The Teacher as Mediator: Pedagogical Practices, Digital Tools, and Conceptual Change in Physical Science Pre-Service Teachers in the Eastern Cape, South Africa

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ABSTRACT

Science education in under-resourced South African provinces requires teachers who can integrate digital tools with sound conceptual-change pedagogy, yet pre-service teachers (PSTs) often share the misconceptions and anxieties about Physical Science that they will later need to help learners overcome. This study explored how final-year Physical Science PSTs at a university in the Eastern Cape understood and enacted their role as pedagogical mediators of conceptual change after completing a training module that combined conceptual-change theory with digital-tool integration. A qualitative phenomenological design was used. Twenty-four purposively sampled final-year PSTs completed an anonymous 20-item semi-structured questionnaire addressing learners' misconceptions, digital-tool use, the teacher-as-mediator role, and the influence of the Eastern Cape context. Responses were analysed thematically following Braun and Clarke's six-phase approach, with descriptive frequency counts used only as a supplementary indication of how widely each theme was shared. Four interrelated themes were identified. First, participants described moving from a deficit view of learners' errors towards eliciting, challenging, and reconstructing learners' ideas. Second, videos and PhET simulations were valued for making invisible processes visible, but their use was shaped by pervasive connectivity and device constraints (reported by 22 of the 24 participants), which participants met with considerable resourcefulness. Third, participants located the success or failure of technology-supported lessons in the teacher's mediation rather than in the tool itself: lessons broke down when a tool was left to "teach itself". Fourth, most participants (17 of 24) recalled their own anxiety with Physical Science content and linked it to greater patience and empathy in their teaching. The findings suggest that teacher-led mediation, rather than access to technology per se, is what enables digital tools to support conceptual change in low-resource classrooms, and that teacher education should rehearse this mediating pedagogy under realistic, low-resource conditions.

Keywords: Conceptual Change, Science Teacher Education, Pre-service Teachers, Technology Integration, Teacher Mediation

INTRODUCTION

Physical Science teaching increasingly calls for teachers who can combine sound content knowledge with digital tools that support learners with diverse learning needs (Ramnarain, 2023). Because Physical Science concepts frequently conflict with learners' everyday, common-sense understanding of the world, meaningful learning requires a process of conceptual change, in which existing but scientifically inaccurate ideas are examined, challenged, and reconstructed (Cheng, 2025; Olaogun & Hunsu, 2025). Internationally, conceptual-change research has increasingly emphasised that confronting learners with contradictory evidence is rarely sufficient on its own: what learners are helped to do with that conflict, through discussion, guided reflection, and teacher support, largely determines whether change occurs (Potvin, 2023; Potvin & Bélanger, 2024). Within this process, the teacher functions as a mediator who guides learners through cognitive conflict, supports the development of critical thinking, and helps learners construct new,

scientifically defensible understanding (Khan, 2021). Developing this mediating capacity is especially important for pre-service teachers (PSTs), who must learn to connect theoretical knowledge of conceptual change with its practical enactment in the classroom during a formative stage of their professional development.

This study investigated final-year Physical Science PSTs in the Eastern Cape province of South Africa, a context marked by considerable diversity in learners' educational histories, constrained access to learning materials, and the requirement to teach within the national Curriculum and Assessment Policy Statement (CAPS) (Mpungose, 2020; Pillay, 2024). Digital tools offer real opportunities to support conceptual change in this setting, but their integration is complicated by uneven learner digital literacy and variable teacher readiness to use them purposefully (Jere & Mpeta, 2024; Shambare & Jita, 2024, 2025). Much of the international evidence on digital tools for conceptual change, moreover, comes from experimental studies that focus on learner outcomes rather than on how teachers mediate tool use (Banda & Nzabahimana, 2023; Ningrum et al., 2026), and far less is known about how beginning teachers in low-resource contexts understand that mediating work. Understanding how PSTs in this province experience their mediating role, which pedagogical strategies they draw on to support conceptual change, and how they integrate digital tools into that mediation is therefore important both for strengthening pre-service preparation and for contributing a low-resource perspective to the wider international discussion.

The study addressed three research questions: (1) How do Eastern Cape Physical Science PSTs understand and enact their role as mediators of conceptual change? (2) Which pedagogical practices do they use to support learners' conceptual change? (3) How do they integrate digital tools into this mediating role, and what do they perceive as the tools' potential and limitations for supporting conceptual change in a resource-constrained context? In addressing these questions, the study aims to inform pre-service teacher-education programmes and to suggest ways of strengthening Physical Science teacher readiness in South Africa and in comparable contexts elsewhere.

