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Research paper

In-Service Secondary School Teachers' Self-Reported Pedagogical Knowledge in Science and Mathematics Instruction

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ABSTRACT

Although effective STEM education depends on teachers' pedagogical knowledge (PK) to enact student-centred dialogic instruction, limited research exists on PK in sub-Saharan African contexts. This mixed-methods study used a sequential explanatory-convergence design to explore Zambian STEM teachers' self-reported PK in dialogic pedagogy in science and mathematics. Quantitative data were collected using a validated online survey (α = .953) administered to 186 in-service teachers, and semi-structured interviews with 10 teachers. Quantitative findings revealed that teachers reported high PK, with only the qualification pursued significantly predicting teachers' self-reported PK. Gender, age, highest qualification, teaching experience, and specialisation did not significantly influence reported PK. Qualitative results indicated that teachers demonstrate adequate knowledge to implement effective instruction in STEM lessons but showed limited ability to anticipate learning difficulties and support productive struggle. Overall, results suggest that teachers are theoretically ready to implement dialogic pedagogy in STEM classrooms. Future research may involve classroom observations and performance assessments to assess classroom enactment.

Keywords: dialogic pedagogy, pedagogical knowledge, self-efficacy, STEM, student-centered

Science, Technology, Engineering, and Mathematics (STEM) education has received considerable attention in education research STEM equips citizens with the essential skills and capability needed in the fast-changing technology-driven 21st century (Auerbach & Andrews, 2018; Teo, 2019). Although STEM often refers to all STEM-based subjects, the present study uses STEM to refer to the teaching of science and mathematics (Gardner et al., 2019). The success of STEM education largely depends on teachers' ability to effectively teach STEM subjects (Auerbach & Andrews, 2018). Accordingly, teachers' competencies for implementing STEM teaching are critical and STEM teachers are urged to adopt student-centred pedagogies/teaching practices (Papagiannopoulou & Vaiopoulou, 2024; Waugh et al., 2025). Researchers have used various terms to describe preferred pedagogies in STEM teaching, including 21st century pedagogies, learner/student-centred instructional strategies or practices, active-learning instruction, and dialogic pedagogy (Betti et al., 2022; Freeman et al., 2014; Teo, 2019). 2018; Velásquezs have reported that these instructional practices tend to enhance learners' emotional and cognitive engagement, as well as their persistence in challenging activities (Auerbach & Andrews, 2018; Velásquez & Quiroga, 2024). Due to the emphasis on knowledge exchange between the teacher and students, as well as among students, this study adopts the term 'dialogic pedagogy'.

The common element in dialogic pedagogy is the placement of the learner at the centre of learning, so that the process is learning-oriented rather than teaching-oriented. These teaching practices are generally associated with enhancing higher-order thinking skills and conceptual understanding (Betti et al., 2022; Gardner et al., 2019). Despite the abundant evidence of the benefits of the dialogic pedagogy in STEM, the adoption rate among teachers has been low (Freeman et al., 2014; García-Carrión et al., 2020; Lyle, 2008). The situation is severe in developing countries, which often face resource constraints and high teaching loads. This low adoption is partly due to the considerable effort and time required for teachers to use these strategies (Velásquez & Quiroga, 2024). The teaching strategies that teachers use reflect the professional knowledge repertoire from which they draw (Auerbach & Andrews, 2018; Evitasari, et al., 2025; Waugh et al., 2025). It may thus be inferred that teachers with a rich repertoire of knowledge would be more likely to succeed in implementing the dialogic teaching practices.

In 1987, Lee Shulman proposed seven domains of teacher knowledge that are central to the teaching profession: "content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of educational aims, purposes, and values" (Shulman, 1987, p.8). Since then, STEM education researchers have recognised the significant role that teacher knowledge plays in improving the quality of teaching and learning (Chan & Hume, 2019; Evitasari, et al., 2025; Mientus et al., 2022). Notably, the majority of studies in this area have focused on teachers' ability to transform content through the blending of content and pedagogical knowledge, specifically pedagogical content knowledge (Park et al., 2020). Comparatively, few studies have explored general pedagogical knowledge. Shulman (1987) defined pedagogical knowledge as the broad principles and strategies of classroom management and organisation that appear to transcend subject matter. Thus, PK covers the knowledge of how to teach that can be applied across various aspects and contexts in science and/or mathematics education.

One of the precursors of teachers' ability to enact effective dialogic pedagogies is their self-reported knowledge and confidence in enacting specific teaching practices [self-efficacy beliefs] (Flanagan et al., 2025; Holzberger & Prestele, 2021). There is sufficient evidence for the value of assessing self-reported knowledge in STEM education (Siemoh et al., 2025). Studies have also investigated whether teachers' characteristics, such as age, gender, teaching experience, and qualifications, can predict or influence their views of classroom instruction (Kosiol & Ufer, 2024; Park et al., 2020; Suprayogi et al., 2017).

Within this context, teacher self-efficacy—the conviction that one can plan and carry out instructional activities that impact student learning outcomes—is equally important (Bandura, 1977). Self-efficacy influences instructional choices, perseverance, and readiness to adopt student-centred strategies in science education (Tschannen-Moran & Hoy, 2007). Findings from investigations into teachers' self-reported knowledge and self-efficacy beliefs can help understand the current state of classroom instruction and inform the planning of tailored interventions to improve STEM education across various contexts. Since self-reports of teacher knowledge and instructional practices play an important role in education (Suprayogi et al., 2017), and there is a paucity of research on pedagogical knowledge in the Zambian, and African contexts, the present study focuses on secondary school STEM teachers' self-reported pedagogical knowledge (PK) which teachers (can) apply across topics, subjects, and contexts in science and mathematics teaching. The following research questions guided this study:

1. What are STEM teachers' self-reported pedagogical knowledge levels?
2. Do STEM teachers' demographic characteristics (i.e., gender, age, qualifications, teaching experience, and specialisation) influence their self-reported pedagogical knowledge level?

By examining self-reported PK levels and teachers' qualitative reasoning about instructional decisions, the study provides a deeper account of STEM instruction. Understanding how STEM teachers perceive their PK levels can help to design targeted support interventions that move beyond self-perception to actual classroom implementation. Insights from the findings may inform policymakers in developing context-responsive professional development aligned with the competence-based curriculum. Teacher educators may embed dialogic micro-teaching into their training programs, while teachers may foster inquiry-based and student-centred dialogic pedagogy. School administrators can use the insights to promote professional learning communities focused on inquiry and feedback to make evidence-based decisions. Overall, the study contributes evidence on how teachers conceptualise PK for dialogic instruction in resource-constrained environments, offering a framework that connects teacher knowledge, classroom enactment, and systemic reform.

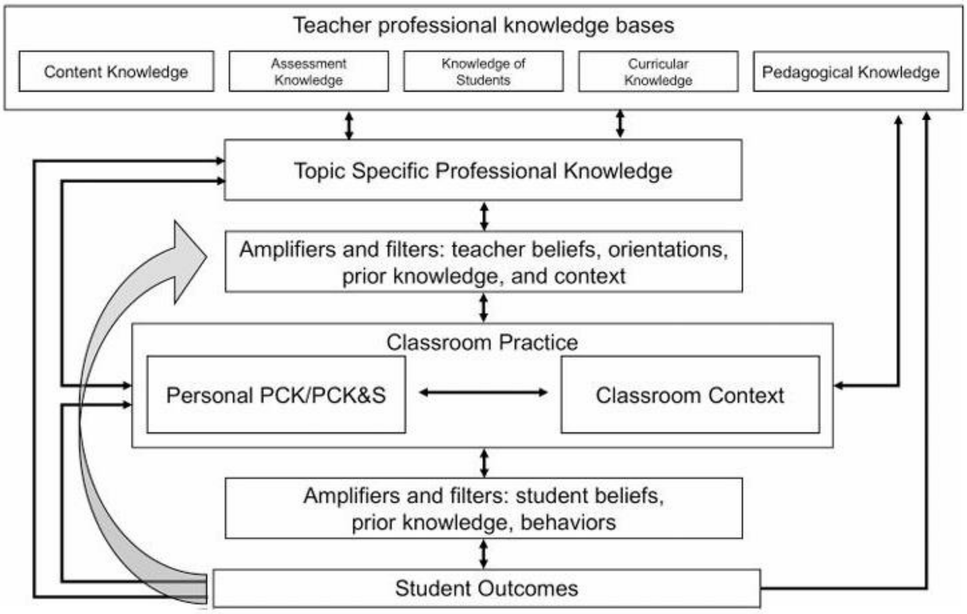
TEACHER PROFESSIONAL KNOWLEDGE

This study is informed by teacher professional knowledge frameworks that originate from Shulman's seminal work on teacher knowledge, which has greatly influenced STEM education research (Shulman, 1986, 1987). Several models have been developed to explain the nature and development of teacher knowledge, such as

