introduced to in-service science teachers enrolled in a Science Education programme at a rural university in South Africa. The teachers, many of whom work in rural and under-resourced schools in the Eastern Cape province of South Africa, were required to design and implement lessons using the 5E instructional model. As part of the course requirements, teachers reflected on their experiences of applying the model in their classrooms, including the opportunities and challenges they encountered during implementation. Reflective practice is widely recognised as a powerful tool for professional learning because it encourages teachers to critically analyse their teaching decisions and consider how their practices influence learner understanding (Loughran, 2019; Schön, 1987).

Within science teacher education, analyzing teachers' reflections can provide valuable insights into how teachers develop pedagogical reasoning and adapt teaching strategies to specific classroom contexts. Reflective accounts allow researchers to examine how teachers interpret learners' responses, address misconceptions, and select representations that support conceptual understanding. When examined through a topic-specific pedagogical lens, such reflections can reveal how teachers integrate pedagogical strategies with disciplinary knowledge when teaching particular science topics. Against this background, the present study examines how in-service science teachers reflected on implementing the 5E instructional model in their classrooms following participation in an international professional development programme. By analyzing teachers' reflections through the lens of Topic-Specific Pedagogical Content Knowledge (TSPCK), the study seeks to explore how inquiry-based teaching approaches can support the development of science teachers' pedagogical reasoning. Specifically, the study investigates how teachers' reflections reveal aspects of TSPCK, including their consideration of learners' prior knowledge, the selection of appropriate representations, and the use of conceptual teaching strategies to support inquiry-based learning.

Through this analysis, the study contributes to ongoing discussions about how professional development initiatives and reflective practice can strengthen science teachers' pedagogical knowledge and promote more effective inquiry-based teaching practices in science classrooms. The findings may also provide insights into science teacher education programmes seeking to support teachers in developing the specialized pedagogical knowledge required for teaching complex scientific concepts. Specifically, the study seeks to answer the following research questions:

1. How do teachers perceive the implementation of the 5E instructional model in their science teaching?
2. What benefits do teachers observe when using the model?
3. What challenges do teachers encounter during implementation?

Understanding teachers' experiences is important for informing teacher education programmes and supporting the effective implementation of inquiry-based science teaching.

## Contribution to the Field

International professional development programmes are increasingly promoted as mechanisms for improving science teaching practices, yet limited research examines how teachers translate these experiences into classroom pedagogical knowledge. This study contributes to science teacher education research by examining how the implementation of the 5E Instructional Model supports the development of Topic-Specific Pedagogical Content Knowledge (TSPCK) among in-service science teachers. By analyzing teachers' reflective accounts following participation in the Third Country Training Programme (TCTP) supported by the Japan International Cooperation Agency (JICA), the study demonstrates how inquiry-based instructional models can foster pedagogical reasoning related to learners' prior knowledge, conceptual teaching strategies, and the use of representations. The study further contributes to the literature by illustrating how reflective practice can serve as a mechanism for strengthening teachers' topic-specific pedagogical knowledge in real classroom contexts. These insights are particularly relevant for teacher education programmes seeking to support the implementation of inquiry-based science teaching in diverse educational settings.

## 2. LITERATURE REVIEW

Enhancing the quality of science teaching is still a major problem in science education around the world because good teaching necessitates both pedagogical expertise and solid topic understanding to translate scientific ideas into forms that learners can understand (Shulman, 1987; Mavhunga & Rollnick, 2013). In this regard, Topic-Specific Pedagogical Content Knowledge (TSPCK) provides a framework for understanding how teachers translate subject matter knowledge into teachable forms, considering learners' prior knowledge, conceptual difficulties, representations, teaching strategies and curricular relevance (Gess-Newsome, 2015). Developing TSPCK is crucial for enabling teachers to design lessons that facilitate conceptual understanding rather than rote memorization particularly in inquiry-based teaching contexts.

