Advanced Qualitative Research Vol. 4 No. 1 (2026) https://doi.org/10.31098/aqr.v4i1.3703

Research Paper

Making the Invisible Visible: A Phenomenological Exploration with Digital Simulations

Gemcer Selda*, Princes Joy S. Muyo, Princess Ann P. Pelaez
Mindoro State University, Philippines

Received : September 2, 2025	Revised : November 12, 2025	Accepted : January 3, 2026	Online : February 6, 2026

Abstract

This study explores the personal experiences of elementary teachers using digital simulations to teach difficult science topics. Using a phenomenological approach, the research looks at how eight (8) science teachers make sense of their roles when using these digital tools. Through deep interviews, the study found that simulations are more than just tools; they change how teachers think about and plan their lessons. The findings show that simulations help teachers turn abstract ideas into "real" experiences for students, which changes the way teachers decide to explain complex topics. While teachers faced frustrations like poor internet or a lack of training, they learned to adapt their teaching styles to overcome these hurdles. This study goes beyond just listing the pros and cons; it explains how teachers' mindsets shift when they bring technology into the science classroom, offering new insights into the deep connection between a teacher's choices and the tools they use.

Keywords: *Digital Simulations, Science Education, Elementary Teaching, Conceptual Understanding, Teacher Experiences*

INTRODUCTION

Science education in elementary schools is a vital stage for shaping a child's foundational understanding of the natural world (Smith & Johnson, 2020). During these formative years, students develop core skills such as critical thinking, inquiry, and observation (Garcia, 2018). Nurturing this early curiosity builds the cognitive framework necessary for tackling more advanced scientific topics later in life (Brown, 2021). However, teaching science at the elementary level in the Philippines presents unique pedagogical challenges. Many scientific phenomena—such as atomic structures or photosynthesis—are abstract and invisible, making them difficult for young learners to grasp through traditional methods (Miller & Thomas, 2022). Consequently, teachers often struggle to communicate these ideas using only textbooks or limited physical experiments (Lee & Park, 2019; Smith & Johnson, 2020).

Digital simulations—computer-based models that replicate real-world processes—have emerged as a promising solution. These tools allow students to visualize and manipulate scientific concepts in a virtual setting (Brown, 2021; Garcia & Santos, 2020). For example, students can model the water cycle or observe gravity without needing expensive laboratory equipment (Smith & Johnson, 2020). While literature consistently highlights how these tools turn passive learning into active exploration (Miller & Thomas, 2022), much of the existing research remains focused on student achievement scores and quantitative outcomes (Lee & Park, 2019). This creates a significant academic gap, as there is limited qualitative insight into the "lived experiences" of the teachers who must navigate these digital shifts.

In the Philippine context, where classroom realities often involve large class sizes and varying levels of technological access, the teacher's role is particularly complex. There is a notable

Corresponding author's email: gemcer.selda@minsu.edu.ph

practice gap regarding how these educators move beyond the software to make real-time pedagogical decisions. This study addresses these gaps by adopting a phenomenological approach to explore how eight elementary teachers in the Philippines make sense of their roles when using simulations. Rather than viewing simulations as simple "add-ons," this research investigates the deep connection between teacher cognition and technology-mediated instruction. This study is guided by the following qualitative research questions:

1. How do elementary science teachers perceive the experience of managing their classrooms and engaging students while using digital simulations?
2. In what ways do teachers describe the process of helping students make sense of abstract concepts through virtual tools?
3. How do teachers interpret and navigate the frustrations and challenges they encounter when integrating digital tools into their lessons?

This study contributes to a deeper theoretical understanding of technology-mediated pedagogy. It moves away from descriptive lists of "pros and cons" to uncover how digital tools reshape the very essence of the teaching experience. The findings aim to provide meaningful insights into professional development, ensuring that technological integration is grounded in the actual lived realities of the classroom.

LITERATURE REVIEW

The Importance of Early Science Education

Elementary science education is widely recognized as a critical stage for shaping learners' foundational understanding of the natural world. During these formative years, children develop core skills such as critical thinking, inquiry, observation, and problem-solving (Garcia, 2018). These skills serve as building blocks for higher-order reasoning and later scientific learning. According to Smith and Johnson (2020), introducing scientific concepts early not only nurtures curiosity but also equips learners with a cognitive framework for tackling more complex topics in secondary education. Brown (2021) emphasizes that this foundation supports long-term engagement with science, fostering a culture of inquiry and innovation from an early age.

