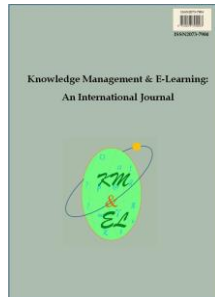

Effects of technological integration and assessment strategies on digital literacy collaborative learning as mediator

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Effects of technological integration and assessment strategies on digital literacy collaborative learning as mediator

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Abstract: This research analyses the relationships between technological integration, assessment strategies, collaborative learning, and digital literacy in early childhood education. Early childhood education is a crucial phase for building lifelong learning foundations. Technology is needed to enhance student engagement and help children develop essential digital skills. Collaborative learning is integrated through interactive activities that encourage cooperation, such as group projects and technology-based educational games. This study is conducted in the context of early childhood education classrooms using digital technology as a primary learning tool. Understanding these dynamics is important for teachers and policymakers to develop more effective and responsive educational methods in the digital age. The primary aim is to examine the interconnections between technological integration, assessment strategies, collaborative learning, and digital literacy within the field of early childhood education in Indonesia. The influence of these factors is uncovered to provide insights into effective educational practices. A quantitative method is used, including the distribution of 250 questionnaires to selected respondents in Banten Province, Indonesia. The research focuses on the perceptions of teachers, education stakeholders, and parents, using Likert scale items and open-ended questions to collect comprehensive data. The method includes statistical analysis to show the relationships among the variables. The results show a significant positive influence of technological integration on collaborative learning and a positive impact of assessment strategies on digital literacy. Additionally, collaborative learning is identified as a mediator in the relationships between the variables. The implications of this research extended to a deeper understanding of the dynamic relationships. A theoretical foundation is offered for further development and provides practical guidance in enhancing the effectiveness of technological integration and assessment strategies to achieve optimal digital

literacy outcomes.

Keywords: Technological integration; Assessment strategies; Collaborative learning; Digital literacy

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Elindra Yetti is a professor at Universitas Negeri Jakarta specializing in Early Childhood Education. She has made significant contributions to the development of theories, practices, and policies related to early childhood education in Indonesia. She also publishes academic books and journal articles, and frequently serves as a speaker at national and international seminars and conferences.

Yufiarti is a professor at Universitas Negeri Jakarta with expertise in education, particularly Early Childhood Education. She focuses her research on fostering children's creativity, innovating learning methods, and studying early childhood education policies. Besides teaching and supervising students, she is involved in various research projects and community service programs to improve the quality of early childhood education.

1. Introduction

In the dynamic landscape of education, the intersection of technology, assessment strategies, and collaborative learning is developed as an important perspective (Coiro, 2021; Mirra & Garcia, 2021). As societies become increasingly digitized, the ability of individuals to navigate the digital field competently has not been more pronounced (Chambers & Sandford, 2019; Kellner, 2021). Technological integration, including the infusion of digital tools into educational practices, and strategic assessment of literacy proficiency, represent two key dimensions influencing the acquisition of skills (Falloon, 2020; Hamad et al., 2020; Ranjan et al., 2024; Sparks et al., 2016). Collaborative learning, which uses group dynamics and shared knowledge to enhance the educational experience (Herrera-Pavo, 2021; Iglesias Rodríguez et al., 2017; Laux et al., 2016). Understanding the contribution of technological tools to the development of digital skills is important for teachers, curriculum designers, and policymakers to cultivate a technologically proficient generation (Cattaneo et al., 2022; Hammoda & Foli, 2024; Wang, 2024).

Effective assessment strategies are integral in promoting digital literacy (Nedungadi et al., 2018). This includes exploring diverse methods in line with the nature of digital skills, ensuring that assessments accurately measure and contribute to the enhancement of proficiency in the digital domain (Kommey & Fombad, 2024; Martzoukou et al., 2020). Collaborative learning introduces a social dimension to the acquisition of digital literacy, optimizing the educational experience and enhancing a collective journey toward digital literacy (List, 2019; Philippe et al., 2020).

The inquiry shows the relationships between technological integration, assessment strategies, and collaborative learning. By analysing the dimensions, the research aims to provide important insights contributing to the ongoing discourse on effective educational practices in the digital age. Through empirical investigation and analysis, educational stakeholders are informed about the factors considered in cultivating digital literacy competencies among learners. Therefore, the objectives are to explore 1) the relationship between technological integration, assessment strategies, and collaborative learning in the context of digital literacy, 2) the impact of technological integration on the development of students' digital skills, 3) the effectiveness of assessment strategies in measuring and enhancing students' digital literacy, 4) the role of collaborative learning in developing the social dimension of digital literacy, 5) the educational experience and supporting the journey towards digital literacy by identifying synergies between technology, assessment, and collaborative learning.

The research questions include:

RQ1: How does the integration of technology in educational practices influence the development of digital skills?

RQ2: What are the effective assessment methods for measuring digital literacy, and what is the relationship with aspects of digital skills?

RQ3: How can collaborative learning enhance the social dimension of students' digital literacy?

RQ4: To what extent are technological integration, assessment strategies, and collaborative learning interconnected in influencing students' digital literacy?

RQ5: What synergies can be identified between technology, assessment, and collaborative learning that positively contribute to the educational experience and the development of digital literacy?