Magnusson's pentagon, consensus, and refined consensus models (Chan et al., 2019; Magnusson et al., 1999). Efforts to reach a consensus understanding of PCK through the PCK summits in 2012 resulted in the consensus model (Figure 1), which describes PCK as teachers' knowledge that informs their classroom action planning, teaching, and reflection on teaching (Gess-Newsome, 2015). Five knowledge bases, including PK, are depicted at the top (Figure 1), with illustrations of how this knowledge flows down to the learners through filters and classroom discourse.

Figure 1

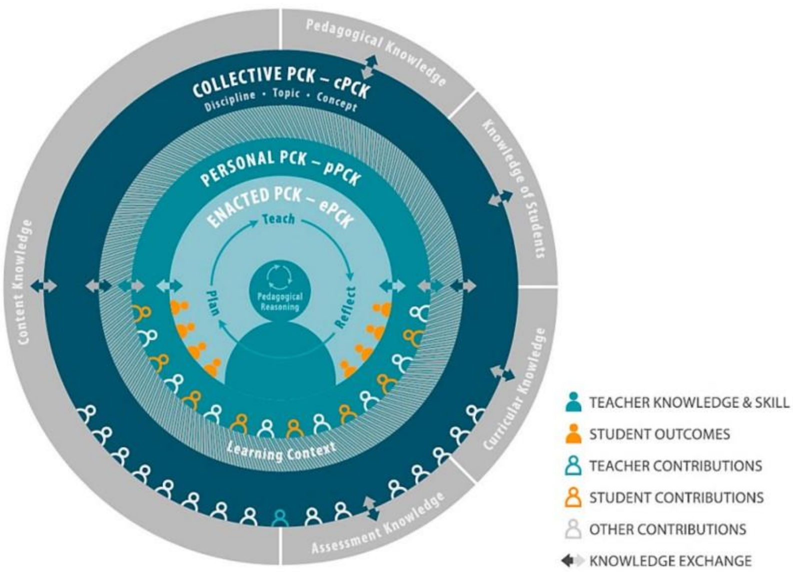
Teacher professional knowledge (Gess-Newsome, 2015)



Furthermore, the refined consensus model (Figure 2) represents the same five knowledge bases and PCK across three realms: collective PCK, enacted PCK, and personal PCK (Carlson et al., 2019). These models illustrate PK's role in transforming content knowledge.

Figure 2

The refined consensus model of PCK (Carlson et al., 2019).



Self-reported teacher knowledge

Since teachers' ability to demonstrate their knowledge (e.g., pedagogical knowledge) is essential for transforming concepts into forms students can understand, previous studies have used self-reports to measure or predict teachers' knowledge. For instance, Choy et al. (2013) investigated novice teachers' views on their PK and teaching abilities. They found that teachers' perceived knowledge grew throughout the first three years of employment, indicating the significance of teaching experience in the growth of teachers' knowledge. Kilic (2015) assessed pre-service teachers' perceptions about their understanding of PK, PCK, curriculum, content knowledge, and learner knowledge. Results showed that pre-service teachers had strong opinions that varied by class and the perceived value of the program they chose. The variations in reported knowledge across classes suggest that specialisation may have influenced their perceptions. Through interviews, Mäkelä et al. (2019) investigated higher education instructors' opinions on their PCK. They found that teachers had favorable attitudes toward using technology and employed a range of instructional and assessment strategies.

Regarding demographic factors, Park et al. (2020) examined whether teachers' PCK was predicted by variables such as gender, credentials, certification, and prior teaching experience. The findings revealed no connection between PCK and years of teaching experience or teachers' gender. Additionally, teachers struggled to connect their understanding of students' learning to their teaching methods. Zolkoski et al. (2020) examined teachers' self-reported knowledge of their professional skills, teaching abilities, school atmosphere, student support resources, and capacity to instruct diverse pupils. It was found that educators held favorable opinions of the school environment and their ability to instruct a diverse student body.

In a study comparing self-reported scores with test scores on technological pedagogical knowledge, Baier-Mosch et al. (2024) concluded that self-reports tend to measure more general knowledge than tests. However, Kosiol & Ufer (2024) reported some correlation between teachers' self-reported knowledge and actual knowledge for some constructs of technological pedagogical content knowledge. Recently, Flanagan et al.'s (2025) study of elementary teachers showed that teachers' self-reports of their knowledge of the science of reading were either lower or higher. Similarly, Siemoh et al. (2025) concluded that elementary science teachers generally reported high self-reported knowledge levels. Although there is debate about self-reported knowledge in education, this field of research continues to receive attention in critical subjects due to the central role that teachers' perceptions play in their practice and students' learning (Siemoh et al., 2025). The above discussion illustrates that self-reports provide insight into teachers' perceived knowledge and instructional practices. Therefore, it is worthwhile to contribute to the field by reporting and reflecting on STEM teachers' self-reported experiences in the present Zambian context.

Dialogic pedagogy for STEM classrooms

Education stakeholders have recently advocated for equipping students with essential skills, including critical thinking, creativity, communication, innovation, and teamwork (Betti et al., 2022; Rahmatika et al., 2024). STEM education offers a promising avenue for teaching these skills (Papagiannopoulou & Vaiopoulou, 2024). One way to accomplish this is to focus on the application of dialogic pedagogies, which involve a series of activities and feedback that provide learners with frequent opportunities to apply what they learn within the classroom (Freeman et al., 2014). These practices encourage back-and-forth communication between fellow students and teachers, thereby promoting favorable learning opportunities (Armbruster et al., 2009; Teo, 2019). By placing students at the center of the learning process, dialogic pedagogy shifts the emphasis from teaching to learning and creates learning environments that foster learners' metacognitive growth, which is required for them to become self-reliant critical thinkers (García-Carrión et al., 2020; Lyle, 2008).

Studies show that dialogic pedagogy helps students grasp concepts and acquire essential life skills (Auerbach & Andrews, 2018; Teo, 2019). According to Toe (2019), dialogic pedagogy aims to support students' knowledge construction through questioning, interrogating, and negotiating ideas and viewpoints in ways that are both intellectually demanding and respectful of one another. This approach draws on Vygotsky's (1978) social constructivist theory, which promotes critical discourse, group projects, and divergent thinking (García-Carrión et al., 2020). The current study draws on the dialogic pedagogy by focusing on teachers' self-reported knowledge in implementing teaching practices focusing on: (a) Inquiry-based learning and conceptual understanding, (b) Assessment and instructional responsiveness, (c) Evidence-based reasoning and communication, and (d) Student-centered problem solving. Although dialogic pedagogies are preferred in STEM, Park et al. (2020) assert that teachers often rely more on teacher-centered pedagogies than learner-centered ones. Hence, the current study contributes to this discourse by exploring the situation in Zambia using self-reported data. Findings may contribute to our understanding of the nature and state of STEM education across contexts.