LITERATURE REVIEW

This review draws together international and South African research on conceptual-change theory, the teacher's mediating role, digital tools in science education, and the South African teacher-education context. It closes by situating the present study within the global discourse and identifying the gap it addresses.

Conceptual Change Theory

Conceptual change theory holds that meaningful science learning requires more than the simple accumulation of new information: learners must substantially revise existing understanding when it conflicts with scientific evidence (Cheng, 2025; Olaogun & Hunsu, 2025; Putri et al., 2022). Posner and colleagues' classical account specifies that conceptual change requires learners to become dissatisfied with an existing conception and to find the new conception intelligible, plausible, and fruitful (Zuccarini & Malgieri, 2022). Subsequent models extend this account by attending to the social, motivational, and classroom-environmental conditions that support or inhibit conceptual change (Putri et al., 2022). For teachers, supporting conceptual change requires identifying learners' typical misconceptions, deliberately creating cognitive conflict that challenges those ideas, and providing opportunities for learners to test and consolidate new understanding (Ginyigazi et al., 2024; Olaogun & Hunsu, 2025). Because learners often resist revising deeply held, intuitively plausible ideas, this process is rarely linear and requires patient, strategic teaching (Cheng, 2025; Kusuma & Suardana, 2025).

Recent international scholarship has refined this picture in three ways that are directly relevant to the present study. First, a systematic review of research on how science learners respond to anomalous data concluded that cognitive conflict is relatively inefficient when it is triggered in isolation, without supportive processing activities or an available alternative conception, and argued for instruction that foregrounds the explanatory usefulness of the scientific idea rather than simply discrediting the learner's initial one (Potvin, 2023). Second, there is growing agreement that resolving conflict depends on additional processing, such as

discussion and structured reflection, through which learners integrate new information (Potvin & Bélanger, 2024). Third, so-called "hot" accounts of conceptual change foreground its motivational and emotional dimensions, including learners' confidence, anxiety, and willingness to tolerate uncertainty (Cheng, 2025; Olaogun & Hunsu, 2025). Taken together, these developments shift attention away from the conflict-inducing event itself and towards the teacher's work before, during, and after it, which is precisely the mediating work this study examines.

The Teacher's Role as Mediator

The idea of the teacher as mediator draws on socio-cultural learning theory, particularly Vygotsky's notion of the Zone of Proximal Development (Hardman & Set, 2021; Khan, 2021). On this view, the teacher's task extends beyond transmitting information to guiding learners from their current understanding toward more sophisticated comprehension, through scaffolding, strategic questioning, modelled thinking, feedback, and the deliberate structuring of learning opportunities (Khan, 2021). Mediation is central to conceptual change because it is through mediation that learners' initial ideas are elicited, confronted with contrary evidence, and gradually reconstructed into more scientifically adequate explanations (Ginyigazi et al., 2024). Effective mediation demands strong subject-matter knowledge, the ability to recognise likely learner errors, and the pedagogical flexibility to match different learners' needs (Chinaka & Sondlo, 2023). South African research on teachers' own perceptions of this mediating role, for example during the disruption of the COVID-19 pandemic, underscores how much the role depends on the specific educational setting in which teachers work (Chauke, 2025).

Digital Tools in Science Education

Digital tools, including interactive simulations, virtual laboratories, data-logging software, educational applications, and online collaborative platforms, are increasingly central to science education because they make abstract or invisible phenomena visible and support learner engagement and collaboration (Jere & Mpeta, 2024; Ramnarain et al., 2023; Shambare & Jita, 2025). Simulations, in particular, allow learners to manipulate variables and observe results immediately, which supports investigative and inquiry-based learning (Makamu & Ramnarain, 2022), while data-logging tools support the development of scientific reasoning through real-time data collection and analysis (Ramnarain et al., 2023). However, access to technology alone does not guarantee improved learning outcomes: teachers need well-developed technological pedagogical content knowledge (TPACK) to select appropriate tools, design suitable learning activities, and monitor how learners use them (Shambare & Jita, 2024). In many South African contexts, and in the Eastern Cape specifically, this potential is constrained by inadequate funding and insufficient teacher training, which can reduce digital-tool use to superficial application rather than genuine pedagogical innovation (Jere & Mpeta, 2024; Shambare & Jita, 2024). Prior research in the Eastern Cape points to uneven digital competence among teachers, continuing institutional difficulties in embedding information and communication technology (ICT) in everyday teaching, and a need for training that addresses technology-based pedagogy rather than basic digital skills alone (Seleke, 2023).