RQ6: How can the results provide deeper insights to educational stakeholders, such as teachers, curriculum designers, and policymakers, to enrich effective educational practices?

2. Literature review

2.1. Diffusion of innovation theory

In the field of education, the application of the Diffusion of Innovations Theory shows an understanding of the process of innovation adoption (Lawrence & Tar, 2018). This theory reports the steps in accepting and adopting innovations, ranging from awareness and persuasion of benefits to the decision to implement the concept in daily practices. In technological integration, teachers must consider factors such as the relative advantages of new technology, ease of use, and observable outcomes in enhancing learning (Al-Rahmi et al., 2021). Similarly, in collaborative learning, social interaction is key in introducing and implementing learning strategies that include student cooperation. In assessment strategies, teachers adopt assessment methods perceived as easy to implement and provide useful feedback. Finally, in digital literacy, individuals accept and adopt digital literacy skills when the concept is perceived as relatively superior and provides significant benefits. Effective strategies can be developed to facilitate innovation in education and shape

practices responsive to the changes experienced by applying the diffusion of innovations theory.

2.2. *Technological integration and collaborative learning*

According to Turugare & Rudhumbu (2020), technological integration refers to the incorporation of tools and resources into the teaching and learning process. This includes using digital devices, software applications, and online platforms to enhance the educational experience. Through technological integration, teachers can create dynamic and interactive learning environments that enable a more engaging and effective educational experience (Maroukas et al., 2023). Gillies (2019) explained that collaborative learning emphasized the importance of students working together towards a common learning goal. This includes the sharing of ideas, resources, and expertise among students, promoting a sense of community and mutual support. Collaborative learning promotes active participation, critical thinking, and problem-solving skills (Duane & Satre, 2014). Integration of technology increases collaborative learning by providing tools for communication, document sharing, and real-time collaboration across geographical boundaries (Grimus, 2020). Technological integration and collaborative learning create a synergistic method of education, where the use of technology enhances efforts among students and teachers (Newland & Byles, 2014). This combination prepares students for the demands of the digital age and cultivates a collaborative mindset essential in an interconnected world. Integration of technology facilitates communication, promotes information sharing, and empowers students to actively contribute to their educational journey (Koul & Nayar, 2021). In essence, technological integration and collaborative learning shape a modern and effective educational landscape. Therefore, the proposed hypothesis is as follows.

H1: Technological integration impacts collaborative learning.

2.3. *Technological integration and digital literacy*

Pangrazio (2016) reported that digital literacy is the ability to critically engage with technologies, including skills such as information, media, and basic technical proficiency. The concept emphasizes the understanding of the evaluation, analysis, and usage of digital information. Digital literacy is a foundational skill set in the 21st century, enabling individuals to access, comprehend, and communicate information effectively (Gretter & Yadav, 2016). Technological integration in classrooms provides a practical context to develop and apply digital literacy skills (Alakrash & Abdul Razak, 2021). As students engage with tools and resources, the ability to discern credible information, critically evaluate digital content, and ethically navigate online spaces is acquired (Cismaru et al., 2018). In addition, digital literacy enhances the effectiveness of technological integration by ensuring that students can harness the full potential for learning and collaboration (Haleem et al., 2022). The synergy between technological integration and digital literacy is crucial for preparing students to be competent and responsible digital citizens (Liu et al., 2020). These concepts form the backbone of a modern education paradigm that embraces technology and instils the essential skills needed to navigate the complexities of the digital age. Therefore, the hypothesis considered is as follows.

H2: Technological integration impacts digital literacy.

2.4. *Assessment strategies and collaborative learning*

According to Gikandi et al. (2011), assessment strategies refer to the methods and tools used to control the progress and understanding of students in a learning environment. These include formative and summative assessments, as well as various types of evaluations. In contrast, collaborative learning shows students working to achieve common learning objectives, promoting shared responsibility and active participation (Lenkauskaitė et al., 2020). The activities provide a unique context for assessment, allowing teachers to observe individual knowledge, interpersonal skills, teamwork, and communication abilities (Kaendler et al., 2015). Group projects, discussions, and problem-solving tasks within this setting become valuable opportunities for formative assessment, offering insights into the individual and collective strengths as well as areas for improvement (Mora et al., 2020). Conversely, assessment strategies improve the effectiveness of collaborative learning by providing students with clear expectations and criteria for efforts (Er et al., 2021). Rubric and assessment for collaborative projects also guide students in understanding learning objectives and standards (Jonsson, 2014). This promotes a sense of accountability within a collaborative group, ensuring that each participant contributes meaningfully (Bovill et al., 2016). Assessment strategies leverage collaborative learning as a rich source of data, allowing teachers to evaluate a spectrum of skills beyond academic knowledge (Chen et al., 2015). Simultaneously, collaborative learning benefits from the structure and guidance provided by assessment strategies, enhancing a more purposeful and outcome-oriented experience. These elements contribute to a well-rounded educational environment that measures individual and collective progress as well as prepares students with the skills necessary for collaborative success (Azman et al., 2019). Therefore, the hypothesis considered is as follows.

H3: Assessment strategies impact collaborative learning.

