

Optimizing Digital Interactive Boards (DIBs) in Building a Student-Centered Learning Ecosystem: An Analysis of Teacher Readiness and Adaptation

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Abstract: This study analyzes the optimization of Digital Interactive Boards (DIBs) in building student centered learning ecosystems, focusing on teacher readiness and adaptation. A Systematic Literature Review (SLR) was conducted, synthesizing 15 peer-reviewed articles published between 2021 and 2026 from Scopus and ERIC databases. The findings reveal that DIB effectiveness is contingent upon three interrelated factors: (1) teacher readiness encompassing technological, pedagogical, and psychological dimensions; (2) a staged adaptation process moving from technical onboarding to pedagogical transformation; and (3) institutional support including ongoing training and collaborative school culture. The novelty of this study lies in its integrated framework linking teacher readiness analysis with student centered ecosystem development, shifting the discourse from technology adoption to human adaptation. Practically, the findings emphasize the need for sustained professional development programs, responsive technical infrastructure.

Keywords: Adaptation Analysis, Digital Interactive Boards, Student-Centered Learning Ecosystem, Teacher Readiness

A. Introduction

Digital transformation in education has become a fundamental imperative in the era of the industrial revolution 4.0, promising increased access, personalization of learning, and 21st-century competency development (Yuwanti et al., 2025). However, a critical gap continues to widen between massive investment in technological infrastructure and real pedagogical changes in the classroom. As expressed by (Septio & Madhakomala, 2025) In their systematic review, digital transformation is a multifaceted process that goes beyond just technology adoption, demanding fundamental changes in pedagogy, school culture, and human resource competencies. (Irvani et al., 2024) emphasizing that access to strong digital infrastructure alone is not enough, as structural challenges such as policy inconsistency and limited professional development of teachers are the main obstacles to the success of technology integration. Learn More, (Yuwanti et al., 2025) In a literature review they identified that although innovative pedagogical strategies such as project-based learning and

flipped classroom have proven effective, their implementation has been hampered by unequal access to technology, limited digital competence of educators, and resistance to educational change. This gap between technology investment and pedagogical change, if not addressed immediately, risks turning digital infrastructure into a mere "meaningless decoration" in the classroom, instead of being a catalyst for meaningful educational transformation.

A review of research on interactive whiteboards (PTIs) in education shows significant potential as well as a persistent implementation gap between technology investment and pedagogical change. On the one hand, various studies confirm that PTI can increase student participation, motivation, and collaboration, especially when integrated with active student centered teaching strategies. However, critical gaps continue to be identified: (Smith et al., 2005) in their critical literature review they warn that although the literature is very positive, evidence about the actual impact of PTI on learning outcomes is still inadequate, and claims of success are largely based on teacher and student perceptions of objective data. (Khambari et al., 2014) asserts that the main debate revolves around teacher centered versus student-centered modes of instruction, where teachers continue to be blamed for the way they use PTI without considering contextual factors such as inadequate training, negative perceptions of technology initiatives, and technical issues that hinder implementation. Further, research in various contexts from Peru to India has consistently revealed that most teachers use PTI only as a digital whiteboard, failing to harness its interactive potential due to a lack of digital pedagogical competence and meaningful ongoing training. This gap between transformational expectations and the superficial realities of use underscores the need for a more holistic approach, where investment in PTI hardware must be balanced with sustainable teacher professional development, restructuring of classroom pedagogy, as well as systematic institutional support for these technologies to truly function as catalysts for meaningful learning changed.

Although various contemporary education reforms explicitly emphasize the importance of student-centered learning ecosystems as well as the use of digital technologies, significant systemic gaps continue to be identified between teachers' readiness, their pedagogical adaptation capacity, and the demands of a learner-centered learning environment. This problem is increasingly complex because the transformation towards student-centered pedagogy demands not only technical mastery of digital devices, but also fundamental changes in the teacher's professional identity as well as context-responsive pedagogical reasoning skills. As revealed by (Lizamuddin et al., 2025) on teachers' pedagogical adaptation to digital culture, the adaptation process is a multidimensional process characterized by a shift from a teacher-centered orientation to a student-centered digital orientation, however this shift is largely determined by the teacher's professional identity and reflective decision-making as a central mechanism. Research by (Dinçer, 2024) further emphasizing this gap by finding that significant deficiencies in teachers' design dimensions and proficiency within the TPACK (Technological Pedagogical Content

Knowledge) framework have a direct impact on their ability to effectively integrate technology to support student-centered learning. Learn More, (La Fleur & Dlamini, 2022) Identifies that the main obstacle to student-centered pedagogy and the implementation of technology-based learning is the misalignment between teachers' digital capabilities and the demands of technology-equipped 21st century classrooms, where existing professional development activities are generally episodic and narrowly focused on pedagogical technical knowledge.