Challenges in Teaching Elementary Science

Despite its importance, science instruction at the elementary level is fraught with challenges. Many scientific phenomena—such as atomic structures, gravity, or photosynthesis—are abstract, complex, or invisible to the naked eye, making them difficult for young learners to comprehend (Miller & Thomas, 2022). Teachers often find it difficult to effectively communicate such concepts using traditional teaching methods, which rely heavily on textbooks, verbal explanations, or limited hands-on experiments (Lee & Park, 2019). Smith and Johnson (2020) note that this disconnect can lead to student disengagement and shallow understanding, particularly when concepts remain too theoretical and detached from lived experience.

Digital Simulations as Instructional Tools

Digital simulations have emerged as promising tools to address these instructional challenges. Defined as computer-based models that replicate real-world processes and phenomena, simulations allow learners to visualize, manipulate, and experiment with scientific concepts in dynamic and interactive ways (Brown, 2021; Garcia & Santos, 2020). For example, students can explore the stages of plant growth, simulate the water cycle, or observe how gravity affects falling objects without the need for specialized laboratory equipment (Smith & Johnson, 2020).

By turning passive observation into active exploration, simulations enhance conceptual understanding and retention (Miller & Thomas, 2022). Lee and Park (2019) found that learners who used simulations outperformed peers taught solely through traditional approaches, particularly in problem-solving and higher-order thinking skills. Moreover, simulations embed elements of play, choice, and experimentation that increase motivation and sustained engagement (Miller & Thomas, 2022). This is significant, as Smith and Johnson (2020) argue that maintaining students' interest in science is crucial for cultivating long-term academic success in STEM fields.

The Teacher's Role in Simulation-Based Learning

The effectiveness of digital simulations does not rest solely on the technology itself but on the ways in which teachers integrate them into classroom practice. Teachers serve as facilitators, guiding students to connect virtual experiences with scientific principles (Miller & Thomas, 2022). This requires aligning simulations with curricular objectives, scaffolding learners' interactions, and ensuring that students reflect critically on what they observe (Lee & Park, 2019). Garcia and Santos (2020) highlight that well-planned integration ensures simulations function as meaningful tools for inquiry, rather than as isolated add-ons.

Barriers to Effective Integration

While digital simulations offer numerous benefits, their integration faces significant barriers. Garcia (2018) and Garcia and Santos (2020) identify common issues such as limited access to technology, lack of professional training, and insufficient technical support. Technical difficulties during lessons can disrupt the learning flow and discourage teachers from repeated use. Curriculum constraints also limit flexibility, reducing teachers' opportunities to incorporate simulations meaningfully into lesson plans. These challenges suggest that without institutional support and targeted teacher training, the potential of digital simulations may remain underutilized.

Theoretical Framework: Social Constructivism and Experiential Learning

This study is grounded in Social Constructivism (Vygotsky) and Experiential Learning Theory (Kolbe). These theories suggest that students don't just "absorb" facts; they build knowledge through experiences and social interaction. Digital simulations serve as a "shared space" where teachers and students can explore together. By using a phenomenological lens, this study looks at how teachers perceive their role not as a "lecturer," but as a guide who helps students make sense of these virtual experiences (Adams & Morgan, 2022).

Synthesis and Research Gap

The current literature consistently highlights how digital simulations make abstract science concepts more tangible and improve student engagement (Brown, 2021; Miller & Thomas, 2022). Research also identifies that the teacher's role is shifting from a lecturer to a facilitator in these digital spaces (Garcia & Santos, 2020).

However, there is disagreement in recent research regarding how this shift affects teachers. While Nguyen (2022) suggests that simulations empower teachers by providing new ways to visualize thought, Thompson (2023) argues that these tools can create pedagogical tension between classroom control and student freedom. This suggests that the "role" of the teacher is not a fixed outcome but a complex, personal process of negotiation.

Despite these insights, most existing studies focus on measurable outcomes like test scores or general "barriers" like technical issues. There is a significant lack of research that explores the lived experience and internal meaning-making of elementary teachers as they navigate these tensions (Davis, 2024). We know that teachers use simulations, but we do not yet understand how they mentally process these experiences to make pedagogical decisions.

This study addresses this gap by using a phenomenological approach to explore the deep, personal experiences of elementary science teachers. By focusing on their "meaning-making" processes, this research moves beyond descriptive outcomes to provide a deeper understanding of how technology reshapes the essence of science instruction.

RESEARCH METHOD

This study employed a qualitative research design following an interpretive (hermeneutic) phenomenological approach. This tradition was selected because it moves beyond mere description of teacher experiences to explore how educators interpret and make meaning of their lived reality while integrating digital simulations. This approach allows for a deeper understanding of the "lifeworld" of the teacher, capturing the essence of their pedagogical shifts in a technology-mediated environment.