2.5. *Assessment strategies and digital literacy*

Spante et al. (2018) stated that assessment strategies included a range of methods used to measure students' understanding and skills, while digital literacy is the ability to critically engage with technologies. In the context of assessment, incorporating digital literacy elements comprises evaluating students on subject-specific knowledge and capacity to ethically and effectively use digital tools, discern credible information online, and navigate digital platforms (Anthonysamy et al., 2020). Assessment strategies can be enriched by integrating digital literacy components, ensuring that evaluations reflect the demands (Ilomäki et al., 2016). For instance, assignments may include researching and synthesizing information from online sources, requiring students to show subject mastery and effective skills (McGrew et al., 2018). Additionally, assessment controls the ability to communicate ideas using digital media, enhancing skills essential in a world where digital communication is ubiquitous (Siddiq et al., 2017). Digital literacy benefits from being embedded within assessment strategies by providing a practical context for the application (Ortlieb et al., 2014). Assessment requiring the use of tools and platforms motivates students to develop technical proficiency, while showing the ability to critically evaluate information in the digital space. (Hsu et al., 2018) This variable becomes an integrated aspect of competence, preparing students to navigate the complexities of the digital landscape (Chetty et al., 2018). In essence, the synergy between assessment strategies and digital literacy ensures that evaluations include the multifaceted skills needed for success in digital society. This integration shows the nature of education and equips students with

digital literacy skills necessary for effective communication, collaboration, and information mastery in the 21st century (Audrin & Audrin, 2022). Therefore, the formulated hypothesis is as follows.

H4: Assessment strategies impact digital literacy.

2.6. Collaborative learning and digital literacy

Janssen et al. (2010) assessed that collaborative learning, characterized by students actively working towards shared academic goals, enhances interpersonal skills and collective problem-solving. In the digital era, this collaborative model is connected with digital literacy, which comprises the ability to navigate, critically assess, and responsibly engage with technologies (Phippen et al., 2021). In collaborative learning settings, students use various tools and platforms to communicate, share resources, and collectively contribute to projects (Al-Samarraie & Saeed, 2018). This integration enhances collaboration and serves as a practical application of digital literacy skills (Yang et al., 2018). In this context, students learn to sift through online information, discerning the reliability, and leveraging digital communication tools to collaborate effectively (Zamiri & Camarinha-Matos, 2018). Therefore, collaborative learning becomes a space where digital literacy is a theoretical concept and an applied skill set (Vodā et al., 2022). Collaborative learning is also strengthened by equipping students with the proficiency to harness resources efficiently. Digitally literate students can navigate online spaces adeptly, evaluate information critically, and engage ethically in collaborative efforts. This proficiency ensures that collaborative efforts are productive and balanced with responsible and ethical digital practices. The connection prepares students for the digital age, changing collaborative learning into a holistic experience for effective and ethical participation in a technology-driven world. Collaborative learning and digital literacy form a dynamic, shaping an educational landscape that values collective intelligence and provides students with essential skills. Therefore, the proposed hypothesis is as follows.

H5: Collaborative learning impacts digital literacy.

2.7. Collaborative learning as a mediator

Collaborative learning serves as a mediator in the educational process, facilitating dynamic interactions and enhancing a shared learning experience among students. In this role, the variable acts as a bridge between individual understanding and collective knowledge acquisition. Collaborative learning comprises students actively relating with one another, sharing perspectives, and constructing knowledge. As a mediator, the variable plays a crucial role in breaking down traditional barriers to learning, promoting open communication, cooperative problem-solving, and the exchange of ideas. This mediation process promotes a deeper understanding of concepts since students collectively explore and discuss diverse perspectives. Moreover, collaborative learning serves as a mediator in the development of crucial skills. Through group projects and interactive activities, students enhance teamwork, communication, and critical thinking abilities. Collaborative process reinforces the subject matter and cultivates essential skills valuable in academic, professional, and social contexts. In the digital age, learning takes on an even more significant role to leverage technology and connect learners beyond physical classrooms. Online platforms, discussion forums, and collaborative tools mediate the sharing of

information and ideas, transcending geographical limitations and promoting a global exchange of knowledge. Therefore, the articulated hypothesis is as follows.

H6: Collaborative learning mediates the relationship between technological integration and digital literacy.

H7: Collaborative learning mediates the relationship between assessment strategies and digital literacy.

Based on the previous literature and hypothesis development, the research framework was proposed as shown in Fig. 1. The framework shows the interconnections among technological integration, assessment strategies, collaborative learning, and digital literacy in the context of early childhood education. Technological integration serves as a foundational element influencing collaborative learning and digital literacy. Meanwhile, assessment strategies impact collaborative learning and digital literacy. The framework shows that collaborative learning plays a mediating role in the relationships of technological integration and assessment strategies with digital literacy. This guides the investigation into the intricate dynamics among key components, providing a structured method to explore interrelationships and collective impact on digital literacy outcomes.

