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Pedagogical Negotiation in an Unequal Digital Ecosystem: A Case Study of Science Education in Higher Education

Ariansyah[1]*, Muhammad Roil Bilad[2], Sutarto[3], Nova Kurnia[1], Kadir Alpan Alaydrus[1], Pathan[1], Irham Azmi[4], & Sergii Sharov[5]

[1] Science Education Department, Universitas Pendidikan Mandalika, Mataram, INDONESIA
[2] Department of Integrated Technologies, Universiti Brunei Darussalam, Gadong, BRUNEI DARUSSALAM
[3] Mathematics Education Department, Universitas Pendidikan Mandalika, Mataram, INDONESIA
[4] Physics Education Department, Universitas Pendidikan Mandalika, Mataram, INDONESIA
[5] Department of Computer Science, Dmytro Motornyi Tavria State Agrotechnological University, Zaporizhzhia, UKRAINE

*Corresponding author e-mail: ariansyah@undikma.ac.id

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Abstract

This study qualitatively investigates the dynamics of digital technology use in science education at the university level, aiming to fill a gap in the literature that predominantly emphasizes quantitative impacts over user experiences. Employing a case study design, data were collected from six lecturers and ten students in West Nusa Tenggara through in-depth interviews. The data were analyzed iteratively using a Grounded Theory approach to develop a theoretical explanation rooted in participants' lived experiences. The main finding of this study is a substantive theory: the Model of Pedagogical Negotiation in an Unequal Digital Ecosystem. This theory posits that the effectiveness of technology lies not in its sophistication but in the ability of lecturers and students to engage in "pedagogical negotiation" to overcome systemic barriers. Two key barriers were identified: (1) a multifaceted digital divide (infrastructural, economic, geographical), often "invisible" to institutions, and (2) institutional fragmentation caused by non-standardized platforms and a lack of coordination among lecturers, which creates a stressful and inefficient learning environment. In conclusion, optimizing digital technology in education requires a paradigm shift from merely providing tools toward building a supportive, inclusive, and human-centered learning ecosystem.

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INTRODUCTION

The advancement of digital technology has triggered a revolution across various aspects of life, including higher education. In the context of science learning, the emergence of technologies such as interactive simulations, Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI) offers transformative potential to reshape how students comprehend complex and abstract scientific concepts (Erduran, 2024). Through multimodal approaches, students can shift from conventional text-based methods toward more visual, interactive, and contextual learning experiences (Cooper et al., 2024). Realistic digital visualizations have been shown not only to enhance conceptual understanding but also to foster active student engagement (Tsivitanidou et al., 2021), in line with 21st-century competency demands (Guan et al., 2022).

This potential is manifested in various forms. The use of AR simulations, for instance, has been shown to improve students' understanding of abstract physical laws by translating them into concrete and manipulable visual forms (Vidak et al., 2023). Similarly, gamification strategies have demonstrated their ability to enhance motivation and student engagement in learning processes that are often perceived as difficult (Khattib & Alt, 2024). Furthermore, digital technology serves as a backbone for active learning approaches such as inquiry-based learning, which encourages students to engage in independent exploration and construct their own knowledge—an essential process aligned with constructivist learning theory (Ješková et al., 2024).

However, despite this optimism, the implementation of digital technology in educational settings is frequently challenged by complex obstacles. The success of technology integration depends not solely on the sophistication of tools but also on the readiness of the educational ecosystem, including user competence and effective pedagogical design (Nilsson & Lund, 2023). Many educators struggle to meaningfully integrate technology into the curriculum, often due to limited digital skills or a lack of understanding of how to harmonize technology and pedagogy (Khaokhajorn & Srisawasdi, 2024).

More importantly, a significant gap exists in the academic literature. Most studies tend to focus on quantitative outcomes, such as learning gains or platform effectiveness (Kotzebue et al., 2021), while deeper insights into qualitative dimensions—such as the dynamics of learning processes, perceptions, and lived experiences of lecturers and students as primary users—remain underexplored (Forde & O'Brien, 2022). Yet, it is this holistic understanding of process and user experience that is crucial for formulating contextual and sustainable interventions, rather than merely offering temporary technical fixes (Ribosa & Duran, 2024).