Inquiry-based teaching has been recognised as a powerful approach to developing both learners' understanding and teachers' pedagogical reasoning (National Research Council, 2012). Among the various inquiry-based models, the 5E instructional model comprising the Engage, Explore, Explain, Elaborate and Evaluate phases have been widely implemented in science education to promote active learning and conceptual understanding (Bybee et al., 2006). Several studies have demonstrated that the 5E model not only improves learners' conceptual understanding but also fosters teachers' reflective practice and pedagogical growth. For instance, Fensham (2008) argues that inquiry-based approaches encourage teachers to critically examine their teaching strategies, assess the effectiveness of representations and consider learners' difficulties when planning lessons. Similarly, Akinbobola and Bada (2018) found that in-service science teachers who implemented the 5E model reported increased awareness of learners' prior knowledge, improved selection of representations and more deliberate attention to difficult concepts. These findings align closely with the components of TSPCK, illustrating how structured instructional frameworks

can enhance teachers' capacity to transform content knowledge into effective teaching practice. The integration of representations in teaching is particularly significant in supporting TSPCK development. Visual and concrete representations such as diagrams, models and demonstrations help learners make abstract concepts tangible and support teachers in clarifying complex ideas (Mavhunga & Rollnick, 2013). Research indicates that when teachers actively reflect on how learners interpret these representations, they refine both their teaching strategies and their understanding of common conceptual difficulties (Tekkaya et al., 2001). The selection of appropriate representations is therefore both a practical and reflective process, linking directly to teachers' pedagogical reasoning.

Reflective practice is another key mechanism through which teachers develop TSPCK. Schön (1983) conceptualizes reflection as a process in which professionals analyse their actions and decisions to improve practice. In science education, reflective journals, classroom observations and post lesson discussion have shown to enhance teachers' awareness of learners' misconceptions, the effectiveness of their representations and the suitability of teaching strategies (Bybee et al., 2006; Hewson, 2007; Mayana, 2024).

Despite the benefits of inquiry-based models such as 5E, teachers often face challenges in implementation, including time constraints, limited resources, and pressures to cover the curriculum (Abd-El-Khalick & Lederman, 2000). These challenges can affect the extent to which teachers are able to engage with all five phases of the model and to fully integrate TSPCK components into their teaching. Research underscores the importance of institutional support and professional development programmes that provide opportunities for teachers to experiment with innovative teaching approaches in authentic classroom contexts (Van Driel & Berry, 2012). Such support enhances both teachers' confidence and their ability to align pedagogy with curriculum goals while addressing learners' prior knowledge and conceptual difficulties.

In the South African context, studies have highlighted the need for targeted professional development to strengthen teachers' pedagogical content knowledge, particularly in science education where learners often struggle with abstract concepts (Mavhunga, 2012; Rollnick & Mavhunga, 2015). The 5E instructional model offers a structured and systematic approach for teachers to engage learners actively, address misconceptions, and reflect on their instructional decisions, thereby supporting the development of TSPCK. By linking inquiry-based strategies with reflective practice, teachers can iteratively refine their teaching approaches, improving both learner outcomes and their own pedagogical expertise.

### 3. THEORETICAL FRAMEWORK

This study is grounded in the theoretical perspective of Topic-Specific Pedagogical Content Knowledge (TSPCK), which is derived from the broader concept of Pedagogical Content Knowledge proposed by Lee Shulman. Shulman introduced the concept of pedagogical content knowledge to explain the specialized knowledge teachers require to transform subject matter into forms that are understandable to learners (Shulman, 1986). According to Shulman, effective teaching requires more than mastery of subject content or general pedagogical strategies; it requires the integration of both forms of knowledge to support meaningful learning. Within science education, this theoretical perspective has been further developed to