Formulating the right research questions and articulating the contribution of the study clearly are two fundamental elements that determine the quality and impact of an academic manuscript. Research questions serve as a compass that guides the entire investigative process, from the selection of methodological design to the interpretation of findings, so they must be formulated explicitly and specifically to avoid ambiguities that can confuse the reader. In this context, the identification of the research gap is a crucial first step, where the researcher does not simply state that no studies have examined topic X yet, but must convincingly explain why the gap is important and how it will be filled in the discipline. As the experts affirm, the contribution of research should be articulated by showing exactly how the study changes, expands, or challenges existing knowledge, rather than simply claiming to be an often insubstantial first study. Learn More, (Sefcik et al., 2024) explains that an effective introduction should gradually narrow the focus from a broad area to a specific question, ending with a statement of purpose that flows seamlessly into the method section. In his analysis of successfully published manuscripts (Mur-Dueñas, 2014), he found that explicit articulation of contributions whether empirical, theoretical, or methodological is a determining factor in editorial decisions, where manuscripts that fail to clearly state contributions are likely to receive major revisions or rejections. Thus, the integration between a sharp research question and a well-defined statement of contribution not only frames the study logically but also convinces the scientific community of the significance and novelty of the work.

B. Methods

This study employed a Systematic Literature Review (SLR) following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The review protocol included the following steps: Research Question: How can the implementation of Digital Interactive Boards be optimized to foster a student centered learning environment, considering the critical factors of teacher readiness and adaptation? Search Strategy: A systematic search was conducted in Scopus, ERIC, and Google Scholar using Boolean operators: (digital interactive board OR interactive whiteboard OR smartboard OR interactive flat panel) AND (teacher readiness OR teacher preparedness OR teacher adaptation) AND (student centered learning OR learner-centered OR active learning). Inclusion Criteria: Articles were included if they were (1) peer-reviewed, (2) published between 2021 and 2026, (3) written in English or Indonesian, (4) focused on K-12 education, and (5) empirically examined the use of

interactive boards in educational settings. Screening Process: Initial database searches yielded X records. After removing duplicates, X articles were screened by title and abstract. Full-text eligibility assessment was conducted for X articles, resulting in 15 articles meeting all inclusion criteria. A PRISMA flow diagram (Figure 1) illustrates this process. Quality Assessment: Included studies were quality-appraised using established criteria (e.g., CASP for qualitative studies, appropriate tools for quantitative studies). Data Extraction and Synthesis: Data were extracted using a standardized form and analyzed using thematic synthesis, identifying patterns, themes, and relationships across studies.

C. Results and Discussion

Table 1. Article Journal Reviewed

No	Title	Author and year	Research Objectives	Research methods	Research results	Conclusion
1	The Impact of Digital Interactive Boards on the Intrinsic Motivation of Grade VI Students in Indonesian Language Subjects	(Adhi Pradana, 2026)	The main purpose of this study is to analyze in depth and interpretively the impact of the use of Digital Interactive Boards on increasing intrinsic motivation grade VI students in Indonesian language subjects at SD Negeri Arjowinangun	Conventional methods in the digital context in fact, there is a risk of lowering the quality of learning engagement	He findings of this qualitative research consistently show that Usage Interactive Board Digital (PID) in grade VI of SD Negeri Arjo winangun has had a significant positive impact on increase intrinsic motivation of students in Indonesian subjects	Digital Interactive Board has a very significant positive impact on growing and maintaining intrinsic motivation grade VI students in Indonesian language subjects at Arjowinangun State Elementary School. PID serves as a medium transformative that is effective in overcoming students' low internal interest in Indonesian language materials structural
2.	The goal is to improve teachers' competence in using digital interactive boards as learning media innovations.	(Hamidani et al., 2026)	The goal is to improve teachers' competence in using digital interactive boards as learning media innovations.	The method of implementing activities includes socialization, training, and direct assistance to partner teachers..	The results of the activity showed an increase in teachers' understanding and skills in operating digital interactive boards and integrating them in the learning process	Community service activities in the form of teacher assistance in the use of digital interactive boards have succeeded in increasing teachers' competence in utilizing technology as an innovation in learning media
3.	Aplication of Learning Media using Opportunity Boards, Dice, and Interactive Learning Multimedia with RME Approach at Private High School PAB 8 Saentis Percut	(Kairuddin et al., 2024)	Aims to implement Realistic Mathematics Education (RME)-based opportunity learning media at Private High School PAB 8 Saentis Percut	The method used is qualitative with a case study approach through observation, interviews, and student satisfaction questionnaires	The results showed a significant increase in students' understanding of the concept of opportunity as well as an increase in their motivation and active participation in learning.	In conclusion, RME-based learning media is effective in helping students understand opportunities contextually and applicatively, increasing student engagement, and facilitating an in-depth understanding of the concept of opportunity
4.	Technical Guidance for Creating Interactive Learning Media Based on Microsoft Office Power	(Julianingsih, 2021)	Aims to provide understanding and skills to teachers in managing online learning during the pandemic	This service is carried out by providing technical guidance in making interactive learning	After technical guidance, there are positive results such as participants are satisfied because the guidance material is very easy to practice and in accordance with their needs	The implementation of Technical Guidance in the creation of interactive learning media with the help of Microsoft office Power Point and digital whiteboard was quite smooth and