International evidence points in the same direction. A quasi-experimental study in Malawian secondary schools found that PhET simulation-based learning improved learners' achievement and motivation in oscillations and waves (Banda & Nzabahimana, 2023), and a recent systematic review of PhET research concluded that, although simulations consistently support conceptual understanding, their impact depends on instructional design, teacher facilitation, and technological access (Ningrum et al., 2026). At a South African teacher-training institution, Singh-Pillay (2024) reported that teachers who learned to integrate simulation-based learning used it to promote learners' conceptual understanding in schools lacking laboratories and functional equipment, but that doing so required them to unlearn and rethink established pedagogies. At the level of theory, Mishra et al. (2023) have argued for an expanded conception of contextual knowledge (XK) within the TPACK framework, extending beyond the immediate classroom to the broader setting in which technology is used; this widened lens is particularly pertinent in resource-constrained settings such as the Eastern Cape.

Context of South African Teacher Education

South African teacher education operates within historical and structural conditions shaped by the legacy of apartheid and continuing efforts to build an equitable, high-quality system (Ramnarain, 2023). Teacher-preparation programmes aim to produce educators capable of teaching diverse learners, reducing social inequality, and developing critical thinking through the curriculum (Pillay, 2024), but they continue to face uneven PST readiness, resource shortages that disproportionately affect rural institutions, and the ongoing need to keep pace with international developments in teaching (Baloyi et al., 2023; Mudau & Netshivhumbe, 2021; Shambare & Jita, 2024). Strengthening Physical Science education specifically requires attention both to PSTs' content knowledge and to their pedagogical capacity to teach complex material, use technology effectively, and produce genuine conceptual change (Mpungose, 2020; Ramnarain, 2023). The Eastern Cape was selected as the research site because its predominantly rural character, resource constraints, and teacher shortages combine to shape how PSTs learn to teach and how they anticipate teaching in future (Baloyi et al., 2023; Pillay, 2024; Seleke, 2023; Shambare & Jita, 2025).

Situating the Study within the Global Discourse

Internationally, research on conceptual change and research on digital tools in science education have developed largely in parallel. Conceptual-change scholarship has become increasingly attentive to the processing, social, and affective conditions that determine whether cognitive conflict leads to change (Cheng, 2025; Potvin, 2023; Potvin & Bélanger, 2024), while research on simulations and other digital tools has accumulated strong evidence of benefit, mostly through experimental comparisons of learner outcomes (Banda & Nzabahimana, 2023; Ningrum et al., 2026). Both bodies of work increasingly point to the teacher as decisive, yet relatively few studies examine how teachers, and still fewer how pre-service teachers, understand and enact the mediating work that connects a digital tool to a learner's conceptual change. Fewer still do so in low-resource settings where connectivity, devices, and electricity cannot be assumed (Mishra et al., 2023; Singh-Pillay, 2024). The present study addresses this gap by examining, from the perspective of PSTs themselves, how conceptual-change pedagogy and digital-tool use come together in the mediating role under the material conditions of the Eastern Cape, and by considering what these accounts imply for teacher education beyond the South African context.

METHODOLOGY

Research Design

This study adopted a qualitative phenomenological design to explore how final-year Physical Science PSTs at a university in the Eastern Cape experienced their preparation to act as mediators of conceptual change through digital tools. A phenomenological approach was appropriate because the research questions concerned participants' lived experience and personal meaning-making rather than the measurement of predefined variables (Chauke, 2025).

Participants and Sampling

Twenty-four final-year Physical Science PSTs (N = 24) were purposively sampled. Inclusion criteria were specialisation in Physical Science, completion of a training module that combined conceptual-change pedagogy with digital-tool integration, and participation in a teaching-practice placement after the module, so that every participant could draw on both their training and their own classroom experience. All participants were drawn from a single university in the Eastern Cape; the sample is therefore context-specific by design, a point returned to in the Limitations.

Data Collection

Data were collected through an anonymous online semi-structured questionnaire comprising 20 open-ended items. The questionnaire was originally intended to be followed by semi-structured interviews and classroom observations; however, these could not be conducted timing of the teaching-practice cycle

resulted to participants' unavailability, and the questionnaire therefore became the sole data source. To compensate in part, items were written to elicit extended, example-based answers, asking participants to describe specific lessons, tools, and episodes rather than to offer general opinions.