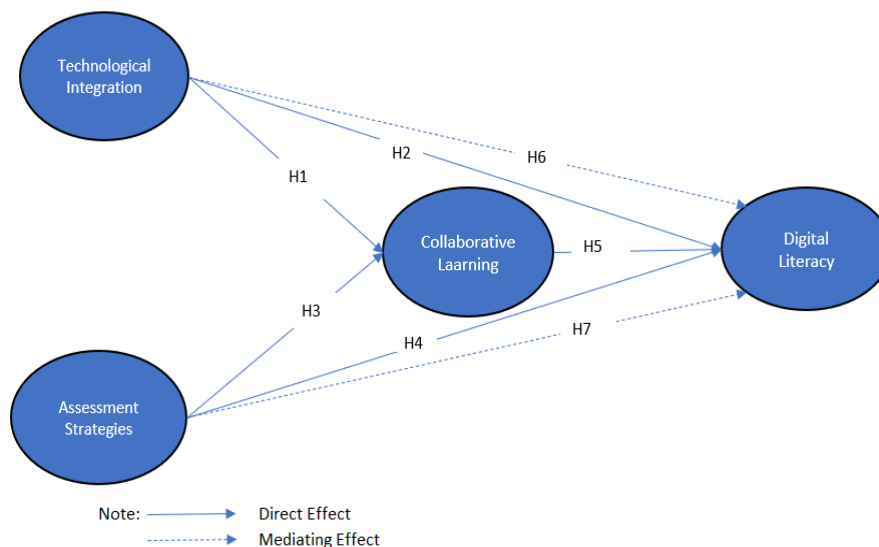


Fig. 1. Research framework

3. Materials and methods

This research shows the population and sample, comprising 250 respondents randomly selected from teachers in Banten province. This diverse sample includes teachers, education stakeholders, and parents. A total of 250 questionnaires were distributed, and only 243 were returned. Only 230 respondents completed the survey, while 13 provided incomplete responses, leaving 230 valid questionnaires available for analysis (see Table 1).

The survey questionnaires were reported using Google Forms, a widely used online platform. By using Google Forms as the primary data collection method, the research aims to gather insights into the perception of technology integration by different stakeholders in

the educational process. The questionnaire, thoughtfully designed to balance with the research objectives, incorporates Likert scale items and open-ended questions to facilitate the collection of quantitative and qualitative data.

Table 1
Research instrument

Variable	Source	Items and indicators	
Technological integration	Duane & Satre (2014) Maroukgas et al. (2023) Turugare & Rudhumbu (2020)	TECH1	Teachers consistently incorporate digital resources such as online simulations, educational apps, and multimedia presentations into lessons.
		TECH2	Classroom activities include interactive technologies, encouraging students to actively engage with learning content.
		TECH3	Technology is integrated into the curriculum, supporting a variety of learning styles.
		TECH4	Teachers provide ongoing professional development opportunities to enhance technological skills.
		TECH5	Students regularly use digital tools for collaborative projects, presentations, and research.
		TECH6	Technology is used to differentiate instruction, addressing the diverse needs of learners in the classroom.
		TECH7	The school's infrastructure supports a reliable and accessible digital learning environment.
Assessment strategies	Chen et al. (2015) Er et al. (2021)	ASTRA1	Formative assessments, such as quizzes, polls, or class discussions, are conducted regularly to control student understanding.
		ASTRA2	Assessment is consistent with clear learning objectives, allowing students to see the purpose of each evaluation.
		ASTRA3	Rubrics are provided for major assessments, outlining the criteria for success and areas for improvement.
		ASTRA4	Teachers use a variety of assessment methods, including both traditional (tests, essays) and alternative (projects, presentations) methods.
		ASTRA5	Peer and self-assessment activities are integrated into the assessment process.
		ASTRA6	Assessment feedback is timely, constructive, and aimed at guiding students toward improvement.
		ASTRA7	The assessment process is transparent, with clear communication of expectations and evaluation criteria.
Collaborative learning	Kaendler et al. (2015) Phippen et al. (2021) Al-Samarraie & Saeed (2018)	COLLAB1	Students critically evaluate online information, considering the reliability and credibility of sources.
		COLLAB2	Digital literacy skills are explicitly taught and assessed as part of the curriculum.
		COLLAB3	Learners show effective use of digital tools for research, information synthesis, and presentation.
		COLLAB4	Students understand and adhere to ethical guidelines for online behavior and information use.
		COLLAB5	Digital literacy is integrated into multiple subjects, emphasizing its cross-disciplinary importance.
		COLLAB6	The curriculum addresses current trends and issues related to digital literacy, such as media literacy and online safety.
		COLLAB7	Students apply digital literacy skills beyond the classroom, showing a real-world understanding of technology use.
Digital literacy	Alakrash & Abdul Razak (2021) Gretter & Yadav (2016) Liu et al. (2020)	DIGLIT1	Students actively participate in group discussions, contributing ideas and perspectives.
		DIGLIT2	Collaborative projects require students to work together, fostering teamwork and shared responsibility.
		DIGLIT3	Technology is integrated into collaborative activities, enabling virtual collaboration and communication.
		DIGLIT4	Learning environment encourages a culture of respect, where diverse viewpoints are valued.
		DIGLIT5	Group projects incorporate elements of peer teaching and cooperative problem-solving.
		DIGLIT6	Students reflect on collaborative experiences, identifying strengths and areas for improvement.
		DIGLIT7	Collaborative learning is embedded into the curriculum, providing regular opportunities for students to work together on meaningful tasks.

The use of a digital platform ensures an easy process for the distribution, completion, and submission of the survey, enhancing accessibility and convenience for participants. Online format allows for the automatic collection and organization of responses, thereby streamlining the subsequent data analysis process.