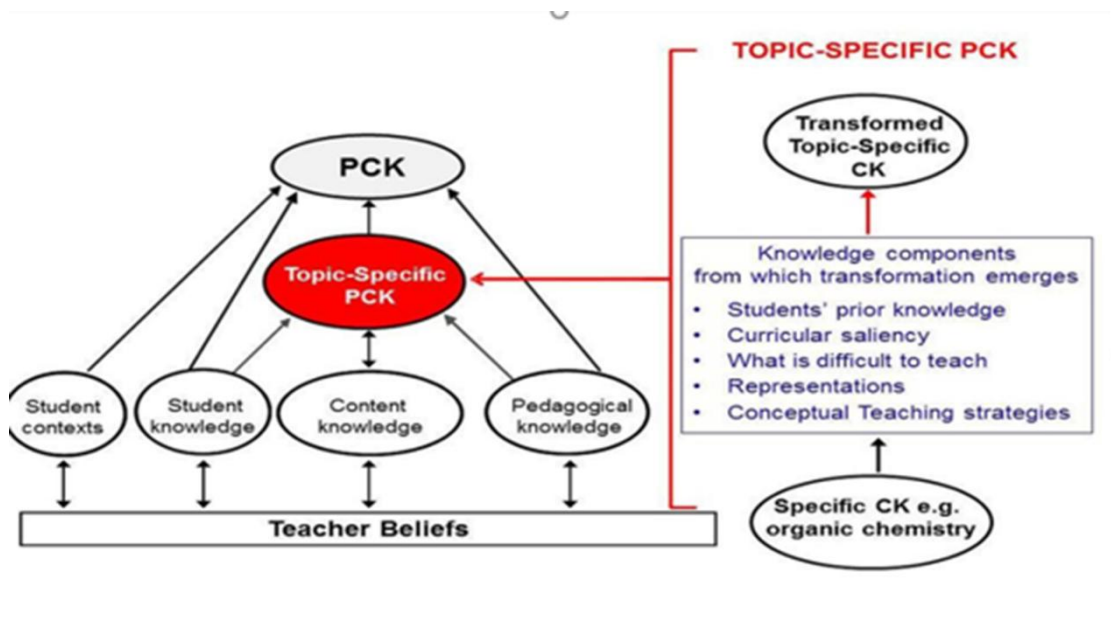
emphasise the topic-specific nature of pedagogical reasoning. Researchers have argued that teaching different scientific topics requires distinct pedagogical approaches because each topic presents unique conceptual challenges and learner misconceptions. In response to this need, Edwin Mavhunga and Marissa Rollnick developed the Topic-Specific Pedagogical Content Knowledge framework. This framework focuses on the knowledge teachers require to transform specific science topics into forms that facilitate conceptual understanding (Mavhunga & Rollnick, 2013).

The TSPCK framework identifies five key components that guide teachers' pedagogical reasoning when teaching particular science topics. The first component is learners' prior knowledge, which refers to teachers' understanding of the ideas, experiences, and misconceptions that learners bring to the classroom. Recognising learners' prior knowledge is critical because new scientific concepts are often constructed based on existing understandings. Teachers who are aware of common misconceptions are better able to design teaching strategies that address these misunderstandings.

The second component is curricular saliency, which refers to teachers' ability to identify the most important concepts within a topic and understand how these concepts connect within the broader curriculum. This knowledge enables teachers to prioritize key ideas and ensure that learners develop a coherent understanding of scientific principles.

The third component focuses on what makes a topic difficult to teach or learn. Certain scientific topics are inherently challenging due to their abstract nature, complex terminology, or the presence of persistent misconceptions. Teachers who recognise these difficulties are better positioned to design instructional strategies that support conceptual understanding. The fourth component is representations, which includes the use of analogies, models, diagrams, demonstrations, and simulations to explain scientific concepts. Effective representations help learners visualize abstract ideas and establish connections between theoretical concepts and real-world phenomena.

The fifth component involves conceptual teaching strategies, which refer to instructional approaches that promote deep understanding rather than rote memorization. Such strategies often involve inquiry-based learning, problem-solving activities, and collaborative discussions that encourage learners to actively engage with scientific concepts. These five components collectively describe the knowledge teachers use when transforming disciplinary knowledge into classroom instruction. The TSPCK framework is particularly useful for analyzing teachers' pedagogical reasoning because it highlights how teachers integrate multiple aspects of knowledge when planning and implementing lessons. Figure 2 below shows a summary of TSPCK.



**Figure 2: Components of Topic-Specific Pedagogical Content Knowledge (TSPCK)**  
(Mavhunga & Rollnick, 2013)

In the context of this study, the TSPCK framework provides a lens for examining how teachers interpret and apply inquiry-based instructional approaches in their classrooms. By analyzing teachers' reflections on their teaching experiences, the study seeks to identify how the components of topic-specific pedagogical knowledge are revealed in their pedagogical decisions and classroom practices.