This gap becomes especially relevant within the context of higher education in Indonesia, which is currently undergoing an accelerated digital transformation. Institutions are encouraged to innovate, yet their success is highly contingent upon an in-depth understanding of grassroots realities (Dewi et al., 2021). The effectiveness of technology-driven approaches has been shown to depend heavily on the readiness of human resources and the design of pedagogical models that support them (Nugraheni & Srisawasdi, 2025). Therefore, this study aims to address this void by exploring the authentic experiences of educational stakeholders. Specifically, this article seeks to characterize the use of digital technology in university-level science education, identify challenges and barriers from the perspectives of lecturers and students, and articulate their aspirations for creating a more effective and human-centered digital learning ecosystem.

METHODS

This study employed a qualitative approach with a case study design to deeply explore the phenomenon of digital technology use in the context of science education in higher education. This design was selected due to its relevance in addressing "how" and "why" questions regarding a contemporary phenomenon within real-life contexts (Yin, 2018), thus enabling the researcher to capture the complexity of participants' experiences and perceptions.

The participants consisted of six lecturers and ten students from several universities in West Nusa Tenggara, Indonesia. Participants were selected using purposive sampling to ensure they had rich and relevant experiences related to the research topic, and this was further expanded through snowball sampling. The number of participants was determined based on the principle of data saturation, in which data collection ceased once no new significant themes or insights emerged from the interviews (Fusch & Ness, 2015).

Data collection primarily relied on in-depth interviews as the main method. These interviews served as the core data source, aimed at richly capturing participants' perceptions, experiences, and subjective meanings. To enhance validity and provide additional context to the narrative data, the study also selectively employed participant observation and document analysis. These two methods served as supporting data sources, used triangulatively to clarify or verify specific findings emerging from the interviews, depending on the analytical needs in the field.

Data analysis was conducted in an interactive and iterative manner, adopting the analytical framework of Miles et al. (2014), combined with strategies from the Grounded Theory approach (Charmaz, 2014). The process involved three main stages: (1) open coding to reduce the data and identify initial categories; (2) axial coding to connect categories and develop core themes; and (3) selective coding to integrate those themes into a theoretically grounded model. To ensure data credibility, the study applied triangulation strategies (comparing data from multiple sources and methods) and member checking by presenting preliminary findings to participants for validation (Creswell, 2014).

RESULTS AND DISCUSSION

In-depth qualitative analysis of interviews with six lecturers and ten students revealed a complex—and often contradictory—dynamic in the use of digital technology for science education. Using a Grounded Theory approach, the analysis not only identified a range of challenges and opportunities but also culminated in the formulation of a substantive theory that encapsulates the participants' collective experiences.

The primary outcome of this study is a conceptual model titled: *The Pedagogical Negotiation Model in an Unequal Digital Ecosystem*.

Formally, the theory can be stated as follows:

> *"The effectiveness of digital technology in science education is not determined solely by the sophistication of the tools themselves, but rather by the success of the pedagogical negotiation process carried out by lecturers and students to bridge the gap between the transformative potential of technology and the systemic constraints they face (digital divide and institutional fragmentation). The success of this negotiation, in turn, depends heavily on the level of institutional support and the visibility of the problems encountered by users."*

This model posits that the effectiveness of technology is the outcome of an ongoing "negotiation" between lecturers and students to overcome various barriers. This can be visualized as illustrated in Figure 1.