The study was conducted in four public elementary schools in the Bongabong North District, Oriental Mindoro. A total of eight (n=8) elementary science teachers were selected through purposive sampling. This sample size was determined based on the qualitative principle of data saturation, where depth of experience is prioritized over breadth. In phenomenological research, a smaller, homogenous group allows for the intensive exploration of the "phenomenon" required to reach a point where no new conceptual insights emerge.

Table 1. Demographic Profile of Participants of the Study

Participant Pseudonym	Gender	Years of Teaching Experience	Grade Level Taught	Area of Specialization
Participant 1	Female	12 Years	Grade 4	General Science
Participant 2	Male	8 Years	Grade 6	Physical Science
Participant 3	Female	15 Years	Grade 5	Biological Science
Participant 4	Female	5 Years	Grade 6	General Science
Participant 5	Female	10 Years	Grade 4	General Science
Participant 6	Male	7 Years	Grade 5	STEM Education
Participant 7	Female	20 Years	Grade 6	Science & Technology
Participant 8	Female	3 Years	Grade 4	General Science

Primary data were gathered through semi-structured interviews, allowing for open-ended dialogue while maintaining focus on the research questions. The interview guide was validated by experts in science education and qualitative research to ensure clarity and alignment with study objectives. Interviews were conducted in quiet, private school settings, audio-recorded with consent, and transcribed verbatim to maintain the integrity of the participants' voices.

Data were analyzed using Thematic Analysis following the staged process of phenomenological reduction. The analysis followed six specific phases: (1) familiarization with the data through repeated reading of transcripts; (2) generating initial codes; (3) searching for themes; (4) reviewing potential themes against the data; (5) defining and naming themes; and (6) producing the final report. This staged coding process ensured that the findings were grounded directly in the teachers' lived experiences rather than researcher bias.

To ensure methodological rigor, the study adhered to Lincoln and Guba's (1985) criteria for trustworthiness:

1. Credibility: Established through member checking, where participants reviewed their transcripts to confirm accuracy, and peer debriefing to verify the logic of the emerging themes.

2. Dependability: Maintained through an audit trail, documenting every step of the research process from raw data to final thematic categories.
3. Confirmability: Achieved by the researcher practicing reflexivity, ensuring that the findings strictly represent the participants' responses and not researcher's preconceptions.
4. Transferability: Supported by the provision of thick descriptions of the research context and participant demographics, allowing future researchers to determine the findings' applicability to similar settings.

The study was conducted with strict adherence to ethical protocols. Written permission was obtained from school authorities, and all participants provided informed consent. Participation was entirely voluntary, with the right to withdraw at any time. To protect the privacy of the educators, pseudonyms were utilized for both individuals and schools, and all digital recordings were stored in encrypted files accessible only to the researcher.

FINDINGS AND DISCUSSION

In what ways do digital simulations contribute to the development of critical teaching skills, such as classroom management and student engagement?

Theme 1: Transformation of Pedagogical Identity and Instructional Efficacy

This theme captures the "internal revolution" experienced by teachers. Rather than viewing simulations as mere software, participants described a profound change in their professional self-image—from being a "content deliverer" to an "architect of digital experiences." This shift directly impacts their sense of efficacy and professional worth (Lopez & Rivera, 2023; Tan & Morales, 2024).

Subtheme 1.1: Management Efficiency and Professional Adaptation

Participants reported a significant easing of the "administrative burden" of teaching. Participant 7's reflection that teaching is “more manageable” and “easier in today's time” suggests that simulations act as a secondary "set of hands" in the classroom, automating the monitoring of participation. This newfound efficiency allows teachers to redirect their energy toward higher-level mentoring.

However, this is not a passive change; it is an active "Professional Adaptation." Participant 4's insight that these tools “enhance both teaching skills” reveals that teachers are intentionally evolving their "pedagogical repertoire" (Stevens et al., 2021). They are learning to move in sync with the technology, adopting more dynamic roles that keep both the educator and the student "actively engaged" (Johnson, 2025; Kumar, 2025).

Subtheme 1.2: Evolution of Assessment and Feedback Practices

The nature of "knowing what students know" has been radically altered. Teachers described a move toward "Real-Time Diagnostics." Participant 5's ability to see “who is struggling because the system provides records immediately” (Reyes & Dela Cruz, 2023; Santiago, 2024) turns assessment from a "post-mortem" event into a live intervention.