### Conceptual Framework

This study integrates the Topic-Specific Pedagogical Content Knowledge (TSPCK) framework with the 5E Instructional Model to explore how inquiry-based instructional approaches can support the development of science teachers' pedagogical knowledge. While TSPCK explains the specialized knowledge teachers require to teach specific science topics effectively, the 5E instructional model provides a structured pedagogical approach that supports inquiry-based learning.

The 5E instructional model consists of five sequential phases: Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 2014). Each phase supports different aspects of learning and provides opportunities for teachers to apply components of topic-specific pedagogical knowledge.

During the Engage phase, teachers activate learners' prior knowledge and stimulate interest in the topic. This phase aligns closely with the TSPCK component of learners' prior knowledge, as teachers must identify learners' existing ideas and misconceptions in order to design effective introductory activities. The Explore phase allows learners to investigate scientific phenomena through hands-on activities, experiments, or problem-solving tasks. At this stage, teachers facilitate inquiry and create opportunities for learners to construct their own understanding. This phase requires teachers to consider conceptual teaching strategies that encourage active engagement with scientific ideas. In the Explain phase, learners

articulate their ideas while teachers introduce scientific concepts and clarify misunderstandings. Teachers often use representations such as diagrams, models, or analogies to support learners' conceptual understanding. This phase also requires teachers to address conceptual difficulties that may arise as learners attempt to interpret scientific explanations. The Elaborate phase encourages learners to extend and apply their understanding to new situations. Teachers design activities that allow learners to deepen their conceptual knowledge and connect scientific ideas across different contexts. This phase relates to the TSPCK component of curricular saliency, as teachers guide learners toward the most important conceptual relationships within the topic. Finally, the Evaluate phase focuses on assessing learners' understanding and reflecting on their learning progress. Teachers use various assessment strategies to determine whether learners have achieved the intended learning outcomes and to identify areas that require further clarification.

The researcher was introduced to the 5E instructional model during participation in the Third Country Training Programme (TCTP) hosted in Malaysia and supported by the Japan International Cooperation Agency (JICA). The programme aimed to strengthen science educators' pedagogical practices by exposing participants to inquiry-based instructional strategies and learner-centred approaches to science teaching. Drawing on the knowledge and skills acquired during the programme, the researcher subsequently introduced the 5E instructional model to an in-service teachers' Honours Science Education class. As part of their professional learning activities, the participating teachers implemented the model in their respective classrooms and later engaged in structured reflection on their teaching experiences. Reflective practice is widely recognised as an important component of teacher professional development, as it enables teachers to critically examine and improve their instructional strategies (Schön, 1983). Furthermore, the 5E instructional model has been widely associated with inquiry-based science teaching and has been shown to support learners' conceptual understanding, academic achievement, and positive attitudes toward science (Bybee et al., 2006; Ruiz-Martín & Bybee, 2022). Empirical studies further indicate that the use of the 5E learning cycle can enhance learners' scientific skills and engagement when effectively implemented in science classrooms. Figure 3 below presents a framework on how 5E model and TSPCK frameworks have related in this study.