The use of a digital platform enables fast distribution, completion, and submission of the survey, enhancing accessibility and convenience for participants. Online format also facilitated the automatic collection and organization of responses, streamlining the subsequent data analysis process. To ensure the ethical conduct of the research, participants were provided with clear instructions and information about the purpose of the research through the introductory section of the Google Form. Meanwhile, informed consent was obtained digitally before respondents proceeded with the survey. Measures were implemented to safeguard confidentiality and anonymity in line with ethical standards.

The research unfolded over three months, from July to September 2023, facilitating comprehensive data collection, rigorous analysis, and meaningful interpretation. The results aimed to contribute valuable insights to the ongoing discourse on technology integration in education, offering practical implications for teachers, stakeholders, and policymakers. The method established a systematic and ethical framework to explore the multifaceted impact of technology integration on the perceptions of teachers in Banten Province.

4. Results

4.1. Validity and reliability

As reported in Table 2 and Fig. 2, the factor analysis provides valuable insights into the reliability and validity of the constructs under investigation. In terms of technological integration, all seven items (TECH1 to TECH7) show strong outer loadings, ranging from 0.922 to 0.944. The high values of Cronbach's Alpha (0.976), rho_A (0.976), Composite reliability (CR) of 0.980, and average variance extracted (AVE) of 0.872 collectively affirm the internal consistency and convergent validity of technological integration.

Similarly, assessment strategies show high outer loadings (above 0.864) across all seven items (ASTRA1 to ASTRA7), reaffirming a strong association with the construct. The reliability indicators, including Cronbach's Alpha (0.971), rho_A (0.978), CR (0.976), and AVE (0.853), attest to the internal consistency and convergent validity of assessment strategies.

Collaborative learning, with items COLLAB1 to COLLAB7, shows high outer loadings above 0.871, reporting a strong connection between the items and the construct. The reliability metrics, including Cronbach's Alpha (0.962), rho_A (0.965), CR (0.969), and AVE (0.815), showed the internal consistency and convergent validity of the variable. However, the digital literacy construct supports scrutiny for item DIGLIT5, which shows a relatively lower outer loading of 0.722. The remaining items (DIGLIT1 to DIGLIT7) report strong outer loadings, ranging from 0.865 to 0.935. The reliability indicators, including Cronbach's Alpha (0.948), rho_A (0.951), CR (0.958), and AVE (0.765), confirm the internal consistency and convergent validity of digital literacy.

This comprehensive analysis shows the strongness of the measurement model, providing a foundation for meaningful interpretation and reliable conclusions regarding the relationships between the constructs. Stakeholders can trust the reliability and validity of the measurement instruments in controlling technological integration, assessment strategies, collaborative learning, and digital literacy.

Table 2
Confirmatory factor analysis

Construct	Items	Outer loading	α	rho_A	CR	AVE
Technological integration	TECH1	0.922	0.976	0.976	0.98	0.872
	TECH2	0.939				
	TECH3	0.942				
	TECH4	0.937				
	TECH5	0.928				
	TECH6	0.944				
	TECH7	0.925				
Assessment strategies	ASTRA1	0.864	0.971	0.978	0.976	0.853
	ASTRA2	0.935				
	ASTRA3	0.941				
	ASTRA4	0.914				
	ASTRA5	0.958				
	ASTRA6	0.902				
	ASTRA7	0.949				
Collaborative learning	COLLAB1	0.871	0.962	0.965	0.969	0.815
	COLLAB2	0.913				
	COLLAB3	0.943				
	COLLAB4	0.915				
	COLLAB5	0.919				
	COLLAB6	0.878				
	COLLAB7	0.88				
Digital literacy	DIGLIT1	0.913	0.948	0.951	0.958	0.765
	DIGLIT2	0.871				
	DIGLIT3	0.935				
	DIGLIT4	0.865				
	DIGLIT5	0.722				
	DIGLIT6	0.907				
	DIGLIT7	0.892				

4.2. Direct effect

The hypothesis testing results show significant relationships among the constructs. Hypothesis H1, reporting the influence of technological integration (TECH) on collaborative learning (COLLAB), obtained a t of 5.418 with a p of 0.000, showing statistical significance (see Table 3). Therefore, H1 is accepted, suggesting a positive and significant impact of the variable on collaborative learning. Similarly, hypothesis H2, investigating the relationship between technological integration (TECH) and digital literacy (DIGLIT), produced a t of 6.303 with a p of 0.000. This implies a substantial and positive association between the variables.

For assessment strategies (ASTRA), hypothesis H3, which explores the impact of ASTRA on collaborative learning (COLLAB), resulted in a t of 3.750 and a p of 0.000. Considering the result, H3 is accepted, signifying a significant positive influence of assessment strategies on collaborative learning. Hypothesis H4, investigating the relationship between ASTRA and DIGLIT, reported a t of 4.933 with a p of 0.000. This shows a substantial and positive connection between the variables.

Hypothesis H5, examining the impact of collaborative Learning (COLLAB) on digital Literacy (DIGLIT), resulted in a t of 4.419 and a p of 0.000. Therefore, there is a

significant positive relationship between the variables. The hypotheses showed consistent and statistically significant relationships among the constructs of technological integration, assessment strategies, collaborative learning, and digital literacy.