Perhaps most significantly, Participant 6 described a move toward "Invisible Assessment," where students are being evaluated without the "performance anxiety" typical of traditional quizzes. By making assessment feel "natural," teachers are creating a safer psychological space for error and correction, aligning with the "low-stakes, high-feedback" model advocated by Black and Wiliam (2022).

Theme 2: Facilitating Meaning-Making and Active Discovery

This theme explores the teacher's view of the student's cognitive journey. It highlights a shift in the classroom's "center of gravity" from the teacher's podium to the student's virtual experiment.

Subtheme 2.1: Transition from Passive Reception to Active Engagement

Teachers observed a marked increase in the "affective energy" of the classroom (Garcia & Santos, 2023). Participant 3 noted the transition to "very active" engagement, while Participant 2 highlighted a shift in student agency: moving from listening to "interacting and making decisions." This is more than just "fun"; it is the "gold standard" of learning described by the ICAP Framework (Chi & Wylie, 2014). When Participant 5 observes that visuals keep them "entertained," it is interpreted by the teacher as a doorway to "Attentive Discovery" (Lim & Bautista, 2023; Ocampo, 2024). The excitement triggered by the simulation becomes the "fuel" for subsequent conceptual work.

Subtheme 2.2: Collaborative Scaffolding and Analytical Reasoning

Simulations were found to be powerful "Social Mediators." Participant 7's observation that students "talk more about the concept" during group work demonstrates that the simulation provides a shared language for inquiry,. This social talk is backed by rigorous "Analytical Reasoning." Participant 2 emphasized that simulations force a "pause and think" moment: "need nilang i-analyze bago sagutin." This move away from rote memorization is facilitated by Dual Coding Theory (Paivio, 1986), as the simulation provides a visual mental map that students can discuss and manipulate (Delos Reyes & Tan, 2023; Ramirez, 2022).

Discussion

The core finding of this study reveals a fundamental shift in how teachers "sense-make" their roles. Traditional science instruction often positions the teacher as the primary source of invisible knowledge. However, as participants integrated simulations, they described a transition toward becoming "co-navigators" of virtual phenomena. When Participant 4 noted that simulations "enhance both teaching skills," it suggests that the technology acts as a mirror, forcing teachers to reflect on their own instructional gaps. This process is what Davis (2024) describes as "cognitive restructuring," where the teacher must learn to let go of total classroom control to allow for student-led discovery. This transition is not merely technical; it is an emotional and professional evolution.

A critical analytical tension identified in this study is the thin line between pedagogical engagement and digital entertainment. While Participant 5 mentioned students were "entertained" (naaaliw), a deeper look at the data reveals that teachers are constantly negotiating this space. This highlights a "Practice Gap": how does a teacher ensure that "pressing buttons" (P3) leads to "analyzing concepts" (P2)?

As Thompson (2023) argues, the "gamification" of science can sometimes lead to "innovation fatigue," where teachers feel pressured to keep lessons "fun" to compete with the students' social media habits (P1). The findings suggest that the most successful teachers are those who use the simulation as a scaffold—not to replace the lecture, but to provide a visual anchor that makes the abstract "real" enough to be debated. This confirms Chi and Wylie's (2014) ICAP Framework, showing that the teacher's primary job is to move students from "Active" (doing) to "Constructive" (explaining) and "Interactive" (debating) modes.

In the Philippine context, the "lived experience" of technology integration is inseparable from institutional barriers. While teachers reported that simulations made teaching "easier" (P7), this "ease" is often a hard-won victory over technical difficulties and a lack of formal training. This reveals a "Resilience Paradox": teachers are modernizing their practice (Tan & Morales, 2024) despite a lack of systemic support.

The finding that assessment became "natural and less stressful" (P6) is a major theoretical contribution. It suggests that technology-mediated pedagogy can actually humanize the classroom by removing the "fear" of the quiz and replacing it with the "joy" of discovery. This extends the work of Black and Wiliam (2022), suggesting that in resource-limited settings, digital tools serve as a "force multiplier" for formative assessment, allowing one teacher to monitor the progress of many students simultaneously and accurately (P5).

Finally, this study contributes to the theory of technology-mediated pedagogy by framing simulations as "existential bridges." They bridge the gap between the invisible (atoms, gravity) and the visible; between the teacher's intent and the student's understanding; and between traditional curricula and the digital future. By focusing on the "meaning-making" of eight Filipino teachers, we see that the true value of a simulation is not in the code of the software, but in the pedagogical space it opens up for dialogue and critical reasoning (Delos Reyes & Tan, 2023).