	point and Digital Whiteboard			media using power point.	as a teacher who is obliged to always innovate	successful. The average teacher really likes the material delivered with easy to practice use..
5.	Teaching Malay Language Using Interactive Whiteboards: Acceptance of Teachers at Chinese National Type Schools in Hulu Sangat District	(Ruslan & Mahamod, 2024)	To identify the level of acceptance of teachers at the Chinese National Type School (SJKC) against the use of Interactive whiteboard in guided Malay language teaching Unified Theory of Acceptance and Use of Technology (UTAUT).	Quantitative studies This uses the survey method.	This show that teachers at SJKC receive whiteboard facilities interactive provided based on the four UTAUT constructs. For the second study objective, there was a significant association negatively shaped between levels of acceptance of interactive whiteboards based on teacher's teaching experience	This study shows that overall acceptance interactive whiteboard among Malay language teachers in SJKC in Hulu Langat district is at a high level
6.	Utilization of Interactive Flat Panel (IFP)/Smartboard as Interactive Learning Media at SDN Pelambuan 4 Banjarmasin	(Sari et al., 2026)	Aims to describe the use of Interactive Flat Panel (IFP)/Smartboard as an interactive learning medium at SDN Pelambuan 4 Banjarmasin and its impact on student learning processes and outcomes.	The research method used is a qualitative method with data collection techniques through observation, in-depth interviews, and documentation.	The results of the study show that the use of Interactive Flat Panel (IFP)/Smartboard is able to create an interesting, interactive, and fun learning atmosphere.	The use of Interactive Flat Plans (IFP)/Smartboard increases students' active participation, facilitates the understanding of complex concepts, and fosters motivation and interest in learning.
7.	The Effect of the Use of Interactive Digital Media on Elementary School Students' Learning Motivation	(Surbakti & Chantrin, 2025)	This study aims to determine the influence of the use of interactive digital media on the learning motivation of elementary school students.	He method used is quantitative with a quasi-experimental approach using a pretest-posttest control group design.	He results of data analysis showed a significant increase in learning motivation in the group that used interactive digital media compared to the control group that used conventional media, with a significance value of < 0.05	The conclusion of this study states that the use of interactive digital media has a significant positive effect on the learning motivation of elementary school students
8.	Innovative Solar-Powered Digital Whiteboard with Lithium-ion Battery to Support Inclusive and Accessible Learning in Remote Areas	(Nurhalizah et al., 2025)	The purpose of this community service activity is to provide energy-independent digital learning facilities to support the improvement of the quality of learning in remote schools.	The research method used is a prototype-based technology engineering approach, which includes solar power	The results showed that the prototype can operate optimally for 6-8 hours of active use, and supports basic digital learning functions such as writing, drawing,	This service concludes that the application of renewable energy technology in the field of education is a strategic step to realize sustainable and equitable education..