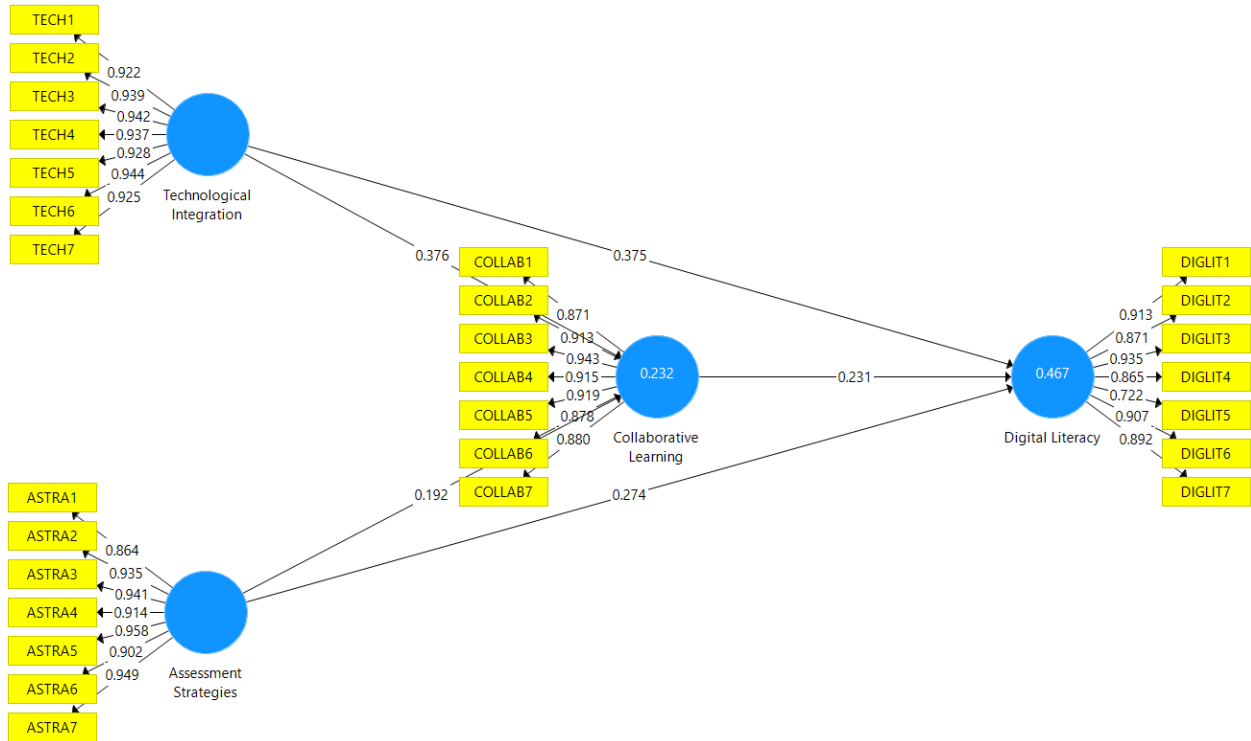


Fig. 2. PLS algorithm

Table 3
Confirmatory factor analysis

Hypothesis	Construct	Original Sample	STDEV	<i>t</i>	<i>p</i>	Result
H1	TECH → COLLAB	0.376	0.069	5.418	0.000	Accepted
H2	TECH → DIGLIT	0.375	0.059	6.303	0.000	Accepted
H3	ASTRA → COLLAB	0.192	0.051	3.750	0.000	Accepted
H4	ASTRA → DIGLIT	0.274	0.056	4.933	0.000	Accepted
H5	COLLAB → DIGLIT	0.231	0.052	4.419	0.000	Accepted

Note. TECH = Technological Integration; ASTRA = Assessment Strategies; COLLAB = Collaborative Learning; DIGLIT = Digital Literacy

4.3. Mediating effect

The data analysis supports the hypothesized indirect relationships among the constructs. Hypothesis H6 investigates the indirect influence of technological integration (TECH) on digital literacy (DIGLIT) through collaborative learning (COLLAB), with a standard deviation of 0.087 (see Table 4). The *t* is 3.286 with a *p* of 0.001, leading to the acceptance

of H6. This implies a statistically significant and positive indirect effect of technological integration on digital literacy through the mediation of collaborative learning.

Hypothesis H7 shows the indirect relationship between assessment strategies (ASTRA) and digital literacy (DIGLIT) through collaborative learning (COLLAB), with a standard deviation of 0.044. The t is 2.736 with a p of 0.006, resulting in the acceptance of H7. This shows a statistically significant and positive indirect influence of assessment strategies on digital literacy through collaborative learning.

The data analysis supports the presence of indirect effects, providing evidence for the hypothesized pathways. Specifically, technological integration and assessment strategies have positive and significant indirect impacts on digital literacy, mediated by collaborative learning. These results contribute to a more comprehensive understanding of the intricate relationships among the constructs.

Table 4
Mediating effect

Hypothesis	Construct	Original Sample	STDEV	t	p	Result
H6	TECH → COLLAB → DIGLIT	0.087	0.026	3.286	0.001	Accepted
H7	ASTRA → COLLAB → DIGLIT	0.044	0.016	2.736	0.006	Accepted

4.4. Discussion

The acceptance of Hypothesis 1 (H1) has significant implications for early childhood education in Indonesia. The results show the important role of incorporating technology into educational practices to enhance collaborative learning experiences. In the context of early childhood education, the positive impact of technological integration on collaborative learning suggests a promising opportunity for pedagogical enhancement (Marougkas et al., 2023).