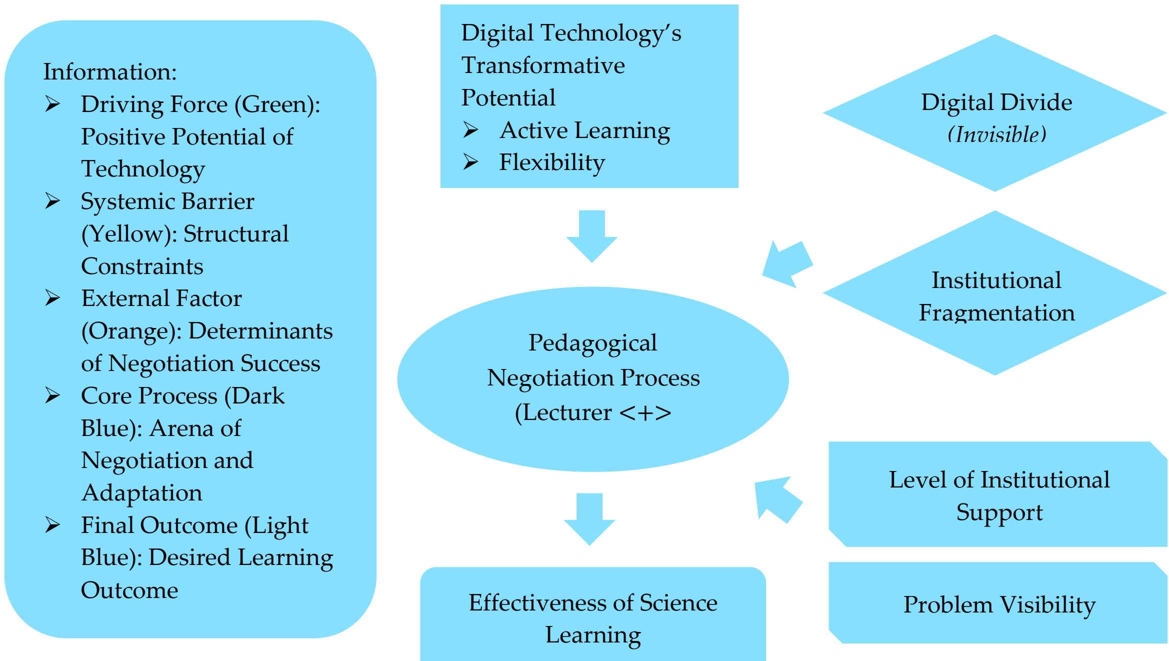

Figure 1. Conceptual model diagram of Pedagogical Negotiation Model

The findings that support this model are presented across three main themes, as summarized in Table 1.

Table 1. Thematic Matrix of Research Findings

Main Theme	Sub-Theme	Description and Key Findings	Key Participant Quotes
Transformative Potential of Technology in Active Learning	Technology as a Catalyst for Active Learning	Technologies such as PhET simulations effectively transform learning from passive to active when integrated within a clear pedagogical framework like inquiry-based learning. This facilitates deep knowledge construction.	*"I didn't just ask them to open the simulation, I gave them a worksheet with guiding questions... So, the technology wasn't just something to watch—it became a tool for investigation."* (DS-06)

Main Theme	Sub-Theme	Description and Key Findings	Key Participant Quotes
	Visualization of Abstract Concepts	Interactive simulations help students grasp abstract science concepts (e.g., electric fields) by converting them into manipulable visual representations, making the learning process more intuitive and effective.	*"What used to be just formulas in a book... when using the simulation, I could drag the charges and see the arrows shift. It just 'clicked'—I immediately understood."* (MS-06)
	Flexibility and Autonomy in Learning	The availability of digital materials, such as recorded lectures, provides students with the flexibility to learn at their own pace, reducing academic anxiety and boosting self-confidence.	*"With recorded lectures, I can replay difficult parts multiple times... This makes me less anxious if I fall behind in class."* (MS-10)
Digital Divide as an Invisible Systemic Barrier	Geographic and Infrastructure Dimensions	Students from areas with unstable electricity and internet infrastructure often miss synchronous learning opportunities (e.g., Zoom classes), creating unequal access to education.	*"I often missed online classes... because in my village in Sumbawa, power outages are frequent. When the electricity goes out, the signal also disappears."* (MS-07)
	Economic Dimensions	Financial constraints force students to make difficult choices, such as sacrificing access to video-based learning materials to save on data costs, which directly hinders full participation.	*"...sometimes I have to skip watching explanation videos just to save data."* (MS-10)
	The Problem as an "Invisible Barrier"	Students tend not to report access issues (connectivity, data) because they perceive them as personal problems. As a result, institutions and lecturers lack a complete understanding of the students' realities.	*"...connection or data problems are personal matters beyond the lecturer's control, so we don't often complain to them."* (MS-06)
Institutional Fragmentation as a Source of Stress and Inefficiency	Non-standardized Platforms	The use of various different learning platforms by individual lecturers creates cognitive and administrative burdens for students, shifting their focus from learning content to managing multiple systems.	*"It feels like more time is spent switching between platforms... than actually focusing on the material. It's really inefficient."* (MS-08)
	Lack of Coordination Among	The accumulation of assignments with overlapping deadlines—due to poor coordination—forces	*"There was a day when we had three assignments from three different courses, all*