Relationship between teacher knowledge, teacher self-efficacy, and dialogic pedagogy

Investigating teachers' self-reported pedagogical knowledge provides insight into how educators view their ability to implement effective teaching strategies and their overall instructional competence. These self-perceptions are closely tied to teaching quality because they influence teachers' professional motivation, self-efficacy, and willingness to adopt novel pedagogies, (Tschannen-Moran & Hoy, 2007). Teachers' self-efficacy

(TSE)—the conviction that they can successfully organise and carry out the instructional activities required to accomplish educational goals, particularly supporting students' learning (Bandura, 1977; Tschannen-Moran & Hoy, 2001)—is strongly related to self-reported teacher knowledge (e.g., PK). Teachers typically choose instructional strategies they believe they can successfully implement, meaning that high self-efficacy supports resilience, persistence, and reception of experimentation and reflective practice (Auerbach & Andrews, 2018). Additionally, TSE is linked to both excellent academic achievement and positive classroom instruction (e.g., student-centered, dialogic, and cognitively stimulating learning settings) (Holzberger & Prestele, 202; Skaalvik & Skaalvik, 2010). Therefore, PK and TSE reinforce one another and jointly shape how teachers conceptualise and carry out their work. Thus, examining PK and TSE may indicate areas where professional development can improve pedagogical knowledge and confidence in creating dialogic, student-centered learning environments.

Examining self-reported PK in the context of dialogic pedagogy offers a potent lens through which to view how teachers' beliefs, knowledge, and teaching methods relate to one another. Effective pedagogic teaching requires both developed PK and TSE in managing lively, unpredictable classroom discussions. Teachers need to be confident in their ability to lead discussions, respond adaptively to students' ideas, and strike a balance between authoritative and exploratory methods to meaning-making (García-Carrión et al., 2020; Teo, 2019). A lack of adequate pedagogical confidence may lead teachers to rely on transmissive teaching methods, limiting opportunities for discussion and critical thinking. Understanding how teachers' perceived PK, self-efficacy, and dialogic capacity interact is therefore crucial for guiding teacher education and professional learning initiatives that strengthen competence and confidence in supporting high-quality dialogic instruction.

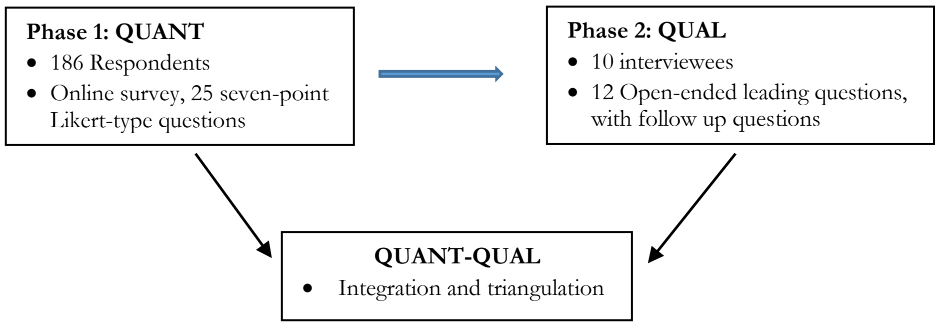
METHODOLOGY

Approach and design

This study employed a mixed-methods research approach, utilising quantitative and qualitative methods (Creswell, 2014; Haynes-Brown, 2023). The sequential explanatory convergence (QUANT-QUAL) design was employed in two phases (Figure 3), Phase 1 (QUANT) and Phase 2 (QUAL). Quantitative data were collected from 186 teachers via an online survey, while qualitative data were collected from 10 subjects using an interview guide. The results of phase 1 and 2 were triangulated. This approach was appropriate for examining the teachers' self-reported PK in STEM education because it facilitated obtaining an in-depth description of STEM instruction (Creswell, 2014). With this approach and design, the study provides insight into teachers' self-reported pedagogical knowledge in teaching science and mathematics.

Figure 3

Visual representation of the study's approach



Sampling and participants

This study employed a convenience purposive sampling strategy, selecting participants from three universities in Zambia. The universities were purposively selected because they train the largest number of teachers in the country, especially those intending to upgrade. As such, the sample comprised in-service teachers who were upgrading their teaching qualifications. The inclusion criteria for the sample were that the individual was enrolled in a science or mathematics education program.

Instruments

(a) Survey questionnaire

An online seven-point Likert scale survey questionnaire developed from the literature (Hodges et al., 2016; Mapulanga et al., 2022) was used. Part A of the questionnaire focused on six demographic characteristics-gender, specialization, highest qualification, qualification being pursued, teaching experience, and age. Part B consisted of 25 items designed to measure teachers' self-reported levels of pedagogical knowledge in enacting dialogic pedagogical practices. Participants chose their responses from 1 to 7, where 1 = emerging, 2 = developing, 3 = foundational, 4 = proficient, 5 = applied, 6 = advanced, and 7 = expert level. The questionnaire's reliability (α = .953) was determined using the dataset reported in this study.

(b) Interview guide

The interview guide consisted of twelve leading questions, three from each theme, as shown in Figure 4. The first author formulated the leading questions, drawing on the survey questions in consultation with an independent researcher. The researcher collaboration enabled alignment and rigour of the questions.

Figure 4

Leading interview questions

Leading Interview Questions

Theme 1: Assessment and instructional responsiveness

Give me an example of how you could

1. Detect learners' learning difficulties in your lesson
2. Use diverse assessment methods in your class
3. Use various teaching aids in your class

Theme 2: Inquiry-based learning and conceptual understanding

In a topic of your choice, kindly illustrate how you could

4. Address students' misconceptions
5. Help learners connect to real-world problems
6. Help students extract and analyse key information

Theme 3: Evidence-based reasoning and communication

Explain how you can

7. Assist students in using claims, evidence, and reasons to illustrate their thinking
8. Help learners apply their learning to support their claims
9. Help learners present the results of their investigations

Theme 4: Student-centered problem solving

How can you

10. Support students to use diverse problem-solving methods
11. Anticipate and facilitate the learning of difficult topics
12. Encourage independent problem-solving and perseverance

Data collection procedures

Firstly, the researcher sought research permits to conduct the research at three Zambian universities. Then, an online questionnaire (Google Form) was sent to participants via WhatsApp, either directly or through their class WhatsApp groups. Participants completed the questionnaire in about 10-15 minutes. The questionnaire was shared several times, with frequent reminders to the participants to complete it. This was done between April and July 2025. The findings from the quantitative phase informed Phase 2 (QUAL), in which one-on-one semi-structured interviews were conducted with a sub-sample to gain more insight into teachers' reported PK.

For the semi-structured interviews, a sub-sample of 15 teachers was purposively selected and invited to participate two weeks after the survey. Only 10 teachers accepted the invitation and were individually interviewed by phone call. The criteria for inclusion were participation in the survey. The interviewees comprised six males and four females, with teaching experience ranging from 1 to 10 years, and representing both mathematics and science specialisations. The interviews were conducted at the teachers' convenience, and all interviewees agreed to have the interviews audio-recorded. The opening question sought to confirm whether the interviewee had participated in the survey. All ten teachers affirmed having completed the survey. Then, the leading questions were applied, along with follow-up questions as needed. On average, each interview lasted 40 minutes.

Participants were informed that participation was voluntary and that their identities and those of their institutions would not be disclosed when reporting the findings. Furthermore, their personal information was not captured by the survey, thereby ensuring participant anonymity and protection. Participants were identified by codes/pseudonyms to protect their identity.

Context of the study

As already mentioned, this study targeted a special group of participant teachers, i.e., in-service science and mathematics teachers who had enrolled to upgrade their teaching qualifications. Since the teachers are already practicing, the findings may provide insight into the situation in the schools where they are currently deployed.

In Zambia, the minimum qualification to teach at the secondary school level is a bachelor's degree. Although many teachers with diplomas are deployed to teach in secondary schools, they are encouraged to upgrade their qualifications to suit their deployment level. Additionally, this upgrade is typically accompanied by a corresponding increase in the salary scale. Most of these teachers opt to attend their training at one of the three universities included in the study.