The acknowledgement of H1 implies that educational institutions, policymakers, and practitioners in early childhood education should consider strategic integration of technology to enhance collaborative learning environments. By leveraging digital tools, interactive platforms, and collaborative learning applications, teachers can create dynamic and engaging activities to stimulate collaboration (Duane & Satre, 2014). This leads to the development of essential social and cognitive skills, such as communication, teamwork, and problem-solving fundamental for a child's holistic development.

The acceptance of H1 suggests the need for investment in teacher training and professional development programs focused on effective technological integration strategies. Teachers play a central role in orchestrating collaborative learning experiences, and proficiency in using technology as an educational tool is crucial. Training programs can empower teachers with the skills and knowledge to integrate technology into teaching methods, ensuring a positive and transformative impact on collaborative learning.

From a managerial perspective, educational leaders and policymakers should prioritize the allocation of resources for the acquisition and maintenance of technological infrastructure within early childhood education settings. Ensuring access to up-to-date devices, educational software, and digital resources becomes important in realizing the benefits of technological integration for collaborative learning. Additionally, strategic

planning and policy frameworks should be established to guide the effective deployment of technology in line with the national educational objectives and goals.

The acceptance of H2 carries significant managerial implications for early childhood education. This result shows the critical role of incorporating technology into educational practices to enhance the development of digital literacy skills. In the context of early childhood education, the positive impact of technological integration suggests a transformative opportunity for educational practices.

H2 suggests that educational institutions, policymakers, and teachers should prioritize and strategically integrate technology to enhance digital literacy skills among students. Digital literacy is becoming a crucial competency, including the ability to access, evaluate, and use digital information effectively (Alakrash & Abdul Razak, 2021). Therefore, embracing technology can contribute to laying the groundwork for digital literacy development from the early stages of a child's educational journey.

Teachers play a central role in guiding students through digital experiences that promote technological proficiency, critical thinking, problem-solving, and ethical considerations (Liu et al., 2020). The acceptance of H2 shows the importance of incorporating digital tools and platforms into the early childhood curriculum. Students are exposed to age-appropriate educational technology that supports the development of digital literacy skills.

From a managerial perspective, educational leaders and policymakers should allocate resources to support the integration of technology. Investments in age-appropriate digital devices, educational software, and teacher training programs are crucial to realizing the potential benefits of technological integration for digital literacy development. Moreover, strategic planning and policy frameworks must be established to guide the ethical and responsible use of technology in line with national educational objectives.

The affirmation of H3 and H4 holds profound managerial implications for early childhood education. These results show the important role of strategic assessment methods in shaping collaborative learning experiences and enhancing digital literacy skills. In the context of early childhood education, foundational learning experiences are established, and the positive impact of assessment strategies suggests a transformative method to educational practices.

H3 implies that educational institutions, policymakers, and teachers should prioritize the development and implementation of effective assessment strategies to enhance collaborative learning environments. Assessment is a tool for evaluating student performance and an integral aspect of the learning process (Mora et al., 2020). Therefore, adopting innovative assessment strategies becomes crucial in early childhood education settings.

The acceptance of H4 emphasizes the significance of assessment strategies in influencing digital literacy development. The variable plays a crucial role in evaluating and promoting digital literacy skills, including the ability to navigate platforms, critically assess information, and apply tools effectively (Chetty et al., 2018). Therefore, the incorporation becomes important in early childhood education.

From a managerial perspective, educational leaders and policymakers should invest in the professional development of teachers to enhance their capacity to design and implement effective assessment strategies. Training programs can empower teachers to create assessments for measuring academic proficiency, as well as collaboration and digital

literacy development. Additionally, resources should be allocated for the acquisition of assessment tools and platforms in line with the objectives of collaborative learning and digital literacy.

Strategic planning and policy frameworks are established to guide the development and implementation of assessment strategies. These frameworks should emphasize integration of innovative and age-appropriate assessment methods in line with collaborative learning objectives and digital literacy competencies. Moreover, enhancing a culture of continuous improvement and reflection within educational institutions can improve the effectiveness in driving positive learning outcomes.

The acceptance of H5 holds significant managerial implications for early childhood education. This result shows the interconnectedness of collaborative learning experiences and the development of digital literacy skills. In the context of early childhood education, foundational learning experiences are established, and the positive impact of collaborative learning on digital literacy suggests a strategic opportunity for practices.

H5 suggests that educational institutions, policymakers, and teachers should prioritize and actively promote collaborative learning environments to enhance digital literacy skills. Collaborative learning is developed as a catalyst for essential skills such as communication, teamwork, and problem-solving, which are integral components of digital literacy.

Teachers play a central role in enhancing collaborative learning experiences to promote social development and contribute to the acquisition of digital literacy skills. By incorporating group activities, collaborative projects, and interactive digital tools into the curriculum, a learning environment is created to motivate young learners to explore, create, and communicate in the digital field.