Main Theme	Sub-Theme	Description and Key Findings	Key Participant Quotes
	Lecturers	students to stay up late, negatively affecting their learning focus and physical and mental health.	*due at 11:59 PM. We ended up staying up late, and couldn't focus the next morning in class."* (MS-08)
	Psychological Burden and Social Isolation	When technology is implemented without efforts to build social interaction, learning feels transactional and may increase feelings of isolation among students.	*"I feel more isolated. Classes feel like transactions... We need to rebuild the social spaces and interactions that were lost."* (MS-09)

To provide a deeper understanding, the following section elaborates on each of the core themes that form the foundation of the theoretical model developed in this study, as summarized in the table above:

Theme 1: The Transformative Potential of Technology in Active Learning

The data reveal that when used effectively, digital technology acts as a catalyst capable of transforming learning from passive to active and meaningful. This potential is realized when lecturers consciously integrate technology into a well-defined pedagogical framework. A physics lecturer (DS-06) described his strategy in utilizing PhET simulations:

> *"I designed it within an inquiry-based learning framework. I didn't just ask them to open the simulation—I gave them a student worksheet containing guiding questions. They had to find the answers by conducting 'experiments' in the PhET simulation. So, the technology wasn't just something to watch—it became a tool for investigation."*

This approach significantly changed students' learning experiences. A student (MS-06) described how this strategy helped him understand abstract concepts more easily:

> *"Concepts that were previously just formulas in a book, like electric fields, were very abstract. But with the simulation, I could drag the charges, see the arrows move. It just 'clicked'—I instantly got it. It felt like playing a game while learning."*

In addition, technology also provided flexibility that supported learner autonomy and reduced academic anxiety. A chemistry student (MS-10) described recorded lecture videos as a "luxury" that helped him master difficult material:

> *"With recorded lectures, I can replay difficult parts again and again in my room until I really understand… Being able to review the material reduces my anxiety if I fall behind in class. It helps me feel more confident in learning."*

Thus, the findings suggest that the transformative potential of technology is maximized when it functions not merely as a tool, but as an integral element of a pedagogical design that empowers students.

Theme 2: The Digital Divide as an Invisible Systemic Barrier

The transformative potential of technology constantly clashes with the most fundamental systemic barrier: the multifaceted digital divide. This issue is not merely theoretical but represents a lived reality. As one lecturer (DS-04) noted, "This is not theory—this is the daily reality in my classroom." The digital divide includes geographic dimensions, as experienced by a student (MS-07) from outside Lombok Island:

"I often missed Zoom classes because in my village in Sumbawa, power outages are frequent. When the electricity goes out, the signal disappears too. In the end, I could only read the materials without hearing the lecturer's explanations."

Moreover, there are economic dimensions that force students into difficult trade-offs between participation and cost. As MS-10 stated:

"...sometimes I have to give up watching explanatory videos just to save on data."

Ironically, these barriers are often "invisible" to lecturers and institutions. Students tend to withhold these issues, viewing them as personal matters, as MS-06 explained:

"...connection or data problems are personal issues beyond the lecturer's control, so we don't really complain about them."

As a result, the digital divide not only hinders access but also becomes an invisible systemic barrier that prevents institutions from designing effective and responsive solutions.

Theme 3: Institutional Fragmentation as a Source of Stress and Inefficiency

The second systemic barrier identified is institutional fragmentation. This manifests in two primary ways: the use of non-standardized learning platforms and poor coordination among lecturers in assigning coursework. These conditions create an inefficient learning environment and serve as a source of psychological stress for students. A student (MS-08) described the impact:

"Lecturers use different platforms—some use Moodle, others Google Classroom, Edmodo… It feels like more time is spent switching between apps and making sure we don't miss information than actually learning the material. It's really inefficient."

This inefficiency is exacerbated by a lack of coordination among lecturers, leading to overlapping assignments and excessive workloads at certain times. This not only disrupts the learning process but also affects students' well-being. MS-08 added:

"There was one day when we had three assignments from three different courses, all due at 11:59 PM. We ended up staying up late, and the next morning's class was hard to focus on. Our health also suffered."

Therefore, institutional-level fragmentation directly diverts students' energy away from substantive learning toward administrative management, ultimately becoming burdensome and counterproductive.

The findings of this study confirm that the successful integration of technology in science education is a process far more complex than the mere provision of digital tools. In line with the view of Nilsson & Lund (2023), technological effectiveness is highly dependent on the preparedness of the educational ecosystem and the pedagogical design accompanying it. Accordingly, this discussion unpacks each component of the proposed model—from the transformative potential of technology and the negotiation arena shaped by systemic barriers, to its theoretical implications—building a coherent argument about the dynamics of digital technology integration in higher education science learning.