Data analysis

Quantitative data were analysed using SPSS version 25, which involved computing descriptive statistics (means and standard deviations) and exploratory factor analysis (to identify underlying factor structures). The multiple regression analysis was conducted to test whether demographic characteristics predicted teachers' self-reported PK. The Likert-scale responses were treated as interval data for analytical purposes because it has been shown that parametric statistical tests are robust to mild violations of the interval assumption, and produce reliable findings when Likert scales have more response categories (Norman, 2010). For qualitative data, firstly, recordings of interviews were transcribed verbatim using Otter.ai. The transcripts were inspected and corrected by the first author and an independent researcher. Then an in-depth analysis of the data was conducted following Braun & Clarke (2019) stages by familiarising with the data and coding it, identifying and reviewing themes, and aligning the themes with the study's aim. The data was analysed by the first author and an independent researcher, and the second author confirmed the results. The analysis was negotiated and discussed when needed until an agreement was reached. However, the coders reached 80% agreement before consensus discussions.

The rigor and authenticity of the qualitative data were enhanced through coder agreement, audit trails, and reflexive practice. Interpretive consistency was established by separate coding by the first author and an independent researcher, followed by consensus discussions to resolve any disagreements (Creswell, 2014). To encourage openness and reliability, an audit trail was maintained throughout the analytical process, including major decisions, codebook revisions, and theme improvements (Nowell et al., 2017). The researchers' background in pedagogical discourse, educational experience, and presumptions may have influenced the data collection, analysis, and interpretation of teachers' self-reported practices. This effect was addressed by employing open-ended, non-evaluative questioning and continuous reflexive note-taking to highlight participants' own interpretations and viewpoints (Berger, 2015).

RESULTS

Quantitative findings

The sample of this study consisted of 73% males, while females accounted for up to 27%. The majority of participants were specialised in mathematics education (39%), followed by biology and Chemistry (23%). Physics education had the fewest participants (3%). Most of the participants held diplomas as their highest qualification (81%) and were pursuing a degree program. The rest (19%) held bachelor's degrees and were pursuing a master's qualification. Regarding teaching experience, nearly half of the participants (49%) had 1-5 years of experience, while 23% had 6-10 years. Only 25 participants had worked for more than 15 years. Age-wise, the majority (57%) of participants were 35 years or younger, and 25% were 40 years or older.

Cronbach's Alpha was computed to assess the questionnaire's reliability. The result ($\alpha = .953$) indicated that the questionnaire was reliable, i.e., items had high internal consistency (Camacho-Tamayo & Bernal-Ballen, 2023). The KMO (.942) and Bartlett's Test of Sphericity ($X^2(300) = 3463.448$, $p < .001$) illustrate that the data meet the criteria for performing factor analysis (Arenas-Peñaloza et al., 2025). Therefore, an exploratory factor analysis (EFA) was performed using the Principal Axis Factor extraction method, with Varimax rotation and Kaiser Normalisation. The retention criterion was eigenvalues greater than 1. Loadings below 0.3 were hidden, while the highest loading coefficients were used to determine the factor to which each item loaded in case of cross-loadings. **Table 1** shows the four factors that accounted for 68% of the explained total variance.

Description of factors

A qualitative analysis of the items' loading showed that the items fit into four themes as described in **Table 2**. The factor-level reliabilities in **Table 2** suggest that the items in each factor loaded quite strongly and thus measured the same construct. It should be noted that factor 4 had the least reliability score of the four factors.

The mean responses for each item were computed to determine the level of teachers' self-reported PK (see **Table 3**). These mean responses were interpreted in terms of the level of teachers' PK as follows: 6.50-7.00 = expert, 5.50-6.49 = advanced, 4.5-5.49 = applied, 3.50-4.49 = proficient, 2.50-3.49 = foundational, 1.50-2.49 = developing, and 1.00-1.49 = emerging. Teachers reported having advanced PK in most items, except for PK9

(Encouraging productive struggle) and PK21 (Anticipating difficult topics), where they reported having an applied level of PK.

Table 1

Categories of the items (Factor loadings based on the rotated factor matrix)

Items	Factor			
	1	2	3	4
PK23	.727			
PK19	.709			
PK22	.693			
PK24	.689			
PK18	.679			
PK17	.673			
PK25	.591			
PK20	.542			
PK7	.526			
PK11	.504			
PK16	.491			
PK1		.748		
PK3		.714		
PK4		.697		
PK2		.658		
PK5		.613		
PK6		.610		
PK8		.471		
PK12			.710	
PK13			.645	
PK14			.629	
PK15			.542	
PK21				.607
PK10				.602
PK9				.516

Table 2

Description of the factors and factor-level reliability

Factor/Theme	Theme description	Items	N	Cronbach's Alpha
1. Assessment and instructional responsiveness	This theme relates to practices for effectively assessing learners' understanding and responding to learners' needs.	PK7, PK11, PK16, PK17, PK18, PK19, PK20, PK22, PK23, PK24, PK25	11	0.929
2. Inquiry-based learning and conceptual understanding	This theme consists of practices for effectively guiding learners to construct knowledge through exploration, inquiry, and critical thinking.	PK1, PK2, PK3, PK4, PK5, PK6, PK8	7	0.921
3. Evidence-based reasoning and communication	The focus of this theme is to support students in making claims, reasoning with evidence, and communicating scientific/mathematical ideas.	PK12, PK13, PK14, PK15	4	0.893
4. Student-centered problem solving	Here, the focus is to encourage perseverance, autonomy, and flexible problem-solving strategies.	PK9, PK10, PK21	3	0.673

Table 3

Teachers' self-reported pedagogical knowledge level

Factor	Item	Focus of the item	Mean	SD	PK Level
1	PK7	Linking learning to real life, future topics, and other subjects	5.97	1.00	Advanced
	PK11	Facilitating hands-on and group activities	5.96	1.09	Advanced
	PK16	Using teaching aids like diagrams and models.	5.97	0.96	Advanced
	PK17	Linking learning to real life, future topics, and other subjects	6.10	0.95	Advanced
	PK18	Facilitating hands-on and group activities	5.93	1.07	Advanced
	PK19	Detecting learning difficulties	6.07	0.95	Advanced
	PK20	Detecting learning difficulties	6.05	0.94	Advanced
	PK22	Asking questions to assess understanding	6.01	1.11	Advanced
	PK23	Asking questions to assess understanding	6.06	0.92	Advanced
	PK24	Using diverse assessment methods	6.18	0.95	Advanced
	PK25	Linking learning to real life, future topics, and other subjects	6.08	0.93	Advanced
2	PK1	Guiding students in forming questions and investigations	5.54	1.18	Advanced
	PK2	Addressing misconceptions	5.64	1.18	Advanced
	PK3	Analysing data for patterns	5.60	1.15	Advanced
	PK4	Extracting key information	5.54	1.16	Advanced
	PK5	Encouraging peer learning	5.80	1.06	Advanced
	PK6	Connecting to real-world problems	5.97	0.99	Advanced
	PK8	Linking evidence to claims	5.67	1.10	Advanced
3	PK12	Using claims, evidence, and reasoning	5.84	1.11	Advanced
	PK13	Applying content knowledge to support claims	5.76	1.11	Advanced
	PK14	Relating investigations to concepts	5.69	1.19	Advanced
	PK15	Presenting results using visual/media tools	5.73	1.30	Advanced
4	PK9	Encouraging productive struggle	5.22	1.63	Applied
	PK10	Supporting diverse problem-solving methods	5.62	1.32	Advanced
	PK21	Anticipating difficult topics	5.26	1.75	Applied

Self-reported pedagogical knowledge (PK) and demographic characteristics

Table 4 shows that the mean self-reported pedagogical knowledge (PK) scores for the demographic characteristics ranged from 5.19 to 6.24, representing the applied and advanced levels. Results reveal that the levels of PK reported by male and female participants were comparable. Participants in physics education reported the lowest PK scores, whereas those in mathematics education reported the highest. Diploma holders and degree holders had similar PK scores in terms of highest qualification. Likewise, individuals who were currently pursuing a degree had a marginally higher score than those pursuing a master's degree. Participants with 16–20 years of teaching experience reported the highest scores, whereas those with 21 years or more reported the lowest. Participants aged 25 and under had the highest PK scores, while those aged 46 and beyond had the lowest.