From a managerial perspective, educational leaders and policymakers should invest in creating a supportive infrastructure for collaborative learning. The allocation of resources for age-appropriate digital devices, collaborative platforms, and teacher training programs can enhance the effectiveness of learning initiatives. Additionally, establishing guidelines and frameworks for the ethical and responsible use of technology is crucial to ensuring a positive and constructive environment. Strategic planning and policy frameworks must also be established to guide the implementation of collaborative learning. These frameworks should emphasize the integration of learning methods in line with digital literacy objectives to enhance the transition into the digital era.

The acceptance of H6 and H7 carries profound managerial implications for early childhood education. These results show the intricate dynamics where collaborative learning acts as a mediator in the relationship between technological integration, assessment strategies, and the development of digital literacy skills. In the context of early childhood education, foundational learning experiences are established, and the positive mediation effects suggest a strategic and multifaceted method to educational practices.

H6 implies that educational institutions, policymakers, and teachers should recognize and harness the mediating role of collaborative learning in the relationship between technological integration and digital literacy. This shows the importance of introducing technology into the learning environment and strategically incorporating collaborative learning experiences. Integration of digital tools within group activities, projects, and interactive platforms can increase the impact of technological integration on the cultivation of digital literacy skills.

H7 emphasizes the important role of collaborative learning as a mediator in the relationship between assessment strategies and digital literacy. Educational stakeholders should prioritize the development and implementation of assessment strategies to evaluate academic performance and enhance collaborative learning experiences. By using assessment methods, teachers can effectively mediate the positive impact of strategies on digital literacy development (Vodă et al., 2022).

From a managerial perspective, educational leaders and policymakers should invest in professional development programs to enhance the capacity to design assessment strategies and integrate technology effectively. Training programs can empower teachers to implement collaborative learning experiences, serving as effective mediators between technological integration, assessment strategies, and the development of digital literacy skills.

Strategic planning and policy frameworks should be established to guide the integration of collaborative learning into the broader educational landscape. These frameworks show the importance of collaborative learning as a mediator, shaping the positive outcomes of technological integration and assessment strategies on digital literacy in early childhood education.

5. Conclusion

In conclusion, this research was carried out to analyse the intricate relationships between technological integration, assessment strategies, collaborative learning, and digital literacy in the context of early childhood education. The acceptance of hypotheses showed the significant impact of factors on each other, as well as the need for a holistic method to educational practices. The connection between technological integration and collaborative learning, as well as the mediating role in the relationships with digital literacy, showed the importance of strategically balancing pedagogical methods with the digital age.

5.1. Theoretical and practical implications

The results have significant theoretical implications for the fields of education, technology integration, and collaborative learning. The identification of the interconnections contributes to the existing body of knowledge in educational theory. The research shows the importance of adopting a holistic theoretical framework that considers the dynamic relationships among key elements. This provides a foundation for theoretical development in understanding the interaction of factors in the educational context.

The practical implications are particularly relevant for teachers, policymakers, and educational leaders in early childhood education. Firstly, the research shows the need for practical interventions that promote effective technological integration in the early childhood curriculum. Teachers can benefit from targeted professional development programs to enhance skills in integrating technology into teaching practices, ensuring a positive impact on collaborative learning and digital literacy.

The practical importance of creating collaborative learning environments is emphasized within educational settings. Collaborative learning strategies that use digital tools should be implemented to show a cooperative and interactive atmosphere. Practical interventions must also address assessment strategies in line with collaborative learning goals to promote a comprehensive understanding of students' abilities and competencies.

Policymakers and educational leaders can use practical insights to guide the development of policies that support integration of technology, collaborative learning initiatives, and innovative assessment strategies. The allocation of resources for infrastructure, teacher training, and digital resources becomes crucial in translating practical implications into tangible improvements in educational practices.

The practical implications provide actionable steps to enhance the quality of early childhood education by strategically integrating technology, enhancing collaborative learning, and implementing effective assessment strategies. These theoretical and practical implications contribute to the ongoing discourse on effective practices, specifically in the digital age, guiding stakeholders toward comprehensive and impactful methods in early childhood education.

5.2. Limitations and recommendations

Acknowledging the limitations of this research is important even though valuable insights are provided. The design, focusing on a specific context and population, may limit the generalizability of the results. Additionally, the reliance on self-reported data and the cross-sectional nature may introduce potential biases and restrict the ability to establish causal relationships. Future research efforts should consider diverse samples and mixed methods to enrich the understanding of the dynamic relationships.

Based on the results, several recommendations were reported for educational practitioners and policymakers in the field of early childhood education. Investing in continuous professional development is crucial to integrating technology, enhancing collaborative learning, and implementing innovative assessment strategies. Educational leaders should also prioritize the establishment of supportive infrastructures, including access to digital devices and collaborative platforms, to enhance the effectiveness of the method.

Future research should explore the long-term impacts of technological integration, collaborative learning, and assessment strategies on students' academic performance, social development, and digital literacy proficiency. Comparative analyses across diverse regions and cultural contexts must provide a more comprehensive understanding of the nuanced dynamics. Policymakers should also consider incorporating the insights into curriculum development, ensuring balance with the broader goals of national educational objectives.

The research shows foundation for transformative practices, stating the role of technology, collaboration, and strategic assessment in nurturing a generation of learners well-equipped for the challenges of the digital era.

Author Statement

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