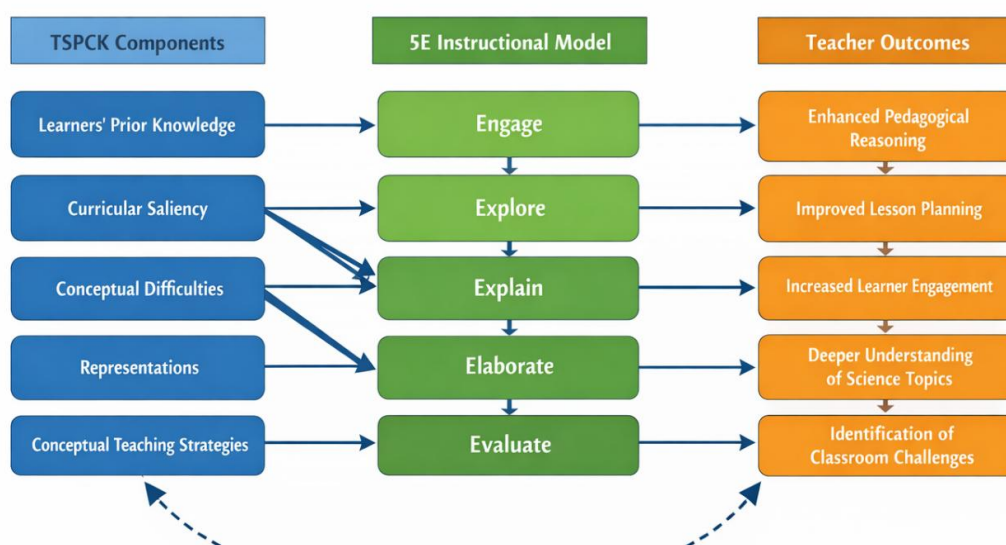


Figure 3: Developing science teachers' TSPCK through 5E instructional model

The conceptual framework of this study proposes that implementing the 5E instructional model provides opportunities for teachers to apply and develop components of Topic-Specific Pedagogical Content Knowledge. Through reflective practice, teachers become more aware of learners' prior knowledge, conceptual difficulties, appropriate representations, and effective instructional strategies. These reflections provide valuable insights into teachers' pedagogical reasoning and the ways in which inquiry-based instructional models support the development of science teachers' professional knowledge.

#### 4. RESEARCH METHODOLOGY

This study employed a qualitative research design to explore in-service science teachers' reflections on the implementation of the 5E instructional model in their classrooms. A qualitative approach was selected because it allows for an in-depth investigation of teachers' pedagogical reasoning, instructional decision-making, and reflective practice within authentic classroom contexts (Creswell & Poth, 2016). This approach facilitated a rich understanding of how inquiry-based teaching strategies influence the development of Topic-Specific Pedagogical Content Knowledge (TSPCK). Participants comprised in-service science teachers enrolled in an Honours Science Education programme at a rural university in South Africa. Participants represented a diverse range of teaching experience and grade-level responsibilities. All participants were secondary school teachers teaching physical sciences, with teaching experience ranging between five and ten years. Data Collection utilized reflective reports completed by participants following the implementation of the 5E instructional model in their science lessons. Reflection prompts were structured around the five phases of the 5E model; Engage, Explore, Explain, Elaborate, Evaluate and guided teachers to document how they facilitated learner engagement, addressed misconceptions, selected representations, applied conceptual teaching strategies, and evaluated learning outcomes. This method enabled teachers to articulate both their instructional decisions and the rationale behind them, providing a rich source of data on pedagogical reasoning.

#### 5. FINDINGS AND DISCUSSION

##### **Analysis of Teachers' Experiences with the 5E Instructional Model**

Analysis revealed several ways in which implementing the 5E instructional model supported the development of Topic-Specific Pedagogical Content Knowledge (TSPCK) among in-service Honours science education teachers. TSPCK emphasises teachers' ability to transform subject matter knowledge into forms that are understandable to learners by considering learners' prior knowledge, conceptual difficulties, representations, teaching strategies, and curricular relevance (Mavhunga & Rollnick, 2013).

##### **Recognising Learners' Prior Knowledge**

Teachers reported that the Engage phase helped them identify learners' existing ideas and misconceptions. For instance, one teacher indicated that:

“I presented electric circuits in grade 10. During the Engage phase I realized that many learners already had ideas about the topic, but some of these ideas were incorrect. When I asked questions at the beginning of the lesson, it became clear that I needed to first address those misconceptions before moving forward. For example, I asked them what

they think happens in the flow of current when resistors are in series. One learner said that the first bulb receives more current since the current reaches it first”

Another teacher mentioned that:

“I presented the topic of lightning in a Grade 10 class. To begin the lesson by asking learners to explain their understanding of how lightning is formed. This activity aimed to elicit their prior knowledge and everyday explanations. During the discussion, one learner explained that in his village there is a belief that a certain man, who is a traditional healer, has the ability to create lightning. Another learner agreed and mentioned that in his village there is also a healer who is believed to have the power to make lightning. I encouraged the learners to freely share their ideas and explanations about how they think lightning occurs. I found the discussion very interesting, as I was not previously aware of such beliefs since, I am not from that particular community. I appreciated all the learners’ contributions and acknowledged their perspectives. After listening to their explanations, I suggested that as a class we should classify the ideas presented, distinguishing between scientific explanations and myths or cultural beliefs. The discussion created an opportunity to address misconceptions that learners may develop from their everyday experiences and community knowledge. It also helped create a respectful learning environment where learners’ backgrounds were acknowledged while guiding them toward scientific understanding of lightning”.