Demographic factors as predictors of teachers' self-reported PK

A multiple linear regression analysis was conducted to determine whether the demographic characteristics predict teachers' overall self-reported PK (Norman, 2010). The results show no significant autocorrelation in the residuals, as indicated by a Durbin-Watson value of 1.64. Values of the variance inflation factor (VIF) ranged from 1.09 to 3.30, indicating no multicollinearity issues. The validity of the regression model assumptions was further confirmed by the residuals, which were roughly normally distributed and within acceptable ranges (Islam, 2020). The overall model was not significant, $F(5, 180) = 1.33$, $p = .252$, $R^2 = .036$, Adjusted $R^2 = .009$. Furthermore, Table 5 shows that only the qualification pursued significantly predicted overall PK ($p = .046$). The negative beta coefficient indicates that teachers pursuing higher qualifications tended to report slightly lower perceived PK scores than their counterparts. The other characteristics did not significantly predict teachers' perceived overall PK (all $p > .05$).

Table 4

Self-reported PK level by demographic characteristics

Variable		N	%	M	SD
1. Gender	Male	136	73.11	5.82	0.81
	Female	50	26.88	5.80	0.71
2. Specialisation	Biology education	26	13.97	5.81	0.61
	Chemistry education	11	5.91	5.71	0.86
	Physics education	6	3.22	5.19	2.13
	Mathematics education	73	39.24	5.87	0.64
	Biology and Chemistry education	43	23.11	5.83	0.83
	Mathematics and Biology education	27	14.52	5.78	0.70
3. Highest qualification	Diploma	151	81.18	5.81	0.78
	Degree	35	18.82	5.82	0.81
4. Qualification pursued	Degree	154	82.80	5.85	0.67
	Master's	32	17.20	5.63	1.17
5. Teaching experience	1-5	92	49.46	5.89	0.59
	6-10	42	22.58	5.65	1.03
	11-15	27	14.52	5.86	0.79
	16-20	18	9.68	5.92	0.73
	21 and above	7	3.76	5.31	1.20
6. Age (years)	25 and below	4	2.15	6.24	0.58
	26-30	37	19.89	5.98	0.56
	31-35	65	34.94	5.74	0.86
	36-40	33	17.74	5.85	0.80
	41-45	35	18.82	5.70	0.82
	46 and above	12	6.45	5.70	0.78

Table 5

Multiple regression: Predictors of teachers' overall self-reported PK

Predictor	B	SE	β	t	p	95% CI for B
(Constant)	6.61	0.44	—	15.15	.000	5.75, 7.47
Age	–0.06	0.07	–.10	–0.84	.405	–0.20, 0.08
Teaching experience	–0.01	0.08	–.01	–0.11	.915	–0.16, 0.14
Highest qualification	0.48	0.27	.24	1.82	.071	–0.04, 1.00
Qualification pursued	–0.53	0.26	–.27	–2.01	.046	–1.05, –0.01
Specialisation	0.00	0.03	.01	0.11	.911	–0.06, 0.07

Qualitative findings

The qualitative results presented here relate to respondents' responses to items that required them to demonstrate their reported PK through examples or explanations of how they could enact specific instructional practices in a classroom situation. This enabled shedding light on teachers' self-reported PK. The results are presented according to the themes from which the questions arose.

Theme 1: Assessment and instructional responsiveness

Teachers demonstrated a good understanding of instructional practices related to assessment and instructional responsiveness. For instance, when teachers were asked to give examples of how they could detect learning difficulties in their lessons, Teacher 1 responded, "*In a chemistry lesson, I would give learners a quick task to predict reactions. Then I would check if they confuse N1 and N2 mechanisms*." Meanwhile, Teacher 2 stated, "*I can ask learners to explain a concept in which misconceptions often arise, such as Newton's first law of motion*". Regarding the use of diverse assessment methods, Teacher 3 stated, "*When teaching genetics, I can combine laboratory reports, concept maps, short quizzes, and labelling diagrams*." Teachers also demonstrated the ability to use various teaching methods in their lessons. For example, Teacher 6 reported, "*When teaching Geometry concepts, I can employ geometry softwares, physical models and measuring tools depending on the concepts being taught*." In addition, Teacher 8 said: "*I would use 3D molecular models, electron micrographs and animations when teaching molecular biology*." Collectively, these responses suggest that teachers are aware of the various aspects they need to use to assess and instruct learners. Their responses also indicate that teachers are aware that the choices and actions depend on the teaching contexts.

Theme 2: Inquiry-based learning and conceptual understanding

Regarding the application of inquiry-based learning and strategies that promote conceptual understanding, teachers demonstrated knowledge of students' misconceptions and strategies for addressing them. For example, Teacher 7 identified misconceptions in the topic of chemical equilibrium and indicated how they would deal with it: "*When teaching chemical equilibrium, I can challenge the idea that pressure always favors products by showing examples that counter the idea.*" However, some teachers identified a misconception but did not indicate how they would address it. For instance, Teacher 10 said, *"I can correct the idea that* $\sqrt{(a+b)} = \sqrt{a} + \sqrt{b}$." Regarding helping learners extract and analyse information, Teacher 6 reported that they would teach learners to identify independent and dependent variables in statistics.

Theme 3: Evidence-based reasoning and communication

Teachers demonstrated knowledge of how to assist students in illustrating their thinking using evidence-based, logical thinking and communication. Teacher 8 demonstrates their knowledge in their response, "*I can use the Punnett square and observing inheritance to help learners support claims and illustrate their thinking.*" In addition, Teacher 7 narrated, "*I can ask learners to use the collision theory to explain the claim that temperature increases the reaction rate.*" Similarly, teachers explained how they can help students to present the results of investigations. Teacher 4 narrated, *"I can ask the learners to present results in their own way, they can create posters, diagrams, or graphs."* Teacher 9 stated, "*I can ask them to present results of an investigation in a format of a research report.*" While Teacher 4 shows that he would allow students to choose a preferred method, giving learners autonomy, Teacher 9 proposes a more directive approach by suggesting the method learners should use.

Theme 4: Student-centred problem solving

Teachers also demonstrated knowledge of implementing student-centred instructional strategies that facilitate problem-solving. This is evident in their sentiments such as "*In algebra, I can teach learners to solve quadratic equations using various approaches such as factoring, quadratic formula, and completing the square.*" (Teacher 6). In mathematics, Teacher 10 stated, "*I can ask learners to solve calculus problems using parts, substitution, and numerical Riemann sums.*" Furthermore, teachers illustrated various approaches through which they may teach students to persevere in individual problem-solving as can be seen in these quotes: "*I can set challenging physics problems that require learners to integrate various concepts*" (Teacher 4), and "*I can set questions in mathematical proofs where they independently choose appropriate theorems.*" (Teacher 5). These quotes demonstrate that teachers advocate for learner-centred strategies that would promote students' learning.

Synthesis of quantitative and qualitative findings

The overall impression from the teachers' responses to the survey and interviews is that they demonstrate adequate PK level to implement engaging instructional practices in science and mathematics classes. As illustrated in the previous section, the quantitative and qualitative data appear to convey a similar impression. The implications for these findings are discussed in the next section.

The integration of qualitative and quantitative data suggests a strong, cohesive understanding of educators' instructional expertise in STEM settings. A high level of conceptual alignment across data sources was indicated by the strong reflection of the four statistically derived elements in the qualitative narratives. Reflective knowledge of teaching techniques supports teachers' advanced PK in assessment, inquiry facilitation, and evidence-based communication. Both data streams, however, reveal significant shortcomings in encouraging constructive struggle and anticipatory preparation, necessitating targeted support for a more comprehensive pedagogical implementation. The integration also highlights how qualitative data reveals subtle discrepancies between quantitative and qualitative findings, despite quantitative self-reports indicating confidence and awareness. The significance of triangulating data types to obtain a comprehensive view of teacher expertise underscores this discrepancy, which is common in self-assessment research. Overall, the results indicate a group of STEM educators with strong roots in inquiry-driven, learner-centered pedagogy, but who would benefit from organised professional development in scaffolding cognitive persistence and adaptive problem-solving.