The 20 items were organised into six sections, each mapped to one or more research questions (RQs). Section A (Q1–Q2) gathered background information and built rapport. Section B (Q3–Q6) explored participants' understanding of conceptual change before and after the training, together with a specific attempt to apply it (RQ1, RQ2). Section C (Q7–Q10) examined which digital tools participants used, why they chose them, the challenges they encountered, and how tool use affected their classroom role (RQ3; Q10 also informs RQ1). Section D (Q11–Q14) explored participants' conception of the teacher-as-mediator role, how they decided between telling and facilitating discovery, and examples of successful and unsuccessful mediation (RQ1–RQ3). Section E (Q15–Q18) addressed the influence of the Eastern Cape context, personal anxiety with Physical Science content, and any change in how participants saw their future role (RQ1, RQ3). Section F (Q19–Q20) invited closing reflections and recommendations. Appendix A summarises every item and its mapping to the research questions.

Data Analysis

Responses were analysed thematically following Braun and Clarke's (2006) six phases: familiarisation with the data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. Coding was primarily inductive, although the research questions and the conceptual-change and mediation literature sensitised the analysis to elements such as cognitive conflict, scaffolding, and tool-specific affordances. Codes were consolidated into an explicit codebook in which each code had a definition, inclusion and exclusion rules, and anchor examples drawn from the data. Responses that did not clearly fit any code were assigned to an "other/unclear" category rather than forced into a theme.

Rationale for Supplementary Frequency Counts

Once themes had been finalised, the codebook was applied to each participant's responses to the key analytic items, and the number of participants whose response contained each theme was tabulated. This step was taken for three reasons. First, qualitative reports routinely make implicit quantitative claims ("most", "several", "a few"), and stating the underlying counts makes such claims transparent and checkable (Maxwell, 2010; Sandelowski, 2001). Second, counting across the whole sample guards against anecdotalism, that is, building an interpretation around a small number of vivid quotations. Third, counts make visible the size of disconfirming and residual categories, such as participants who reported no change in their thinking. The counts are, however, strictly supplementary. They describe how widely a theme was shared within this sample of 24; they carry no inferential or statistical weight; and they are not a measure of a theme's importance, which rests on its interpretive significance for the research questions (Braun & Clarke, 2006; Nowell et al., 2017). Because a single response could express more than one theme, counts within a table can sum to more than 24 and percentages to more than 100%.

Trustworthiness and Potential Response Bias

Credibility was supported by comparing patterns across the six questionnaire sections and by actively searching for disconfirming cases, such as participants who reported no change in their thinking, who described the mediator role in directive terms, or who reported no digital-tool use, rather than reporting only confirming instances (Nowell et al., 2017).

Two threats to validity specific to this design were also considered. First, participants described their pre-training beliefs retrospectively, after the training had already reshaped their thinking. Such accounts are vulnerable to hindsight bias, in which earlier beliefs are reconstructed in the light of later understanding and the degree of change may be overstated. Second, several items used the vocabulary of the training module itself ("conceptual change", "misconceptions", "teacher as mediator") and asked directly whether the training had changed participants' views. This wording may have cued the theoretical language that participants then used, and may have invited socially desirable responses in which positive change was

reported because it was perceived as the expected answer, particularly if participants associated the questionnaire with the module and its teaching staff (Bergen & Labonté, 2020).

Several features of the design partially mitigated these risks. Responses were anonymous; most items asked for concrete examples of particular lessons and episodes, which are harder to supply in a merely socially desirable way than general endorsements; and items explicitly invited negative answers, such as accounts of lessons that broke down or a "no" response to whether the training had changed one's view.

That a quarter of participants reported no change in how they saw their future role, and that some described the mediator role in directive terms, suggests that responses were not uniformly shaped by social desirability. Nonetheless, reported shifts in belief are interpreted throughout this article as participants' perceived change, not as verified change in practice.

Ethical Considerations

Ethical approval and informed consent were obtained prior to data collection. Participation was voluntary, responses were collected anonymously, and participants are referred to by anonymised identifiers (P1–P24) throughout.

RESULTS

The findings are presented under four themes that follow the questionnaire sections and research questions: understanding and enacting conceptual change (Section B; RQ1, RQ2); digital tools: use, rationale, and challenges (Section C; RQ3); the teacher as mediator (Section D; RQ1–RQ3); and the Eastern Cape context, personal anxiety, and reported transformation (Section E; RQ1, RQ3).

Each theme is presented primarily through participants' own accounts. The descriptive counts in Tables 1–4 are supplementary and indicate how widely a theme was shared within the sample (N = 24). The full codebook and coded data are provided in the accompanying data-analysis workbook (Survey_Analysis_Coded.xlsx).