This reflection demonstrates that teachers were actively attending to learners’ prior knowledge, a key component of TSPCK. By eliciting learners’ existing conceptions, teachers could anticipate misconceptions and plan instruction that connected new content to learners’ current understanding. This also strengthens conceptual teaching strategies, as addressing misconceptions early allows learners to build accurate mental models. For instance, another teacher mentioned that:

“The Engage activity helped me see what learners already knew about the concept. Some learners had partial understanding, while others had misconceptions. This helped me plan the rest of the lesson more effectively.

Here, the teacher’s awareness of prior knowledge aligns with the recognition of difficult concepts, as understanding learners’ starting points enabled targeted scaffolding. This shows how the Engage phase supports the TSPCK components of learners’ prior knowledge and curricular saliency, by making teachers aware of which concepts are essential to address immediately (Mavhunga & Rollnick, 2012).

### **Use of Representations in Teaching**

Participants reported that the Explain phase encouraged the use of multiple representations, including diagrams, demonstrations, and models.

“When I reached the Explain stage, I used diagrams and demonstrations to help learners understand the concept of electric circuits in parallel and in series connections. I realized that when learners could see the concept visually, they understood it better.”

This observation illustrates the representation component of TSPCK, highlighting how teachers translate abstract scientific ideas into forms accessible to learners. It also supports conceptual teaching strategies, as visual and concrete representations facilitate deeper understanding rather than memorization.

“Using models and drawings helped learners to visualize what was happening in the experiment. Some concepts are difficult to explain with words only.”

By selecting appropriate representations, the teacher addressed difficult concepts and ensured that learners could connect new knowledge to prior understanding. This demonstrates a direct link between the representation and learners’ prior knowledge components of TSPCK.

### **Development of Conceptual Teaching Strategies**

Teachers reported that the Explore and Elaborate phases promoted learning that emphasised conceptual understanding over rote memorization. Another teacher mentioned that:

“The Explore phase allowed learners to investigate the concept themselves before I explained it. I noticed that learners were more engaged because they were actively involved in the learning process.”

The teacher’s reflection indicates that the 5E model fosters conceptual teaching strategies, one of the core components of TSPCK. By enabling learners to construct understanding through inquiry, teachers were actively transforming content knowledge into teachable experiences. Another teacher indicated that:

“During the Elaborate phase, learners applied what they had learned in a new situation. This helped them see how the concept works beyond the example we discussed in class.”

This highlights the integration of curricular saliency, as the teacher connected classroom learning to broader contexts, reinforcing essential scientific concepts and helping learners see relevance. This approach strengthens multiple TSPCK components simultaneously: conceptual strategies, recognition of difficult concepts, and curricular saliency.

### **Recognising Difficult Concepts**

Teachers indicated that implementing the 5E model helped them identify concepts that learners struggled with.

“When learners were doing the Explore activity, I noticed that many of them struggled to explain what they observed. This helped me realize that the concept was more difficult for them than I had initially thought”.

Here, teachers demonstrated their ability to recognise difficult concepts, a central component of TSPCK. This awareness allows teachers to adjust instruction and scaffolding strategies to address areas where learners typically struggle. One teacher mentioned that:

“Through the discussions in the lesson, I could see which parts of the topic learners found confusing. This helped me adjust my explanation.”

By identifying conceptual bottlenecks, teachers can strategically select representations and adapt teaching strategies, thereby integrating learners’ prior knowledge, representations, and conceptual teaching strategies within TSPCK.

### **Constraints to Implementation**

Despite the benefits, teachers reported challenges such as time limitations, limited resources, and curriculum pressures.

“Some activities require resources that are not always available in our schools, which makes it challenging to implement the Explore phase effectively.”