DISCUSSION

This study provides new evidence that, although teachers self-report high pedagogical competencies, they consistently struggle to anticipate student learning difficulties and to scaffold productive struggle (Botes, 2024). A possible explanation for the high self-reported PK is that participants were exposed to tertiary upgrading programs that emphasise reflective, student-centred instructional approaches, which may have enhanced their perceived competence. Additionally, the self-reported PK could have been inflated by social desirability bias and cultural expectations to demonstrate mastery of the subject they teach. Therefore, the high PK levels may indicate both genuine pedagogical awareness and aspirational self-perception, which could be ascertained by classroom-based research. While some research has shown some correlation between teachers' self-reported knowledge and actual knowledge (Kosiol & Ufer, 2024), a disconnect reinforces the need to complement self-reported data with classroom observation and performance-based assessment of teachers' PK (Lucero et al., 2013). Therefore, these results should be interpreted as evidence of readiness and pedagogical intent rather than verified instructional proficiency. Although these results concur with previous studies, in which teachers reported high levels of enacting differentiated instruction and a favorable opinion of teaching quality (Suprayogi et al., 2017; Zolkoski et al., 2020; Bharti, 2025), Flanagan et al. (2025) reported that teachers' self-reported knowledge was either low or high.

The findings that the lowest scores were recorded in "encouraging productive struggle" and "anticipating difficult topics" suggest specific pedagogical gaps. These results support Park et al. (2020), who concluded that teachers struggle to connect their knowledge of students to effective teaching strategies. In the Zambian context, this may be linked to examination-oriented teaching, large class sizes, and limited access to instructional resources, which may discourage teachers' intention to use dialogic instruction. The implication is that teachers can improve students' learning by aligning their instructional strategies with what they know about students or the students' needs. There may be a need to enhance teachers' knowledge of applying instructional strategies to students' knowledge (Natsi & Vitsou, 2025).

Regarding demographic characteristics, the study found that only one of the six characteristics (qualification pursued) significantly predicted teachers' self-reported knowledge level. The findings that teaching experience did not predict teachers' reported pedagogical knowledge support earlier findings by Park et al. (2020). Similarly, Klassen et al. (2011) found that teachers' self-efficacy frequently exhibits a non-linear pattern, peaking in their early career stages and then plateauing or declining in the absence of consistent professional support. Therefore, even as experience adds to knowledge, PK development is sustained over time through reflective practice and genuine engagement with educational issues. However, the findings contradict previous studies (Choy et al., 2013; Friedrichsen et al., 2009; Suprayogi et al., 2017; Sarkar, 2025). For instance, Choy et al. (2013) found that teachers' PK increased as they gained more teaching experience. Similarly, Suprayogi et al. (2017) reported that teachers with more than five years of teaching experience reported higher knowledge of implementing differentiated instruction than those with less than five years of experience.

The result that the majority of the participants (73%) were male suggests that STEM is a male-dominated field. This finding aligns with previous studies, which have shown that males are more represented than females (Kosiol & Ufer, 2024; Siemoh et al., 2025). The predominance of male teachers in this study likely reflects the influence of structural, cultural, and sampling factors. Furthermore, cultural norms and historical gender roles also influence career specialisation, leading to a higher concentration of men in higher-level teaching positions, while women are predominantly concentrated in early childhood and primary education (Singh & Bipath, 2024; Tovar-Correal & Pedraja-Rejas, 2025). Sampling accessibility and professional engagement differences may have further amplified male representation (Ulferts, 2019). The results may relate to the gender stereotype associated with STEM, a global problem that needs urgent attention from all education stakeholders (Halpern et al., 2025).

The findings that gender did not explain any differences in teachers' reported pedagogical knowledge support previous recent studies (e.g., Kosiol & Ufer, 2024; Park et al., 2020; Siemoh et al., 2025; Almusharraf & Almusharraf, 2021), which concluded that although females scored lower on self-reported knowledge, there was no statistically significant gender influence. The findings add to the mounting corpus of evidence that, teachers' claimed pedagogical knowledge is not significantly influenced by their gender, directing focus instead to other explanatory factors such as experience, subject-matter expertise, and access to professional development. Therefore, professional development and teacher preparation programs might place more emphasis on ensuring that all teachers have equitable access to high-quality training than on gender-tailored interventions.

Concerning specialisation, this study's revelation of no influence implies that subject specialisation by itself is not a reliable indicator of more comprehensive pedagogical knowledge. According to Shulman (1986), the integration of pedagogy and content is essential for effective teaching, as disciplinary knowledge alone may not significantly enhance teacher knowledge. However, this result seems to contradict previous studies (Kilic, 2015; Park et al., 2020). For instance, while Kilic (2015) observed that pre-service teachers' perceptions varied according to the program they enrolled in, Park et al. (2020) found that certification in biology influenced teachers' PCK. These studies suggest that the specialisation played a role in determining teachers' perceptions of their knowledge (Collier, 2023).

Similar to the present study, Park et al. (2020) found no significant influence based on teachers' age, implying that teachers' perceived pedagogical knowledge is not improved solely by age. This result is also consistent with other research, which shows that professional experience and age are not the only primary drivers of pedagogical progress and skill (Klassen et al., 2011; Tschannen-Moran & Hoy, 2001). Since the majority of the participants were 35 years old or younger, they present a younger generation of teachers with great potential and available time to develop their professional abilities within the profession. Additionally, this presents an opportunity for conducting longitudinal studies with the same sample to follow up on classroom enactment and identify the need for targeted, effective professional development interventions.

The results that teachers with higher educational qualifications perceive as having higher PK are consistent with the assertion that advanced content and theoretical engagement with instructional practice enhance pedagogical expertise (Shulman, 1986). Higher self-assessed PK may result from teachers having more exposure to curriculum design, pedagogical theory, and evidence-based teaching methods. Additionally, studying may increase participants' awareness of educational complexity, which could prompt them to critically re-evaluate their own knowledge—a phenomenon known as "conscious incompetence". Research on professional learning contexts indicates that increased comprehension first lowers self-perceived efficacy before fostering long-term development (Skaalvik & Skaalvik, 2010). Within Zambia's competency-based curriculum, which emphasises inquiry and learner-centered approaches (Curriculum Development Centre, 2023), the results may represent aspirational alignment with policy rhetoric rather than classroom reality, which may be limited by large class sizes and restricted access to laboratories.

Limitations of the study

There are several limitations to consider when interpreting the findings of this study. Firstly, social desirability bias may affect the cross-sectional, self-reported design, limiting the ability to evaluate causality. Secondly, the representativeness of the survey may have been compromised by the exclusion of teachers with limited internet access, which resulted from the use of an online questionnaire. Furthermore, the generalisability of the results outside this cohort is limited by the gender imbalance (a higher proportion of males) and the convenience purposive sampling from only three institutions. Although useful for depth, the tiny qualitative subsample might not fully represent the variety of experiences that teachers have. Finally, it is impossible to completely rule out researcher interpretation bias, even with increased triangulation and coder agreement, which enhances the trustworthiness of the findings. To validate and expand on these findings, future research should employ experimental or longitudinal approaches, combine self-reports with classroom observations and students' data, or extend the study to other contexts and larger samples.

CONCLUSIONS AND RECOMMENDATIONS

This study contributes to the global understanding of in-service STEM teachers' self-reported PK for dialogic pedagogy using the Zambian secondary school education context. It connects quantitative factor structures with qualitative classroom reasoning. By linking self-perceived PK to teacher knowledge, self-efficacy, and dialogic pedagogy, the study contributes practically and conceptually to the global discourse on teacher knowledge. It found that teachers report high levels of pedagogical knowledge, with no significant differences across gender, specialisation, highest qualification, teaching experience, or age. Only the qualification pursued significantly predicted PK levels, suggesting that engagement in formal study may heighten teachers' awareness of their own PK. The findings highlight teachers' confidence and the need to verify self-reports through classroom-based evidence.