Understanding and Enacting Conceptual Change

Looking back on their thinking before the training, participants overwhelmingly described learners' misconceptions in deficit terms, as mistakes, forgotten facts, or evidence that a learner "didn't study", and reported addressing them by re-explaining the correct content, giving further examples, or repeating the correct formula (P1, P8, P13, P22). As P4 put it: "I just corrected them. I would say, 'No, that's wrong, the formula is…' I didn't ask why they thought that way." Following the training, participants' descriptions of conceptual change used the language of the theory: eliciting learners' existing ideas, creating cognitive conflict or dissatisfaction with those ideas, and guiding learners toward a scientifically adequate replacement (P8, P14, P19). P4 summarised the shift: "conceptual change is not about adding correct info on top of wrong info … you make them dissatisfied with the old idea, then show the new one works better."

When describing a specific attempt to apply this approach, most participants described a similar three-step pattern: eliciting a prediction, confronting it with contrary evidence (a demonstration, a simulation, or a calculation), and discussing why the original idea failed. Reported outcomes varied in depth. P8 reported that after such a lesson on Newton's First Law, "more than 80% could correctly explain that force is needed to change motion, not to maintain it", whereas P1 reported that despite a free-fall demonstration, "30% of learners retained their original intuition" that heavier objects fall faster.

Digital Tools: Use, Rationale, and Challenges

Table 1 summarises the digital tools participants reported using in their Physical Science teaching (Q7). Videos and PhET or similar simulations were by far the most common. Two participants reported that they

had not yet used any digital tool, in both cases because their placement school lacked the necessary devices or connectivity.

Table 1. Digital tools reported by participants (Q7; N = 24; multiple responses possible)

Theme / Category	n	% of N=24
Videos (YouTube and other)	17	71%
Simulations (chiefly PhET)	11	46%
PowerPoint / slides	9	38%
WhatsApp (for sharing material)	5	21%
Apps / quizzes (e.g. Kahoot)	4	17%
None / not yet used	2	8%
Posters / printed visuals	1	4%

Participants generally chose a specific tool because it made an otherwise invisible or abstract process visible, such as current flowing in a circuit, the relationship between force and acceleration, or the shape of a field line, and several described this as the means of creating the cognitive conflict needed for conceptual change. P8 explained choosing the PhET Circuit Construction Kit because it "allows learners to SEE current moving and measure it at different points, which challenged their prior idea directly" that current is used up by a bulb.

Almost all participants (22 of 24) reported at least one resource-related barrier when using digital tools in lessons (Q9). As Table 2 shows, unreliable network connectivity or the cost of mobile data was the most frequently cited barrier, followed by a shortage of learner devices; load shedding, faulty projectors, and a lack of laboratory equipment were also mentioned.

Table 2. Barriers encountered when using digital tools in lessons (Q9; N = 24; multiple responses possible)

Theme / Category	n	% of N=24
Network / internet / data connectivity	17	71%
Lack of devices	12	50%
Lack of laboratory or other resources	7	29%
Load shedding / electricity outages	3	13%

Lack of / faulty projector	3	13%
Time constraints / lesson pace	3	13%
Classroom management / distraction	1	4%
No challenge reported	1	4%

Participants described a range of resourceful adaptations to these constraints: downloading videos and offline PhET simulations in advance (P4, P8, P13), grouping several learners around a single device or laptop (P2, P8, P22), taking screenshots of a simulation as a low-tech backup (P8, P22), and pre-loading material onto a personal flash drive for offline playback (P5). As P4 summarised: "we have to download everything at home, use our own data, and fix equipment ourselves. Support for teachers in rural schools would really help us use what we learned."

Using a digital tool was widely associated with a shift in the participant's own classroom role (Q10). Eleven participants explicitly described talking less and guiding, questioning, or facilitating more, and a further two described a related positive shift, such as less time spent writing on the board. As P2 described it: "I move around asking probe questions instead of standing at the board." The remaining responses did not clearly describe a role shift, most often because the item was answered only briefly.

The Teacher as Mediator

Asked what "teacher as mediator" meant to them (Q11), eight participants described the role primarily as guiding or facilitating learners' own construction of understanding, and a further five used explicit bridging or "go-between" language, for example P4's description of the teacher as "the bridge between the science content and the learners" and P8's account of being "the bridge between the learner, the science content, and the tools." Two participants described the role in more directive, classroom-management terms, as being "in charge" or needing to "control everything happening", indicating that the mediating conception, although predominant, had not displaced a more authority-centred view for every participant.

When asked how they decided between directly telling learners information and facilitating discovery (Q12), just over half of participants (13 of 24) grounded their decision explicitly in the nature of the concept: telling for definitions, safety information, or entirely new terminology, and facilitating discovery where a misconception was present or the concept was abstract. P8 articulated this rule clearly: she preferred "to facilitate discovery using a simulation or activity to create cognitive conflict first" for abstract, misconception-prone topics such as current in a circuit, but would "directly tell or explain first" for factual content such as definitions or safety rules.