These constraints highlight the importance of institutional support to allow teachers to fully realize all five TSPCK components. They suggest that systemic factors must be addressed for inquiry-based approaches to be implemented effectively.

### **Implications for Science Teacher Education**

Reflective practice should be embedded in teacher education to allow teachers to analyse their instructional decisions, strengthen pedagogical reasoning, and adapt teaching strategies effectively (Schön, 1983). Professional development programmes should provide opportunities for teachers to experiment with innovative teaching approaches in real classroom contexts, thereby integrating theory and practice while supporting the development of TSPCK (Bybee et al., 2006; Mavhunga & Rollnick, 2013).

## **6. CONCLUSION**

This study examined in-service teachers’ reflections on implementing the 5E instructional model following exposure to the approach through an international professional development programme. Using a TSPCK lens, the study demonstrated how the model supported teachers in developing pedagogical reasoning related to teaching specific science topics. The findings demonstrate that engaging teachers in the design, implementation, and reflection on inquiry-based lessons can play an important role in strengthening pedagogical reasoning related to the teaching of specific science topics. By drawing on the 5E instructional model, teachers were encouraged to move beyond traditional transmission-oriented approaches and instead focus on strategies that actively engage learners in the construction of scientific understanding.

The reflections of participating teachers revealed that the 5E model supported several components of TSPCK. In particular, teachers reported an increased awareness of the importance of identifying and building on learners’ prior knowledge at the beginning of a lesson. The Engage phase of the model enabled teachers to recognise existing learner conceptions and misconceptions, which informed the design of subsequent learning activities. Furthermore, teachers demonstrated greater attention to the use of appropriate representations, such as demonstrations, analogies, and visual explanations, to support learners’ conceptual

understanding of abstract scientific ideas. The Explore and Explain phases of the model were especially valuable in encouraging teachers to adopt more learner-centred and inquiry-based strategies that allow learners to investigate phenomena and construct meaning through guided discussion and experimentation.

Another important outcome of the study is the role of reflective practice in supporting professional learning. Through structured reflection on their teaching experiences, teachers were able to critically examine their instructional decisions, identify areas of success, and recognise aspects that required further improvement. This reflective process aligns with the pedagogical reasoning cycle, in which teachers continuously interpret classroom experiences and adapt their teaching strategies accordingly. As such, the study illustrates that reflection, when combined with structured instructional models such as the 5E framework, can contribute to the development of more sophisticated topic-specific pedagogical knowledge.

Despite these positive outcomes, the findings also revealed several contextual challenges that constrained the full implementation of the 5E instructional model. Teachers reported that time limitations within the school timetable, pressure to cover the prescribed curriculum, and limited availability of laboratory resources made it difficult to fully enact all phases of inquiry-based lessons. These challenges reflect broader systemic constraints commonly experienced in many science classrooms, particularly in under-resourced or rural educational contexts. Addressing these constraints requires sustained support for teachers through professional development initiatives, improved resource provision, and curriculum structures that allow greater flexibility for inquiry-based teaching approaches.

This study highlights the value of integrating inquiry-based instructional models and reflective practice within science teacher education programmes. The experience gained through the Third Country Training Programme (TCTP) provided an opportunity to transfer international professional learning into the local teacher education context, demonstrating how global professional development initiatives can contribute to strengthening science teaching practices. The findings suggest that teacher education programmes should create more opportunities for teachers to experiment with instructional models such as the 5E framework, reflect on their experiences, and link their classroom practices to theoretical frameworks such as TSPCK.

Future research may further explore how sustained engagement with inquiry-based instructional approaches influences teachers' pedagogical knowledge and classroom practices over time. Longitudinal studies could provide deeper insights into how teachers integrate these strategies into their routine teaching and how such practices influence learner engagement and conceptual understanding in science. Ultimately, strengthening teachers' pedagogical content knowledge through reflective, inquiry-oriented professional learning remains a key pathway toward improving the quality of science teaching and learning.

## 7. ACKNOWLEDGEMENTS

I would like to acknowledge the TCTP for granting me the opportunity to participate in the training programme in Malaysia, and JICA for generously funding the project. I also extend

my sincere appreciation to the BEd Honours in Science Education students who participated in this study.

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