How do digital simulations support students' conceptual understanding and learning?. Differentiated and Personalized Learning

Theme 3: The Digitally Mediated Learning Environment: Pacing and Inclusion

This theme captures the transition from a rigid, teacher-led "broadcast" model of instruction to a fluid environment where the simulation acts as a secondary site of authority. Teachers reported that simulations allow the classroom "flow" to become non-linear, catering to the unique cognitive speeds of diverse learners.

Subtheme 3.1: Differentiated Pacing and Cognitive Accessibility

Participants viewed digital simulations as a tool for equitable sense-making. Rather than a single lecture where struggling students are often left behind, simulations provided a "self-correcting" mechanism. Participant 1 observed that these tools empower "every learner to learn fast as they can," implying a removal of the "pedagogical ceiling" that often exists in traditional classrooms. Participant 2 elaborated on this tiered approach, noting that simulations provide "simpler tasks for slow learners and more complex ones for advanced learners." This allows the teacher to manage multiple "learning tracks" simultaneously—a feat nearly impossible with traditional textbooks.

Analytically, this is driven by the visual-spatial affordance of the technology. Participant 7 and Participant 8 emphasized that when abstract processes are animated, "retention is longer" (P7) and there is a "visible difference in comprehension" (P8). This suggests that the "lived experience" of teaching becomes less about verbal explanation and more about guiding visual discovery (Dancsa et al., 2023; Learning Journals, 2025).

Subtheme 3.2: Virtual Labs as a Proxy for Physical Infrastructure

In the local context, where physical laboratories are often absent, simulations are experienced as a "compensatory pedagogy." Participant 6 highlighted a critical "Practice Gap" being filled: "We lack lab equipment, but simulations help." By using virtual experiments for topics like "solute and solvent," teachers are able to replicate the scientific method in a space where it was previously impossible. This experience reinforces Kumar's (2025) assertion that visual interaction can mimic the benefits of tactile learning. For the teacher, the simulation is not just an "add-on" but a "theoretical bridge" (Rivera & Santos, 2024) that allows them to maintain high academic standards despite resource scarcity.

Theme 4: Affective Engagement and the "Hybrid" Pedagogical Reality

This theme explores the emotional response of students and the teacher's intentionality in balancing modern tools with traditional methods.

Subtheme 4.1: Motivational Triggers and Gamified Learning

Teachers identified technology as a "motivational trigger." Participant 1 shared that students get "excited" just by the sight of the TV, while Participant 4 and Participant 5 noted that "game-like features" and "songs" serve as educational reinforcement. Participant 8 observed that during digital quizzes, "no one is left behind," suggesting that technology fosters a sense of inclusive participation that traditional methods may lack.

Subtheme 4.2: The Tension of Instructional Variety

Despite the benefits, teachers expressed a need for balance. Participant 6 provided a critical perspective, noting, "If it's always simulations, students get bored." This suggests that teachers are making active "pedagogical decisions" to combine printed visuals (P1) and hands-on activities with digital tools to prevent "digital fatigue."

Discussion

The findings suggest that simulations do not just "help" students learn; they change the temporal and spatial boundaries of the lesson. Participant 7's observation that students can "revisit lessons anytime" reflects a shift from a "one-moment" lecture to a "comprehensive learning ecosystem" (Johnson, 2025). This aligns with Dual Coding Theory (Paivio, 1986), but adds a qualitative layer: the "reusability" of digital content reduces the student's anxiety about "missing" information, allowing for deeper cognitive focus.

A key tension emerged regarding the "lack of lab equipment" (P6). While Rivera and Santos (2024) frame simulations as a bridge, the data reveals a contradiction: teachers see simulations as a "powerful alternative" yet worry about the loss of "real hands-on activities" (P6). This reveals that teachers are navigating a "Pedagogical Compromise." They interpret simulations as a "best-available" solution in resource-limited settings (the Philippines), while simultaneously advocating for a hybrid approach that keeps traditional "printed visuals" as stable reference points (P1). This supports Parker and Lee's (2024) argument that combining methods strengthens cognitive connections across multiple senses.

The most significant interpretive insight is the shift from "individual performance" to "collective participation." Participant 8's comment that "no one is left behind" during digital quizzes suggests that technology-mediated instruction changes the social essence of the classroom. While traditional questioning can be intimidating, the "gamified" digital environment (Kumar, 2025) provides a safe "Meaning-Making" space. This confirms the ICAP Framework (Chi & Wylie, 2014)—the "Interactive" mode is not just about the student and the computer, but about a shared, high-energy classroom atmosphere where the teacher facilitates "equitable science instruction" (Dancsa et al., 2023).