Participants' accounts of successful mediation (Q13) shared a common structure: the teacher paused a video or simulation at a key moment, asked a guiding question, allowed learners to predict or discuss, and only then connected the observation back to the scientific concept (P4, P8, P11, P23). Accounts of unsuccessful mediation (Q14) were comparatively rare, as most participants either reported no such instance or gave an unclear answer. Where a clear cause was identified, however, it was almost always that the tool had been left to "teach itself", with a video or simulation played straight through without pausing for questions. P8's account of a lesson on covalent bonding is illustrative: "I played the video straight without pausing or asking questions, thinking the animation would explain itself … I think it broke down because I did not mediate. I left the tool to do the teaching instead of me being the mediator." P11 and P23 described near-identical breakdowns with a video on projectile motion and with a simulation, respectively.

Eastern Cape Context, Personal Anxiety, and Reported Transformation

Resource constraints also dominated participants' accounts of how the Eastern Cape context shaped their planning of digital-tool use (Q15). Whereas Table 2 reports the barriers participants met while teaching with digital tools, Table 3 reports the contextual factors they said they take into account when planning; the two overlap in content but derive from different items. Unreliable connectivity, device shortages, and a lack of laboratory equipment were named most often, alongside load shedding, large class sizes, and, for one participant, the challenge of teaching in English while many learners' home language is isiXhosa.

Table 3. Eastern Cape contextual factors cited as influencing the planning of digital-tool use (Q15; N = 24; multiple responses possible)

Theme / Category	n	% of N=24
General resource constraints (unspecified)	11	46%
Connectivity constraints	10	42%
Device shortages	8	33%
Laboratory / other resource shortages	7	29%
Learner background / context	4	17%
Load shedding / electricity	3	13%
Large class sizes	1	4%
Language of instruction (English/isiXhosa)	1	4%

Seventeen of the 24 participants reported having personally experienced anxiety or a lack of confidence with Physical Science content during their own studies (Q16), most often in mechanics, electricity, or organic chemistry. Almost without exception, these participants linked the experience to greater patience and empathy in their own teaching (Q17).

P8 described this connection explicitly: her own struggle with stoichiometry and chemical equilibrium meant that she now had "more patience with learners who are struggling" and did "not label them as lazy." P4 offered an almost identical account regarding mechanics: "that experience makes me patient now. I don't rush learners, I explain with real life examples because I know how it feels to be confused."

Finally, 18 of the 24 participants reported that the training had changed how they saw their future role as a Physical Science teacher (Q18; Table 4). The most common and clearly articulated change, described by nine participants, was an explicit shift from seeing themselves as transmitters of content toward seeing themselves as facilitators or mediators of learners' understanding. P4's reflection captures this: "before I thought my role was to explain well and finish the syllabus.

Now I see my role is to be a mediator who finds what learners already think and uses simple digital tools to change that thinking, even with few resources." Six participants reported no clear change in how they viewed their future role.

Table 4. Personal anxiety with Physical Science content (Q16) and reported change in view of future role (Q18) (N = 24)

Theme / Category	n	% of N=24
Personally experienced anxiety with Physical Science content (Q16 – Yes)	17	71%
Did not report personal anxiety (Q16 – No)	6	25%
Training changed view of future role (Q18 – Yes)	18	75%
– of which: explicit shift to facilitator/mediator identity	9	38%*
Reported no change in future role (Q18 – No)	6	25%

* Percentage of the full sample (N = 24) reporting this specific sub-theme, not of the 18 participants who answered "yes" to Q18.

In their closing reflections (Q19–Q20), participants repeatedly returned to two linked recommendations: that university training modules should include practical experience of designing and delivering digital lessons under realistic, low-resource conditions rather than idealised classroom set-ups, and that continued institutional support, in the form of offline resource packages, data, or further training, would be needed for them to sustain this mediating, technology-supported practice once qualified.

DISCUSSION

The central finding of this study is that participants located the conceptual value of digital tools not in the tools themselves but in the teacher's mediation around them. Their accounts of successful lessons followed a recognisable sequence that maps onto the classical conditions of dissatisfaction, intelligibility, plausibility, and fruitfulness (Zuccarini & Malgieri, 2022); more tellingly, their accounts of failure located the breakdown in the omission of the final, guiding step. This aligns closely with recent international syntheses. Potvin (2023) concluded that anomaly-induced conflict is relatively inefficient without supportive processing activities, and Potvin and Bélanger (2024) emphasise that discussion and structured reflection are needed for learners to integrate conflicting information. The PSTs in this study appear to have reached a similar conclusion from their own classroom experience. Their accounts also complement the outcome-focused simulation literature, which reports reliable benefits from PhET and similar tools while repeatedly noting that these depend on teacher facilitation (Banda & Nzabahimana, 2023; Ningrum et al., 2026): they show, from the teacher's side, what such facilitation consists of and what happens when it is absent.