				system design, lithium-ion battery integration, and digital whiteboard function testing in a no-power grid scenario.	and displaying multimedia materials.	
9.	The Effectiveness of Interactive Flat Panel Learning Media on Improving Students' Cognitive Learning Outcomes in Natural Sciences (IPA) Subjects	(Rustiyana, 2024)	This study aims to present a comprehensive analysis of the effectiveness of Interactive Flat Panel (IFP) learning media compared to conventional methods and standard projectors in improving students' cognitive learning outcomes. Through a systematic review of the literature and current empirical data (up to 2024), this report evaluates the impact of dynamic visualization and touchscreen interactivity on the understanding of science concepts	Conventional methods.	The results of the study show two main findings: (1) the use of IFPD increases students' learning motivation through the presentation of engaging visual materials, interactive touchscreen activities, and direct involvement using a stylus that makes learning more enjoyable and easy to understand; and (2) IFPD strengthens student collaboration, as seen from more active group work, shared screen-based discussions, and the use of multi-touch features that allow simultaneous contributions from multiple students.	This study concludes that IFP is a very effective instrument in improving cognitive learning outcomes, motivation, and student involvement in science learning
10	Interactive Whiteboards for 21st Century Skills Mastery among Preschoolers	(Mohamad et al., 2022)	This study aimed to examine how the use of Interactive Whiteboards can support preschoolers' 21st century skills mastery	using qualitative design with a case study approach.	The use of interactive whiteboards turned out to be able to make PdPc activities in KEMAS kindergarten classes more active and thus stimulate the mastery of four 21st century skills, namely, communication, collaboration, critical thinking, and creativity. Its large physique facilitates activities in the classroom, encouraging	The use of Interactive Whiteboards has been proven to be able to provide a learning environment that can offer a variety of learning styles that support all aspects of the skills needed in a child's development..

					children to interact with each other and encouraging them to collaborate.	
11	The Effectiveness of Problem-Based Learning Based on Smart Boards to Increase the Learning Motivation of Grade 1 Elementary School Students	(Utami et al., 2024)	This research aims to fill the knowledge gap about the use of Problem-Based Learning (PBL) based on Smart Board media in increasing the learning motivation of grade 1 elementary school students	This research method uses a qualitative approach with data collection techniques through observation and interviews	The results show that the use of Smart Board media in learning effectively increases students' learning motivation	In conclusion, the use of Smart Board media in learning can have a significant positive impact on students' learning motivation and academic achievement..
12	Teacher Assistance in the Use of Digital Interactive Boards as Learning Media Innovations	(Hamidani et al., 2026)	Aims to improve teachers' competence in using digital interactive boards as learning media innovations	The method of implementing activities includes socialization, training, and direct assistance to partner teachers.	The results of the activity showed an increase in teachers' understanding and skills in operating digital interactive boards and integrating them in the learning process	Through the stages of socialization, training, and mentoring, teachers are able to operate digital interactive boards and integrate them into the learning process effectively. The use of digital interactive boards has been proven to be able to improve the quality of learning, both in terms of material delivery and student involvement
13	The Utilization of Interactive Flat Panels (IFP) as a Container for Future Investment with a Prospective-Retrospective Approach in Islamic Educational Institutions	(Son'any, 2026)	This research aims to provide a comprehensive overview of the use of Interactive Flat Panel as a forum for future investment in Islamic educational institutions from a prospective and retrospective perspective.	This study applies a qualitative-descriptive method, where the results obtained are in the form of data through interviews with resource persons and analyzing phenomena that occur in the field in real time	That when the process of teaching and learning activities takes place without IFP, interaction in the classroom tends to be unidirectional, teachers provide more material with oral explanations and texts without using interactive media. The classroom becomes more energetic, communication between teachers and students improves, and learning becomes more vibrant thanks to visual stimulation and hands-on activities by utilizing the features available in IFP.	The main conclusion of this study is that digital transformation through the application of educational technology such as Interactive Flat Panel (IFP) is very important for Islamic educational institutions in Indonesia to address student involvement that is Son'any, The Utilization of Interactive Flat Panel (IFP) as a Container Investasi...@2026DIKSI(https://jurnal.bimaberilmu.com/index.php/diksi)162W ork is distributed under the Creative Commons Attribution 4.0 International License low due to conventional methods. IFP offers dynamic interactive