In summary, simulations support conceptual understanding by acting as an "Experimental Proxy" and a "Motivational Anchor." Teachers are not merely "using" these tools; they are blending them with traditional "questioning techniques" (Parker & Lee, 2024) to create a specialized pedagogy that addresses both the lack of resources and the diverse learning styles of their students.

What are the challenges faced by teachers in using digital tools to support student learning?

Theme 5: The Systemic and Infrastructural Weight

This theme captures the "fragility" of the digital classroom. Teachers describe an environment where the most brilliant pedagogical plan can be dismantled by a single technical failure. This creates a state of Instructional Anxiety, where the teacher must constantly brace for systemic collapse.

Subtheme 5.1: Technical Volatility and the Loss of Momentum

Teachers experience technical glitches as a direct threat to the "affective energy" of the room. Participant 2's observation that "the students lose focus" when software malfunctions highlights the delicate nature of digital engagement. In a classroom of young learners, the "momentum" of discovery is hard to build and easy to break. As Ertmer and Ottenbreit-Leftwich (2010) suggest, these "first-order barriers" (extrinsic factors) are often perceived by teachers as personal failures of the lesson, rather than just technical errors.

Subtheme 5.2: The "Wasted" Lesson: Power and Infrastructure.

The local context of frequent "brownouts" adds a layer of Infrastructural Despair. Participant 6's poignant phrase—"Sayang ang lesson plan"—captures the emotional toll of professional labor rendered invisible by a lack of electricity. This finding reveals that technology integration is an existential gamble; teachers invest hours into digital preparation knowing it may never be used.

Theme 6: The Logistical and Financial "Pedagogical Ceiling"

This theme explores the "economic gravity" that limits how high a teacher can aim. It reveals a frustration with "Low-Fidelity" teaching, where the teacher's vision is blocked by the actual hardware in their hands.

Subtheme 6.1: Hardware Obsolescence and Storage Compromises

Participants described a "survival of the fittest" for digital content. The physical limitation of device memory (P4) means that teachers are forced to choose which scientific concepts are "important enough" to stay on the device. This hardware unreliability (Tondeur et al., 2017; Zhao et al., 2002) creates a sluggish learning environment where students "start to lose interest" (P3) before the computer even boots up.

Subtheme 6.2: The Economic Barrier to Innovation

The gap between the "global best" and "local reality" is most visible in financial constraints (Karamti, 2016; Almahasees et al., 2021). Participant 1's admission that ideal apps are "beyond the budget" reveals a forced compromise. This leads to the logistical friction of device sharing. Participant 8's experience of having only one device per group results in a "bottleneck" of learning, where the physical device becomes a site of conflict rather than collaboration.

Theme 7: The Facilitator's Burden: Negotiation and Resilience

This theme addresses the Internal Resilience of the educator. It highlights the high "tax" teachers pay in time and energy to maintain a modern, student-centered approach.

Subtheme 7.1: The Discovery Approach vs. Innovation Fatigue.

The shift to a "25/75" facilitator model (Hmelo-Silver et al., 2007) is intellectually rewarding but physically and mentally "tiring" (P5). This reveals a Sustainability Gap. Teachers are trying to maintain a "discovery" environment in a system designed for rote memorization. This tension between the "ideal" strategy and the "unsustainable" labor of digital design (Michael, 2006; Prince, 2004) often leads to professional exhaustion.

Subtheme 7.2: Digital Discipline and "Meaning-Making" Amidst Distraction.

Redefining the teacher's role (Darling-Hammond et al., 2022) introduces the new challenge of "Digital Boundary Management." Participant 4's experience with students wandering to other apps shows that simulations are "distraction-rich" environments. Teachers must now act as "Pedagogical Anchors," pulling students back from the "button-pressing" surface of the app to the "knowledge construction" required for science mastery (Chi & Wylie, 2014).

Discussion

The findings reveal a profound "Resilience Paradox" within the Philippine elementary science classroom. While teachers are successfully shifting toward the student-centered "discovery approach" (Hmelo-Silver et al., 2007)—with Participant 2 reporting a "25/75" split in labor—this progress is occurring in spite of, rather than because of, the institutional environment.

The data suggests that the teacher's pedagogical sense-making is characterized by a "survivalist innovation." Participant 3's strategy of saving offline backups to combat "brownouts" is more than just a workaround; it is a sophisticated cognitive adaptation to systemic instability. This confirms Thompson's (2023) theory that in resource-constrained settings, the "Technological Knowledge" (TK) of a teacher is defined less by software expertise and more by troubleshooting resilience.

A major interpretive insight is the tension between digital freedom and classroom discipline. As Chi and Wylie (2014) argue, interactive behavior is not a guarantee of constructive learning. Participant 4's experience of students wandering to "other pages" reveals that simulations introduce a new "noise" into the classroom.