Based on the study's findings, the authors make the following recommendations:

1. Teachers can promote learner dialogue and inquiry by establishing classroom routines that emphasise questioning, peer discussion, and evidence-based reasoning; designing tasks that promote constructive struggle through strategic scaffolding to address identified learning difficulties; and engaging in reflective practice through journals or peer feedback to continuously evaluate and refine dialogic strategies, and aligning self-perception with classroom realities.
2. The Ministry of Education and the Teaching Council of Zambia may integrate dialogic and inquiry-based competencies into teacher performance frameworks and continuous professional development guidelines. Furthermore, policy should encourage school-based professional learning communities and lesson study models that promote reflective collaboration and the ongoing improvement of dialogic teaching practices.
3. Teacher education institutions may design their courses around iterative cycles of planning, teaching, observation, and reflection on dialogic lessons to develop adaptive expertise. They may also emphasise strategies for managing dialogic learning within Zambia's typical classroom constraints, such as large class sizes, exam pressures, and limited resources, to ensure teachers can effectively translate theory into practice.

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Competing interests

Authors declare no conflict of interest, whether financial, personal, or professional, related to this manuscript.

Author contributions

TM was responsible for the research concept and design, data collection and assembly, data analysis, interpretation, and writing the original draft. LCJ contributed to the research concept and design, reviewing and editing, and financial resources. All authors read, revised, and approved of the final version of the article.

Data availability

The data for this study are available upon reasonable request from the corresponding author.

AI disclosure

N/A

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REFERENCES

Almusharraf, N., & Almusharraf, A. (2021). Postsecondary instructors' reflective teaching practices pertaining to gender differences and teaching experience. *Journal of Ethnic and Cultural Studies, 8*(3), 1–16. https://doi.org/10.29333/ejecs/788

Arenas-peñaloza, J. A., Sarmiento, A. S., Rodríguez-vásquez, F. M., Ariza-hernandez, F. J., Rodríguez-nieto, C. A., Miguel, A., Jiménez, I., Magdalena, U., Marta, S., & Cisnero, I. E. T. C. F. J. (2025). Exploring in-service university teachers' beliefs about the design of mathematical tasks. *EURASIA Journal of Mathematics, Science and Technology Education, 21*(8), 1–12. https://doi.org/10.29333/ejmste/16641

Armbruster, P., Patel, M., Johnson, E., & Weiss, M. (2009). Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE-Life Sciences Education, 8,* 203–213. https://doi.org/10.1187/cbe.09

Auerbach, A. J. J., & Andrews, T. C. (2018). Pedagogical knowledge for active-learning instruction in large undergraduate biology courses: A large-scale qualitative investigation of instructor thinking. *International Journal of STEM Education, 5*(1).1-25. https://doi.org/10.1186/s40594-018-0112-9

Baier-Mosch, F., Schulze-Vorberg, L., Horz, H., & Kunter, M. (2024). Exploring the suitability of self-reports to gain insights into teachers' technological pedagogical knowledge. *Studies in Educational Evaluation, 83*(September), 1–11. https://doi.org/10.1016/j.stueduc.2024.101402

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychology Review, 84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Bharti, M. (2025). Engendering education and organisation: The women's reform movement in India. *Feminist Encounters: A Journal of Critical Studies in Culture and Politics, 9*(2), 30. https://doi.org/10.20897/femenc/16788

Berger, R. (2015). Now I see it, now I don't: Researcher's position and reflexivity in qualitative research. *Qualitative Research, 15*(2), 219–234. https://doi.org/10.1177/1468794112468475

Betti, A., Biderbost, P., & Domonte, G. A. (2022). Can active learning techniques simultaneously develop students' hard and soft skills? Evidence from an international relations class. *PloSONE, 17*(4), 1–22. https://doi.org/10.1371/journal.pone.0265408

Botes, W. (2024). Demonstrating pedagogical content knowledge through the development of educational science board games. *European Journal of STEM Education, 9*(1), 1–16. https://doi.org/10.20897/ejsteme/14136

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Carlson J, Daehler KR, Alonzo AC, Barendsen E, Berry A, Borowski A, Carpendale J, Kam Ho Chan K, Cooper R, Friedrichsen P, Gess-Newsome J. (2019). The refined consensus model of pedagogical content knowledge in science education. In: *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp.77–94). Springer. https://doi.org/10.1007/978-981-13-5898-2_2

Camacho-Tamayo, E., & Bernal-Ballen, A. (2023). Validation of an instrument to measure natural science teachers' self-perception about implementing STEAM approach in pedagogical practices. *Education Sciences, 13*(8). https://doi.org/10.3390/educsci13080764

Chan, K. K. ., & Hume, A. (2019). Towards a consensus model: Literature review of how science teachers' pedagogical content knowledge is investigated. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning PCK in teachers' professional knowledge* (pp. 3–76). Routledge.

Chan, K. K. H., Rollnick, M., & Gess-Newsome, J. (2019). A grand rubric for measuring science teachers' pedagogical content knowledge. In *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science* (pp. 251–269). Routledge.

Choy, D., Wong, A. F. L., Lim, K. M., & Chong, S. (2013). Beginning teachers' perceptions of their pedagogical knowledge and skills in teaching: A three year study. *Australian Journal of Teacher Education, 38*(5), 68–79. https://doi.org/10.14221/ajte.2013v38n5.6

Collier, K. M. (2023). Surviving COVID isolation: A phenomenological study exploring high school teachers' lived experiences in a rural setting. *American Journal of Qualitative Research, 7*(2), 19-40. https://doi.org/10.29333/ajqr/12974

Creswell, J. W. (2014). *Research design: qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE.

Curriculum Development Centre. (2023). *2023 Zambia Education Curriculum Framework*. Zambia Educational Publishing House

Evitasari, A. D., Wilujeng, I., Tohani, E., Astuti, A. D., Triyanti, M., & Musyadad, F. (2025). Prospective elementary school teachers' science PCK: An analysis of perceptions and implicit knowledge. *European Journal of STEM Education, 10*(1), 37. https://doi.org/10.20897/ejsteme/17652

Flanagan, S. M., Brown-Chidsey, R., Cuba, M. J., & Will, K. D. (2025). Elementary teachers' self-reported knowledge of the science of reading: An exploratory study. *Journal of Education, 205*(4), 330-342. https://doi.org/10.1177/00220574251333347

Freeman, S., Eddy, L. S., McDonough, M., Smith, K. M., Okoroafor, N., Jordt, H., & Wenderoth, P. M. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS, 11*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Friedrichsen, P. J., Abell, S. K., Pareja, E. M., Brown, P. L., Lankford, D. M., & Volkmann, M. J. (2009). Does teaching experience matter? Examining biology teachers' prior knowledge for teaching in an alternative certification program. *Journal of Research in Science Teaching, 46*(4), 357–383. https://doi.org/10.1002/tea.20283

García-Carrión, R., López de Aguileta, G., Padrós, M., & Ramis-Salas, M. (2020). Implications for social impact of dialogic teaching and learning. *Frontiers in Psychology, 11*(February), 1–11. https://doi.org/10.3389/fpsyg.2020.00140

Gardner, K., Glassmeyer, D., & Worthy, R. (2019). Impacts of STEM professional development on teachers' knowledge, self-efficacy, and practice. *Frontiers in Education, 4*(April), 1–10. https://doi.org/10.3389/feduc.2019.00026

Gess-Newsome, J. (2015). *A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK summit*. In A. Berry, P. J. Friedrichsen, & J. Loughran (Eds.), *Teaching and learning in science series. Re-examining pedagogical content knowledge in science education* (pp. 28–42). Routledge.