A key finding of this study is the characterization of digital technology use as having evolved beyond its function as a mere technical aid. As articulated in the first component of the Pedagogical Negotiation Model, digital technology serves as a driving force with transformative potential. However, this potential is not inherent in the technology itself; it is realized through deliberate alignment between the tools used and the pedagogical strategies employed by lecturers. The clearest example of this transformation is illustrated in the case of Lecturer DS-06, who explicitly framed the use of PhET simulations within an inquiry-based learning approach. By providing student worksheets (LKM) with guiding questions, he turned technology from a passive "visual aid" into an active "investigation tool."

This strategy fundamentally altered classroom dynamics. Student MS-06 described this experience with the phrase "it just clicked—I instantly understood," which is a tangible manifestation of successful knowledge construction. This "click moment" empirically supports Constructivist Theory, which posits that learning is an active process of building understanding through interaction and exploration (Ješková et al., 2022). Interactive simulations create a digital "learning environment" where students can independently manipulate variables and observe consequences, enabling them to form deep scientific representations—a finding that aligns with results from Cirkony et al. (2022).

From an instructional standpoint, this alignment between technology and pedagogy reflects mastery of the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006). Effective lecturers like DS-06 demonstrate capabilities beyond Technological Knowledge and Content Knowledge; they successfully integrate these with Pedagogical Knowledge to create meaningful learning experiences. They do not merely select appropriate technologies—they consciously design pedagogical experiences around them. This reinforces findings from Nugraheni & Srisawasdi (2025), which emphasize that mastery of TPACK is key to delivering student-centered science education.

Moreover, the characterization of technology as a transformational tool is further evidenced by its impact on student motivation, which can be examined through the lens of Self-Determination Theory (SDT). The experience of Student MS-10, who described the ability to rewatch recorded lectures as a "luxury" that helped him understand difficult material, provides a concrete example of how technology supports autonomy in learning. He noted:

> *"With recorded lectures, I can replay difficult parts over and over in my room until I really understand… Being able to review the material reduces my anxiety if I fall behind*

in class. It helps me feel more confident in learning."

This quote illustrates how technology, when used to provide flexibility, directly meets the psychological needs for autonomy (control over learning pace) and competence (ability to master material), which in turn reduces anxiety and enhances intrinsic motivation—consistent with the core principles of SDT (Ryan & Deci, 2000). Thus, the most impactful use of technology occurs when it evolves from being merely a tool for information delivery into an integral component of a transformative pedagogical design—one that repositions students from passive recipients to active, motivated, and autonomous constructors of knowledge.

Despite the apparent transformative potential of technology, the findings of this study reveal that such potential does not operate in a vacuum. It is constantly confronted by a series of systemic barriers, creating what the *Pedagogical Negotiation Model* refers to as a "negotiation arena." It is within this arena that the actual effectiveness of digital technology is determined. The first and most fundamental barrier is the digital divide—a real, multifaceted issue. This is not merely a matter of slow internet speeds but a complex problem involving infrastructure, economic conditions, and geography, all of which directly exacerbate educational inequality—a risk also highlighted by Zhong (2024).

This reality puts a human face on statistical data about inequality, as illustrated by Student MS-07 in Sumbawa, who described how external factors beyond his control severely hindered his learning opportunities:

"I often missed online Zoom classes because in my village in Sumbawa, there were frequent power outages. When the electricity goes out, the signal also disappears. In the end, I could only read the materials without hearing the lecturer's explanation."

This quote highlights the direct impact on the learning process: students lose access to the rich, discursive understanding offered through live instruction—an essential element that cannot be replaced by text-based materials. Additionally, there is an economic dimension that forces students into difficult trade-offs between active participation and financial limitations. For instance, Student MS-10 shared that he had to *"…sacrifice watching explanation videos just to save on data."*

This dilemma directly undermines students' autonomy in learning. According to Self-Determination Theory (SDT), choices made under external constraints diminish intrinsic motivation and autonomy, as decisions are no longer based on academic needs but on economic necessity.

Ironically—and this represents one of the study's most critical findings—these systemic issues often become "invisible barriers" for lecturers and institutions. Students tend not to report access and cost-related challenges, viewing them as personal matters not appropriate to raise. Student MS-06 explained this dynamic clearly:

"...problems with connection or data are personal issues beyond the lecturer's control, so we don't often complain to them."