Teachers are therefore caught in a contradiction: they want to facilitate "autonomy" and "discovery" (Darling-Hammond et al., 2022), yet the technology itself provides avenues for distraction that require them to revert to "monitoring and policing" (Michael, 2006). This suggests that the transition to digital tools does not make classroom management "easier"; it makes it more cognitively demanding, as the teacher must navigate the students' digital impulses while ensuring conceptual focus.

The financial barriers mentioned by Participant 1 ("Hindi kaya ng budget") represent a "Pedagogical Ceiling." When schools cannot afford premium simulations, teachers are often forced to use "low-fidelity" free versions. According to Almahasees et al. (2021), this inadequate investment directly affects the sustainability of the learning environment.

Analytically, this creates a "two-tier" science education system: one where students have "high-agency" virtual labs and another where students share a single device in a group (P8), leading to "uneven participation." This reality nuances the optimistic findings of Prince (2004) by showing that "Active Learning" is a luxury that requires significant financial scaffolding to be truly inclusive.

Finally, the discussion must address the myth that technology simplifies teaching. The "unsustainable issues" identified by Participant 5—feeling "tiring" to prepare digital activities, reveal that the teacher is the one bridging the gap left by a lack of institutional support.

When teachers describe the process as "exhausting," it indicates that the "Innovation vs. Fatigue" tension is nearing a breaking point. While Freeman et al. (2014) found that active learning improves scores, our qualitative data reveals the human cost of that improvement. For technology to be meaningfully integrated in the long term, the narrative must shift from "teacher-led resilience" to "institutionalized support," ensuring that the facilitator's role remains focused on science, not just systemic survival.

CONCLUSIONS

Based on the findings, it is recommended that elementary science teachers continue integrating digital simulations to enhance student engagement, critical thinking, and conceptual understanding while maintaining a balanced approach with traditional methods to support foundational learning. To overcome challenges such as technical issues, device limitations, and financial constraints, teachers should prepare offline alternatives and seek administrative support for reliable infrastructure and resources. Regular professional development and training are encouraged to strengthen teachers' digital competence, while collaborative teaching practices and ongoing technical assistance should be promoted to ensure effective and inclusive integration of digital tools in science instruction.

LIMITATION & FURTHER RESEARCH

The study is limited by its focus on teachers' experiences within a specific educational context, which may not reflect the diverse realities of schools with varying access to technology, infrastructure, and resources. Since the findings were based on qualitative insights, they may not fully capture the measurable effects of digital simulations on student performance and long-term learning outcomes. Further research should examine the impact of digital simulations through experimental or mixed-method designs, explore student perspectives on their effectiveness, investigate context-specific barriers in under-resourced schools, and assess the sustainability of professional development programs in strengthening teachers' digital integration practices.

REFERENCES

Adams, R., & Morgan, K. (2022). Digital mediation in the primary classroom: A phenomenological study of teacher–student interactions. *Journal of Educational Technology Systems, 50*(3), 345–362.

Almahasees, Z., Mohsen, K., & Amin, M. O. (2021). Faculty's and students' perceptions of online learning during COVID-19. *Frontiers in Education, 6*, Article 638470. https://doi.org/10.3389/feduc.2021.638470

Black, P., & Wiliam, D. (2022). Classroom assessment and the regulation of learning. *Assessment in Education: Principles, Policy & Practice, 29*(1), 12–25. https://doi.org/10.1080/0969594X.2022.2038198

Braun, V., & Clarke, V. (2021). *Thematic analysis: A practical guide*. SAGE Publications.

Brown, A. (2021). *Digital frontiers in elementary science: A qualitative perspective*. Academic Press.

Chi, M. T. H., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49*(4), 219–243.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications.

Dancsa, J. K., et al. (2023). Differentiated instruction through digital platforms: Meeting diverse learner needs in STEM. *Journal of Interactive Learning Research, 34*(2), 145–168. https://www.learntechlib.org/p/222145/

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97–140. https://doi.org/10.1080/00461520.2019.1673242

Davis, L. (2024). The digital transition: Qualitative insights into elementary teacher cognition and technology-mediated science. *International Journal of Qualitative Studies in Education, 37*(1), 12–29. https://doi.org/10.1080/09518398.2023.2178341

Delos Reyes, A., & Tan, R. (2023). Collaborative digital simulations: Promoting higher-order thinking in elementary science. *Journal of Philippine Education Research, 45*(2), 101–118.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education, 42*(3), 255–284.

Freeman, S., et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415.