Halpern, B., Aydin, H., & Halpern, C. (2025). Seeing multilingual learners through media and AI: Pre-service teachers' perceptions in an ESOL course. *Journal of Interdisciplinary Research in Artificial Intelligence and Society, 1*(1), 4. https://doi.org/10.20897/jirais/17647

Haynes-Brown, T. K. (2023). Using theoretical models in mixed methods research: An example from an explanatory sequential mixed methods study exploring teachers' beliefs and use of technology. *Journal of Mixed Methods Research, 17*(3), 243–263. https://doi.org/10.1177/15586898221094970

Hodges, C. B., Gale, J., & Meng, A. (2016). Teacher self-efficacy during the implementation of a problem-based science curriculum. *Contemporary Issues in Technology & Teacher Education, 16*(4), 434–451. http://slider.gatech.edu

Holzberger, D., & Prestele, E. (2021). Teacher self-efficacy and self-reported cognitive activation and classroom management: A multilevel perspective on the role of school characteristics. *Learning and Instruction, 76*(July 2020), 101513. https://doi.org/10.1016/j.learninstruc.2021.101513

Islam, T. M. (2020). *Learning SPSS without pain: A comprehensive manual for data analysis and interpretation of outputs* (First, Issue August). ASA Publishers. https://doi.org/10.6084/m9.figshare.12812837

Kilic, H. (2015). Preservice teachers' perceptions about teacher knowledge. *Procedia - Social and Behavioral Sciences, 191,* 1838–1842. https://doi.org/10.1016/j.sbspro.2015.04.306

Klassen, R. M., Tze, V. M. C., Betts, S. M., & Gordon, K. A. (2011). Teacher efficacy research 1998-2009: Signs of progress or unfulfilled promise? *Educational Psychology Review, 23*(1), 21–43. https://doi.org/10.1007/s10648-010-9141-8

Kosiol, T., & Ufer, S. (2024). Teachers' self-reported and actual content-related TPACK–new results on their relation and gender differences. *Computers and Education Open, 7,* 100205. https://doi.org/10.1016/j.caeo.2024.100205

Lucero, M., Valcke, M., & Schellens, T. (2013). Teachers' beliefs and self-reported use of inquiry in science education in public primary schools. *International Journal of Science Education, 35*(8), 1407–1423. https://doi.org/10.1080/09500693.2012.704430

Lyle, S. (2008). Dialogic teaching: Discussing theoretical contexts and reviewing evidence from classroom practice. *Language and Education, 22*(3), 222–240. https://doi.org/10.1080/09500780802152499

Magnusson, S., Krijcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In Magnusson, Shirley, Joseph Krajcik, and Hilda Borko. Nature, sources, and development of pedagogical content knowledge for science teaching. *Examining pedagogical content knowledge: The construct and its implications for science education, 19*(11), 1649–1654. Springer. https://doi.org/10.1007/0-306-47217-1_4

Mapulanga, T., Nshogoza, G., & Ameyaw, Y. (2022). Teachers' perceived enacted pedagogical content knowledge in biology at selected secondary schools in Lusaka. *International Journal of Learning, Teaching and Educational Research, 21*(10), 418-435. https://doi.org/10.26803/ijlter.21.10.23

Mäkelä, E., Auvinen, P., & Juuti, T. (2019). The Finnish product development teachers' perceptions of their pedagogical content knowledge in higher education. In *Proceedings of the Design Society: International Conference on Engineering Design* (ICED19). 609–618. https://doi.org/10.1017/dsi.2019.65

Mientus, L., Hume, A., Wulff, P., Meiners, A., & Borowski, A. (2022). Modelling STEM teachers' pedagogical content knowledge in the framework of the refined consensus Model: A systematic literature review. *Education Sciences, 12*(6), 1–25. https://doi.org/10.3390/educsci12060385

Natsi, I., & Vitsou, M. (2025). Belonging and identity negotiation among Japanese-background learners in Greek schools. *European Journal of Education & Language Review, 1*(1), 5. https://doi.org/10.20897/ejelr/17642

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education, 15*(2010), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Papagiannopoulou, T., & Vaiopoulou, J. (2024). Teachers' attitudes towards STEM education: Exploring the role of their readiness via a structural equation model. *European Journal of Investigation in Health, Psychology and Education, 14*(11), 2850–2864. https://doi.org/10.3390/ejihpe14110187

Park, S., Choi, A., & Reynolds, W. M. (2020). Cross-national investigation of teachers' pedagogical content knowledge (PCK) in the U.S. and South Korea: What proxy measures of teacher quality are related to PCK? *International Journal of Science Education, 42*(15), 2630–2651. https://doi.org/10.1080/09500693.2020.1823046

Rahmatika, N., Hanapi, M. H. bin M., Jendriadi, Sariasih, Y., Imami, M. K. W., & Uslan. (2024). The impact of flipped learning on students' critical thinking; A systematic literature review. *International Journal of Learning, Teaching and Educational Research, 23*(10), 180–206. https://doi.org/10.26803/ijlter.23.10.9

Sarkar, R. (2025). Global agendas and education reforms: A comparative study. *Asia Pacific Journal of Education and Society, 13*(2), 2. https://doi.org/10.20897/apjes/17469

Shulman, L. S. (1986). Those who understand knowledge. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–20. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Siemoh, R. K., Duku, P., & Boye, S. (2025). In-service elementary school science teachers' self-reported pedagogical content knowledge in Ghana. *Discover Education, 4*(1). https://doi.org/10.1007/s44217-025-00459-w

Singh, R., & Bipath, K. (2024). Challenging South African early childhood development teachers' perceptions and pedagogical practices regarding gender. *Education 3-13, 4279*(July), 1–16. https://doi.org/10.1080/03004279.2024.2382172

Skaalvik, E. M., & Skaalvik, S. (2010). Teacher self-efficacy and teacher burnout: A study of relations. *Teaching and Teacher Education, 26*(4), 1059–1069. https://doi.org/10.1016/j.tate.2009.11.001

Suprayogi, M. N., Valcke, M., & Godwin, R. (2017). Teachers and their implementation of differentiated instruction in the classroom. *Teaching and Teacher Education, 67*, 291–301. https://doi.org/10.1016/j.tate.2017.06.020

Teo, P. (2019). Teaching for the 21st century: A case for dialogic pedagogy. *Learning, Culture and Social Interaction, 21*(March), 170–178. https://doi.org/10.1016/j.lcsi.2019.03.009

Tovar-correal, M., & Pedraja-Rejas, L. (2025). Gender, ethnicity and teaching competencies: Do they influence intercultural communicative competence in teacher education? *Education Sciences, 15*(5), 1–22. https://doi.org/10.3390/educsci15050520

Tschannen-Moran, M., & Hoy, W. A. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education, 17*(2001), 783–805. https://doi.org/10.1016/S0742-051X(01)00036-1

Tschannen-Moran, M., & Hoy, W. A. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education, 23*(2007), 944–956. https://doi.org/10.1016/j.tate.2006.05.003

Ulferts, H. (2019). The relevance of general pedagogical knowledge for successful teaching: Systematic review and meta-analysis of the international evidence from primary to tertiary education. In *OECD Education Working Papers* (Issue 212). OECD Publishing. https://dx.doi.org/10.1787/ede8feb6-en

Velásquez, S., & Quiroga, A. (2024). Impacts of active learning strategies on science classes at Colegio San Mateo. *Pedagogica, 24*(37), 246–267. https://doi.org/10.26620/uniminuto.praxis.24.37.2024.246-267

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Waugh, A. H., Green, K. E., & Andrews, T. C. (2025). How do early-career biology faculty develop pedagogical content knowledge? Exploring variation and longitudinal development. *CBE Life Sciences Education, 24*(1), 1–23. https://doi.org/10.1187/cbe.24-08-0211

Zolkoski, S. M., Aguilera, S. E., West, E. M., Miller, G. J., Holm, J. M., Sass, S. M., & Stocks, E. L. (2020). Teacher perceptions of skills, knowledge, and resources needed to promote social and emotional learning in rural classrooms. *Rural Educator, 41*(3), 1–11. https://doi.org/10.35608/ruraled.v41i3.1098