This attitude creates a significant information gap. As a result, even teaching strategies developed under ideal TPACK conditions become ineffective because they are not grounded in an accurate understanding of students' lived realities. The failure to grasp this context becomes a critical point that impedes successful pedagogical negotiation, reinforcing the idea that no matter how advanced the technology, contextual user factors remain the primary determinants of its effectiveness (Mulla, 2024).

Beyond the digital divide stemming from individual and infrastructural levels, this study identifies a second systemic barrier originating at the institutional level: fragmentation. This barrier manifests in two main forms: (1) the use of non-standardized learning platforms across lecturers, and (2) poor coordination in the assignment of coursework. Collectively, these conditions create an inefficient learning environment, increase students' cognitive load, and become a significant source of psychological stress. These findings underscore that the success of technology integration heavily depends on institutional preparedness and the design of a supportive ecosystem (Dewi et al., 2021).

Platform fragmentation forces students to constantly switch between applications—official LMS, Google Classroom, WhatsApp, email—simply to ensure that no information is missed. This practice has proven to be highly counterproductive. A student (MS-08) described how this fragmented environment diverted their focus away from actual learning:

> "*Lecturers use all sorts of platforms—some use Moodle, others Google Classroom, Edmodo… It feels like we spend more time switching between apps and checking for updates than focusing on the course material. It's really inefficient*."

This situation directly disrupts the constructivist learning process. Instead of using their cognitive resources to construct scientific understanding, students are burdened by confusing administrative management tasks. The inefficiency is compounded by a lack of coordination among lecturers, resulting in an accumulation of tasks at certain times and directly impacting students' physical and mental well-being. MS-08 further noted:

> "*There was a day when we had three assignments from three different courses, all due at 11:59 PM. We ended up staying up late, and the next morning's class was hard to focus on. Our health also suffered*."

This phenomenon illustrates what Lecturer DS-06 referred to as a form of "policy irony": institutions aggressively promote innovation without strengthening the foundational coordination and standardization mechanisms required to support it. When the system fails to provide a coherent framework, the burden of managing that chaos falls entirely on students. This highlights that, without coordinated policies and systemic support, innovations at the individual level—whether from lecturers or students—are unsustainable and may, paradoxically, generate new burdens (Sidik et al., 2023).

Beyond offering a deep understanding of field dynamics, the findings of this study also provide significant theoretical implications, particularly in enriching two major frameworks: Technological Pedagogical Content Knowledge (TPACK) and Self-Determination Theory (SDT). The study reveals that applying these frameworks in the context of an unequal digital learning environment requires greater emphasis on dimensions that are often overlooked.

First, the study highlights the limitations of the TPACK model when it is not supported by a deep contextual understanding. The TPACK framework, developed by Mishra & Koehler (2006), brilliantly maps the three core knowledge domains required by educators. However, the phenomenon of *"invisible barriers"* uncovered in this study shows that a lecturer may possess strong TPACK capabilities, yet still fail in instructional strategy due to a disconnect from the students' socio-economic and geographic realities. When a lecturer (DS-04) deliberately selected technology based on an "awareness of students' socio-economic and geographic context," they were, in fact, applying a domain of knowledge that lies beyond traditional TPACK.

Therefore, we argue that the TPACK model must be enriched with a crucial fourth dimension: Contextual Knowledge. Without an accurate understanding of students' actual conditions—access, infrastructure, and local realities—even the most advanced integration of technology, pedagogy, and content risks becoming irrelevant and exclusionary.

Second, the study strongly emphasizes the importance of relatedness—a core component of SDT that is frequently underemphasized in educational technology literature. While many studies focus on how technology supports autonomy and competence, they often overlook the fact that learning is inherently a social process. The pointed critique from Student MS-09, who felt that learning had become "just a transaction" and led to a greater sense of isolation, provides powerful empirical evidence of the negative effects of technology implementation that neglects human connection:

> *"I feel more isolated. Classes feel like just a transaction: the lecturer gives material, we complete the task, submit it, get a grade… The point is, we need more than just transferring materials to digital. We need to rebuild the social interactions and spaces that have been lost."*

This quote underscores that fulfilling the need for relatedness is not optional—it is a prerequisite for creating a healthy and intrinsically motivating learning environment. These findings address a gap noted by Dewi et al. (2021) and Susyanah & Fajar (2024), who highlight the lack of research exploring how technology affects classroom social dynamics. Accordingly, this study offers a theoretical reminder that the ultimate goal of digital innovation is not to create cold efficiency, but to reinforce—rather than replace—the human connections that are at the heart of education.