Garcia, M. (2018). Integrating technology in the classroom: Motivation and engagement in primary education. *Journal of Educational Technology Systems, 47*(2), 201–218.

Garcia, M., & Santos, L. (2023). Technology-enhanced instruction and student motivation in the digital age. *Educational Media International, 60*(3), 215–230.

Garcia, R., Smith, J., & Lee, T. (2020). Adaptive learning through simulations: Catering to diverse learning styles and paces. *Educational Technology Research and Development, 68*(4), 234–250. https://doi.org/10.1007/s11423-020-09755-1

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning. *Educational Psychologist, 42*(2), 99–107.

Johnson, D., Smith, R., & Lee, T. (2020). The role of teachers' attitudes and beliefs in technology integration effectiveness in classrooms. *Computers & Education, 157*, Article 103973. https://doi.org/10.1016/j.compedu.2020.103973

Johnson, L. (2025). Instructional quality and integrated digital tools: A 2025 perspective. *Global Education Review, 10*(1), 15–32.

Karamti, C. (2016). Measuring the impact of ICTs on academic performance. *Journal of Research on Technology in Education, 48*(1), 21–36.

Kumar, S. (2025). Visual interaction and conceptual understanding in science. *Journal of Educational Multimedia and Hypermedia, 34*(1), 45–60.

Learning Journals. (2025). The role of multimodal content in elementary science mastery. *International Journal of STEM Education, 12*(1), 88–102.

Lee, S., & Park, J. (2019). The impact of digital simulations on student conceptual understanding in science. *Computers & Education, 134*, 45–59. https://doi.org/10.1016/j.compedu.2019.02.003

Lim, J., & Bautista, M. (2023). Interactive learning tools and student attention: A qualitative inquiry. *Journal of Computer Assisted Learning, 39*(4), 1102–1115.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications.

Lopez, C., & Rivera, K. (2023). Fostering innovation through digital simulations in primary education. *Technology, Knowledge and Learning, 28*(1), 45–62.

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*(4), 159–167.

Miller, T., & Thomas, L. (2022). Virtual laboratories and the shift toward student-centered learning. *International Journal of STEM Education, 9*(1), Article 12. https://doi.org/10.1186/s40594-022-00330-w

Nguyen, T. (2022). Visualizing the invisible: A case study of teacher sense-making using science simulations. *Education and Information Technologies, 27*(4), 5121–5140. https://doi.org/10.1007/s10639-021-10825-7

Ocampo, R. (2024). The role of immersive visuals in knowledge retention. *Philippine Journal of Science Education, 12*(1), 34–50.

Paivio, A. (1986). *Mental representations: A dual coding approach*. Oxford University Press.

Parker, M., & Lee, S. (2024). Bridging the tactile and the virtual: A hybrid approach to primary science. *Educational Technology Research and Development, 72*(3), 412–430.

https://doi.org/10.1007/s11423-023-10255-w

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231.

Ramirez, J. (2022). Analytical reasoning and decision-making in virtual environments. *Science & Education, 31*(5), 1245–1263.

Reyes, E., & Dela Cruz, J. (2023). Streamlining formative feedback through technology-assisted tools. *Assessment & Evaluation in Higher Education, 48*(2), 302–315.

Rivera, M., & Santos, D. (2024). Virtual labs in resource-constrained environments: A qualitative study. *Journal of Science Education and Technology, 33*(1), 55–70. https://doi.org/10.1007/s10956-023-10064-y

Saldaña, J. (2021). *The coding manual for qualitative researchers* (4th ed.). SAGE Publications.

Santiago, M. (2024). Real-time data and targeted instruction in the modern classroom. *Computers & Education, 210*, Article 104932.

Smith, J., & Johnson, R. (2020). *Pedagogical shifts in the digital age: A handbook for teachers*. Routledge.

Stevens, R., et al. (2021). 21st-century education principles and real-world application. *Educational Leadership, 78*(5), 44–51.

Tan, P., & Morales, G. (2024). Modernizing lesson delivery: The impact of simulations on teacher efficiency. *Journal of Science Teacher Education, 35*(2), 180–198.

Thompson, S. (2023). Freedom vs. control: A qualitative inquiry into the pedagogical tensions of virtual labs in elementary schools. *Journal of Science Education and Technology, 32*(2), 210–225. https://doi.org/10.1007/s10956-022-10012-4

Tondeur, J., et al. (2017). Preparing pre-service teachers to integrate technology in education. *Technology, Pedagogy and Education, 26*(2), 157–175.

Zhao, Y., et al. (2002). Conditions for classroom technology innovations. *Teachers College Record, 104*(3), 482–515.