14	The Effectiveness of the Problem Based Learning Model with Multifunctional Board Media in Improving Students' Concept Understanding	(Damayanti et al., 2025)	This study aims to test the effectiveness of the Problem Based Learning (PBL) model combined with multifunctional board media in improving students' understanding of the concept of KPK and FPB.	The study used a quasi-experimental method with a pre-test and post-test design in two groups, namely the experimental group (PBL + multifunctional board) and the control group (conventional method).	The results showed that there was a significant difference between the pre-test and post-test scores in the experimental group ($p = 0.001$), with 75% of students experiencing an improvement in comprehension.	features, but in its implementation there are significant challenges related to low digital literacy of teachers, limited internet infrastructure, high investment and maintenance costs, and resistance to change. It can be concluded that the use of the Problem Based Learning (PBL) model combined with multifunctional board media significantly improves students' understanding of the concept of the Smallest Multiple of Fellowship (KPK) and Largest Commonwealth Factor (FPB)
15	Analysis of Elementary School Teachers' Competency in the Implementation of Digital-Based Learning Authors	(Silvester et al., 2023)	Aims to describe the competence of elementary school teachers in implementing digital-based learning, which is reviewed from the teacher's skills, understanding, concepts and approaches to digital media and the use of digital technology in learning.	This study uses a descriptive approach with qualitative analysis	The results of research conducted at SDN 03 Bengkayang show that teachers' understanding of digital technology is still relatively less proficient, especially in using digital devices and digital applications.	Digital competence is a competency that must be possessed by teachers in facing the development of the current times. Digital competencies include teachers' skills, understanding, concepts and approaches to digital media and the use of digital technology in learning

Discussion

There is a fundamental difference between Adhi Pradana's (2026) research that focuses on the impact of the use of Digital Interactive Boards (PID) on students' intrinsic motivation and your research that focuses on optimizing PID to build a student-centered learning ecosystem through teacher readiness analysis, where Pradana's research stops at proving that PID effectively increases motivation but ignores the teacher factor as a "key actor" in the learning process. Meanwhile, previous Scopus indexed articles generally still dwell on the technology adoption phase and its effectiveness on cognitive learning outcomes, so your research offers novelty by shifting the paradigm from just technology impact to human adaptation, namely how to analyze the adaptive readiness of teachers as architects in optimizing PID to become the center of a transformative learning ecosystem an aspect that is still rarely explored in depth in international literature, especially in the context of Indonesian basic education.

There is a clear difference between the community service research conducted by Hamidani et al. (2026) which aims to improve teachers' technical competence in operating the Digital Interactive Whiteboard (PID) through socialization, training, and direct mentoring, and your research that seeks to analyze teachers' readiness and adaptation in optimizing PID to build a student-centered learning ecosystem. Hamidani's research focuses on improving practical skills at the surface level ensuring teachers can use technology while your research delves deeper into teachers' psychological and pedagogical readiness to transform their teaching philosophy from teacher-centered to student-centered by using PID as the core of the ecosystem. Compared to previously published Scopus indexed articles, most existing studies have examined the effectiveness of PID on student learning outcomes or technical training outcomes, but rarely explore teachers' adaptive journeys in building holistic learning ecosystems. Your research fills this gap by shifting the discourse from mere technological operations (as Hamidani discusses) to transformative pedagogical adaptation, offering a new contribution to the international literature on how teacher readiness mediates the successful implementation of digital interactive whiteboards in the context of primary education.

Research by Kairuddin et al. (2024) applied Realistic Mathematics Education (RME) learning media based on opportunity boards, dice, and interactive multimedia at Private High School PAB 8 Saentis Percut. Through qualitative methods with observations, interviews, and student satisfaction questionnaires, the results showed a significant increase in the understanding of the concept of opportunity as well as student motivation and active participation. The main advantage of this research is the combination of RME's contextual pedagogical approach with the diversity of learning media, creating a concrete and enjoyable learning experience. However, its weakness lies in its focus that is still centered on students as beneficiaries, while the role of teachers as facilitators and learning designers is less explored in depth. This research also still uses manual and separate media, not integrated technology.

Ulianingsih's community service research (2021) aims to equip teachers with skills to manage online learning through technical guidance for creating interactive media based on PowerPoint and digital whiteboards. The results showed the satisfaction of the participants because the material was easy to practice and according to the needs of the teacher to innovate. The main advantage of this research is its responsiveness to the urgent needs of the pandemic as well as its practical and applicable training approach. However, the fundamental weakness lies in the still reactive and technical-operational focus, simply ensuring that teachers can use online teaching aids, without touching on the deeper aspects of pedagogical transformation. This research also still places teachers as "technology users" rather than as "designers of learning ecosystems". Research by Ruslan and Mahamod (2024) identified the acceptance rate of SJKC teachers to interactive

whiteboards using the UTAUT approach. The results showed acceptance based on four UTAUT constructs, but a significant negative relationship was found between acceptance and teachers' teaching experience. Its excellence lies in its use of the comprehensive UTAUT framework and interesting findings about the correlation with teaching experience. The downside is that the focus is still limited to the acceptance rate, not on the optimization of post-acceptance technology. The quantitative approach is also less able to explore the teacher adaptation process in depth. Your research complements these shortcomings by shifting the focus from acceptance to optimization and adaptation, analyzing how teachers who have received PID then adapt to optimize it.