CONCLUSION

Based on the analysis and discussion presented, this study concludes that the effectiveness of digital technology in university-level science education is not determined by the sophistication of the tools themselves, but rather by the success of the pedagogical negotiation process undertaken by lecturers and students in navigating an unequal digital ecosystem.

First, the most effective use of technology is characterized by its pedagogical transformation. When technologies such as interactive simulations are deliberately integrated into active learning strategies—such as inquiry-based learning—they have been shown to significantly enhance students' understanding of abstract concepts and boost motivation. Second, the main challenges encountered are systemic and external in nature, rooted in two fundamental issues: (1) a multifaceted digital divide (infrastructure, economic, and geographic), often manifesting as "invisible barriers," and (2) institutional fragmentation that leads to inefficiencies and psychological burdens for students.

The primary implication of this study is the need for a paradigm shift among higher education stakeholders: from merely focusing on the provision of digital tools toward a more foundational effort to build a supportive, inclusive, and well-coordinated digital learning ecosystem. This requires investments in reliable infrastructure, platform standardization, and the development of digital pedagogical competencies grounded in an understanding of students' real-life contexts.

This study is limited by its qualitative nature and the specificity of its context, which restricts the generalizability of its findings. Therefore, future research is encouraged to adopt quantitative or mixed-methods approaches to measure the impact of the proposed model on a broader scale, or to conduct longitudinal studies to observe the evolution of pedagogical negotiations over time.

LIMITATIONS

This study has several limitations that should be acknowledged. First, the research employed a qualitative case study design with a relatively small sample of six lecturers and ten students from universities in West Nusa Tenggara. While this design enabled rich and in-depth exploration of participants' lived experiences, it inherently restricts the generalizability of the findings beyond the studied context. Second, the study's reliance on self-reported data through interviews may have been subject to participant bias, such as selective recall or a tendency to underreport challenges perceived as personal (e.g., connectivity or financial issues). Although triangulation with observation and document analysis was used to enhance credibility, the possibility of bias cannot be fully eliminated. Third, the study is context-bound to a specific geographic and socio-economic environment in Indonesia, where infrastructural and institutional challenges are particularly pronounced. Consequently, the proposed Pedagogical Negotiation Model may not fully capture the dynamics in regions with more advanced digital infrastructure or different institutional structures. Finally, the research captures a single temporal snapshot of participants' experiences. As digital ecosystems evolve rapidly, future studies employing longitudinal or mixed-methods designs are needed to track how pedagogical negotiations adapt over time and to test the model's applicability across broader educational contexts.

RECOMMENDATIONS

Based on the findings of this study, several recommendations can be proposed for educators, institutions, policymakers, and future researchers. For educators, it is important to integrate digital technologies within clear pedagogical frameworks such as inquiry-based learning so that these tools serve as active instruments for knowledge construction rather than passive aids. Professional development programs should also focus on strengthening lecturers' mastery of Technological Pedagogical Content Knowledge (TPACK) while incorporating Contextual Knowledge to ensure that teaching strategies are responsive to students' socio-economic and geographic realities. At the institutional level, universities should address systemic challenges by standardizing digital learning platforms and improving coordination mechanisms among lecturers to reduce administrative fragmentation and inefficiencies. Institutions also need to invest in robust digital infrastructure and provide targeted support for students in disadvantaged regions, thereby helping to bridge the digital divide. From a policy perspective, national and regional education authorities should design strategies that go beyond promoting technological innovation to actively ensure equity of access. This includes providing subsidies for internet access, improving rural digital infrastructure, and fostering inclusive digital ecosystems that empower both lecturers and students.

Finally, for future research, it is recommended that mixed-methods or quantitative approaches be employed to assess the broader impact of the Pedagogical Negotiation Model across diverse educational contexts. Longitudinal studies are also needed to trace how pedagogical negotiations evolve over time in line with technological advancements and institutional reforms. Furthermore, comparative studies across regions or countries with varying levels of digital infrastructure would provide valuable insights into the model's transferability and adaptability.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

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Conflict of Interests

The authors declare no conflict of interest.

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