The pervasiveness of connectivity and device constraints confirms that schools in the Eastern Cape continue to face infrastructural barriers to digital integration (Jere & Mpeta, 2024; Pillay, 2024). More analytically significant is the form participants' responses took. Downloading simulations in advance, sharing a single device across a group, and preparing screenshots as low-tech backups are not merely workarounds; they are expressions of the contextual knowledge that Mishra et al. (2023) argue should be recognised within teachers' technological pedagogical knowledge. In well-resourced systems much of this knowledge remains invisible because infrastructure can be taken for granted. In the Eastern Cape it is foregrounded, yet it appears to be learned informally during teaching practice rather than taught. This is consistent with Shambare and Jita's (2025) account of rural teachers adapting virtual-laboratory use to infrastructural limits and with Singh-Pillay's (2024) finding that simulation-based learning can partly substitute for absent

laboratories. It suggests that teacher education which presupposes reliable infrastructure leaves an important component of TPACK to chance.

Participants' widespread description of a move from transmitter to facilitator or mediator is consistent with the aim of teacher-education programmes to move PSTs beyond a transmission model of teaching (Pillay, 2024). Two qualifications are important. First, a minority continued to frame the mediator role in directive, classroom-management terms, indicating that this shift in professional identity is neither automatic nor complete after a single module, in line with Chauke's (2025) observation that teachers' understanding of mediation varies considerably with setting and circumstance. Second, because these shifts were reported retrospectively and partly in the module's own vocabulary, they are best understood as changes in how participants now talk about and make sense of their role, which may not yet be reflected in sustained classroom practice. Participants' detailed accounts of specific successful and unsuccessful lessons are therefore the stronger evidence that the mediating role had begun to shape what they actually did.

The link participants drew between their own past difficulty with Physical Science content and their present patience with learners adds an affective dimension that is less prominent in technically oriented accounts of TPACK (Shambare & Jita, 2024). It resonates with "hot" accounts of conceptual change, which hold that emotion and motivation shape whether conceptual change occurs (Cheng, 2025; Olaogun & Hunsu, 2025). If conceptual change is emotionally demanding for learners, teachers who remember that demand from the inside may be better placed to sustain learners through it. This does not mean that content anxiety is desirable; unresolved anxiety could equally lead teachers to avoid difficult topics, a possibility the present data cannot rule out. It does suggest that PSTs' own conceptual histories can be treated as a pedagogical resource, rather than solely as a deficit to be remediated before qualification.

Taken together, these findings contribute to the international discourse in two ways. They provide practice-level evidence, from the perspective of beginning teachers, for the convergent claim in recent conceptual-change and simulation research that it is the teacher's mediation that turns cognitive conflict and digital representation into conceptual change. They also show that in low-resource contexts this mediation is inseparable from contextual knowledge about working around infrastructure, knowledge that is largely absent from accounts developed in better-resourced systems. The implication for teacher education is that conceptual-change pedagogy, digital-tool use, and low-resource adaptation should be taught as a single, integrated practice rather than as separate competencies.

CONCLUSION AND RECOMMENDATIONS

This study examined how 24 final-year Physical Science PSTs in the Eastern Cape understood and enacted their role as mediators of conceptual change following a training module that combined conceptual-change pedagogy with digital-tool integration. Participants readily adopted the language and logic of conceptual change and, in most cases, described a shift toward a facilitator or mediator identity. Digital tools, chiefly videos and PhET simulations, were widely used to make abstract concepts visible and to create the cognitive conflict needed for conceptual change, but participants consistently attributed their value to active teacher mediation: their own accounts of unsuccessful lessons attributed the failure to the tool being left to teach itself, not to any deficiency in the tool. Resource constraints, above all unreliable connectivity and a shortage of devices, were reported by almost all participants, who met them with considerable resourcefulness, and personal anxiety with Physical Science content appeared to function as a source of empathetic teaching rather than only as a limitation.