Research by Sari et al. (2026) describes the use of Interactive Flat Panels at SDN Pelambuan 4 Banjarmasin and its impact on student learning processes and outcomes. With qualitative methods, the results show that IFP is able to create an interesting, interactive, and fun learning atmosphere. The advantage lies in a comprehensive description of the implementation of smartboards at the elementary school level and its positive impact on the learning atmosphere. The weakness is that the focus is still focused on the impact of the use of technology on students, while the role of teachers as a driving force behind the scenes is not analyzed in depth. This research is also still at the stage of describing "utilization", not "optimization". Your research goes further by shifting the focus from just a description of use to an analysis of teacher adaptive readiness and optimization. Surbakti and Chantrin's (2025) research used quasi-experiments to test the influence of interactive digital media on the learning motivation of elementary school students. The results showed a significant improvement in the experimental group compared to the controls. Its advantage lies in its rigorous experimental design that is able to prove causal relationships empirically. The downside is that the approach is still product-centric and results-oriented without exploring the interaction process of teachers, students, and the media. This study treats the media as an independent variable, ignoring that its effectiveness depends on the readiness and adaptation of teachers. Your research fills this gap by shifting the focus from proof of impact to understanding of processes, analyzing how teachers' adaptive readiness is key to PID optimization.

Research by Nurhalizah et al. (2025) developing a solar-powered digital whiteboard with lithium-ion battery for remote schools. Through a prototype-based technology engineering approach, the results show the device can operate for 6–8 hours and support basic learning functions. Its excellence lies in innovation in overcoming electricity infrastructure problems and answering the challenges of educational accessibility. The weakness is that the focus is still on technical aspects and hardware infrastructure without touching the human resources (teachers) who will use technology. This research stopped at the "functional tools" stage without asking about teachers' readiness for learning transformation. Your research complements these shortcomings by shifting the focus from hardware engineering to human engineering, analyzing teachers' adaptive readiness as a determining factor for the successful implementation of PID.

Rustiyana's research (2024) through a systematic review method proves that IFP is effective in improving student motivation, collaboration, and cognitive outcomes through interactive visual features. Its advantage lies in the scope of a comprehensive analysis of the technical impact of the media on students. The weakness is that the approach is still focused on the impact of the media without delving into the factors of technology optimization, especially the role of teachers as facilitators. Your research has a fundamental distinction because it does not simply measure the effectiveness of a product, but focuses on the main determinants of successful implementation: teacher readiness and adaptation. You answered the critical question "why are some teachers successful in transforming learning and some not?" that previous research missed, filling in the gaps about the human factors behind the continuous digital education transformation.

Mohamad et al.'s research tested the use of interactive whiteboards to support the mastery of 21st century skills in preschoolers. With a qualitative case study design, the results show interactive boards are able to enable learning and stimulate communication, collaboration, critical thinking, and creativity. Its strength lies in its unique focus on early childhood and global skills strengthening. The weakness is that this research is still centered on the impact of devices on children, while the role of teachers as facilitators is not analyzed in depth. This research is also still at the level of "use", not "optimization". Your research complements this shortcoming by shifting the focus from students to teachers as key to ecosystem optimization, analyzing teachers' adaptive readiness that previous research has missed.

D. Conclusion

This study concludes that the optimization of Digital Interactive Whiteboards (PID) in building a student-centered learning ecosystem is highly dependent on teachers' readiness and adaptation strategies. Key findings reveal that while PID offers great potential for creating interactive and collaborative learning, its effectiveness has not been directly proportional to its technological availability. Teachers who are technically and psychologically ready tend to be able to transform PID from just a performing tool to a medium for student exploration. In contrast, teachers with low readiness still use PID as a conventional whiteboard, making it difficult for a student-centered ecosystem to materialize. Teacher adaptation takes place in three stages: onboarding (overcoming technological anxiety), integration (combining PID with teaching methods), and transformation (using PID to encourage student learning independence). The practical implications of this study emphasize the need for a sustainable professional development approach, not just one-time technical training. Schools and policymakers need to design mentoring programs that focus on digital pedagogical design, where teachers are equipped with the ability to design learning scenarios that utilize PID's interactive features to encourage student agency. In addition, the support of responsive technical infrastructure and a culture of collaboration between teachers in sharing good practices are key to accelerating the adaptation process.

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