Three recommendations follow for Physical Science teacher-education programmes in similar contexts. First, PSTs should be given structured practice in the specific mediating moves that distinguished successful from unsuccessful mediation in this study, namely eliciting predictions, pausing digital tools for questioning, and connecting observations to concepts, rather than receiving training that treats conceptual-change pedagogy and digital-tool use as separate skills. Second, this practice should take place under realistic, low-resource conditions (offline simulations, single-device group work, and load-shedding contingencies) rather than in idealised, well-resourced settings, so that PSTs graduate already equipped with the adaptations that

Eastern Cape schools currently require of them informally. Third, because PSTs' own past difficulty with Physical Science content appears to support rather than undermine their teaching, programmes might draw explicitly on PSTs' conceptual histories, for example through reflective activities that ask them to trace their own past misconceptions, as a resource for developing patience and pedagogical empathy.

LIMITATIONS AND FUTURE RESEARCH

Several limitations should be noted. First, data were collected through a single anonymous online questionnaire rather than the semi-structured interviews and classroom observations originally planned. This limited the opportunity to probe responses, some of which were brief, and precluded triangulation with observed classroom practice. Follow-up interviews with a subset of participants were considered as a means of triangulating and deepening the findings but were not feasible: because responses were collected anonymously in order to reduce social-desirability pressure, individual responses could not be linked to identifiable participants for follow-up. As discussed in the Methodology, participants' accounts of their pre-training beliefs were retrospective and are vulnerable to hindsight bias, and the use of the module's own vocabulary in several items may have cued theoretically framed and socially desirable responses; reported changes in belief should therefore be read as perceived rather than demonstrated change. Third, although inter-coder agreement was checked on a subsample, the frequency counts remain descriptive indicators of prevalence within a small sample and should not be read as estimates for any wider population. Fourth, the sample of 24 PSTs was drawn from a single university in a single province. The study sought to illuminate experience in depth within a specific context rather than to generalise statistically; its findings are most likely to be transferable to similar low-resource, predominantly rural settings, and their relevance to better-resourced provinces or institutions cannot be assumed.

Future research should combine questionnaires with follow-up interviews, using a consent-based design that permits re-contact, and with direct classroom observation; follow PSTs longitudinally into their first years of independent teaching to examine whether the reported mediator identity is sustained; and compare the experiences of PSTs across provinces and institutions with differing resource profiles, including international comparisons with other low-resource systems.

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APPENDIX A

Summary of the Questionnaire

The questionnaire comprised 20 open-ended items in six sections and was administered anonymously online. Table A1 summarises the focus of each item and the research question(s) it informed (RQ1: understanding and enactment of the mediator role; RQ2: pedagogical practices supporting conceptual change; RQ3: integration of digital tools in a resource-constrained context). Items Q16 and Q18 also invited a yes/no response before an explanation.

Table A1. Questionnaire items, their focus, and their mapping to the research questions

Item	Section	Focus of item	RQ
Q1	A. Introduction	Background: year of study and teaching-practice placement	Context
Q2	A. Introduction	Reasons for specialising in Physical Science	Context
Q3	B. Conceptual change	How learners' misconceptions were understood and addressed before the training	RQ1
Q4	B. Conceptual change	What conceptual change means to the participant after the training	RQ1
Q5	B. Conceptual change	A specific lesson in which the participant tried to bring about conceptual change, and the strategy used	RQ1, RQ2

Q6	B. Conceptual change	The outcome of that lesson and evidence that learners' ideas changed	RQ2
Q7	C. Digital tools	Digital tools used in Physical Science teaching	RQ3
Q8	C. Digital tools	Why a particular tool was chosen for a particular concept	RQ2, RQ3
Q9	C. Digital tools	Challenges encountered when using digital tools and how they were handled	RQ3
Q10	C. Digital tools	How using a digital tool changed the participant's role in the classroom	RQ1, RQ3
Q11	D. Mediator role	What "teacher as mediator" means to the participant	RQ1
Q12	D. Mediator role	How the participant decides between telling learners and facilitating discovery	RQ1, RQ2
Q13	D. Mediator role	An example of successful mediation using a digital tool	RQ2, RQ3
Q14	D. Mediator role	An example in which mediation broke down, and why	RQ2, RQ3
Q15	E. Context and self	How the Eastern Cape context influences planning for digital-tool use	RQ3
Q16	E. Context and self	Personal experience of anxiety or low confidence with Physical Science content (yes/no, then explain)	RQ1
Q17	E. Context and self	How that experience influences the participant's teaching	RQ1, RQ2
Q18	E. Context and self	Whether the training changed how the participant sees their future role (yes/no, then explain)	RQ1
Q19	F. Closing	Recommendations for improving the training module	RQ2, RQ3
Q20	F. Closing	Any further reflections or comments	All