



Application of the TPACK Framework in Digital Assessment of Elementary School Students' Mathematical Communication Skills Based on Level of Self-Confidence

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Abstract

Integrating digital technology into elementary math education presents both opportunities and challenges, particularly in assessing students' mathematical communication skills. This study applies the Technological Pedagogical Content Knowledge (TPACK) framework to develop digital assessments for elementary students, focusing on varying self-confidence levels. Utilizing platforms like online portfolios and interactive simulations, the research evaluates students' abilities to communicate mathematical ideas through writing, visuals, and expressions. A mixed-methods approach combined quantitative data from self-confidence questionnaires and digital scores with qualitative data from digital portfolios and interviews. Fifth-grade students from the Assifa Learning Center Pasuruan Foundation were grouped by self-confidence levels. Findings indicate a positive correlation between self-confidence and mathematical communication skills: students with high self-confidence met all indicators, while those with moderate and low self-confidence met fewer. Digital assessment tools enhanced evaluations and data richness. This study underscores the importance of integrating technology, pedagogy, and content knowledge in digital assessments and recommends ongoing teacher training and child-friendly platforms to boost equitable math assessment.

Keywords: TPACK; Digital Assessment; Mathematical Communication; Self-Confidence; Online Portfolio.

INTRODUCTION

The communication science and technology field is experiencing significant advancement in games that utilize technology to captivate children's interest in learning (A. et al. et al., 2022; Nafisah et al., 2023;

Suharsiwi et al., 2018). The progress in information and communication technology has impacted many sectors (Kurwiyah et al., 2023), like trade (F. Fauzi et al., 2022), health (Rokhmawati et al., 2022), games (Alfaeni et al., 2022). Technological advancement in gaming is a specific technological development (Setiyanti et al., 2022; Supriatna et al., 2023; Wati et al., 2023). Games are a form of technology designed primarily for entertainment, but with time, technology can also serve as an educational tool to enhance children's skills and academic curriculum (Purba et al., 2021; Salamah, 2018; Simorangkir et al., 2022).

Mathematics in elementary schools is often encountered several obstacles, including the lack of ability of students to communicate their understanding to both the teacher and other students. And others (Nurlaila et al., 2018; Sugianto et al., 2017). The purpose of learning mathematics at school is for students to have the ability to communicate ideas with symbols (Waite, 2019; Yamada, 2019), tables (Kearns, 2021), diagrams (Fauza et al., 2022), or other media to clarify situations or problems. This happens because one of the elements of mathematics is logic which can develop students' mathematical thinking skills (Araya, 2021). According to the National Council of Mathematics Teachers (NTCM) (Rizki et al., 2022; Tripathy, 2015), the primary standard competencies in math skills are problem-solving skills (Anggraini et al., 2022; Hidayat et al., 2020), connection skills (Usmiyatun et al., 2021), reasoning skills (Vidyastuti et al., 2022), and representation (Ahmed et al., 2021; Darmayanti et al., 2022), and communication skills (Collver, 2018; Muzumdar, 2017).

Mathematical communication ability is the ability to express mathematical ideas to others both orally and in writing (Nava & Park, 2021; Rosenkoetter et al., 2015). Mathematical communication can be interpreted in the form of conversational activities and reciprocal relationships in the classroom environment where information is conveyed (Beveridge et al., 2021), as well as the information sent contains mathematical material that students learn, such as concepts, formulas, and methods of solving cases through material exchange. Oral or written statements (Zizka, 2021; Zulkarnain & Zubaedi, 2021). Mathematical communication skills can provide rational reasons for solving problems, changing the form of descriptions in mathematical models (Villegas & Marin, 2022), and illustrating mathematical ideas or ideas in the form of relevant reports (Hendriana & Kadarisma, 2019; Pariyar, 2020). Mathematical communication ability is a potential that students have to equip mathematical concepts orally and in writing (Jonsson, 2021; Qodarsasi et al., 2021), and this ability can be improved through the learning process at school (King, 2017), including in the process of learning mathematics, because mathematics is a science of reasoning that can describe students' thinking potential (Koch, 2021; Partono et al., 2021; Ramadhani & Indrawati, 2020). One way to improve mathematical communication skills is the need for personality development by fostering self-confidence in these students. With confidence, students can express ideas or ideas more boldly and confidently with their own opinions (Beilstein et al., 2021; Erna et al., 2021).

Confidence is everyone's belief in their abilities so that a person can feel confident and trustworthy about what he does himself and will be able to optimize his abilities (Maulidya & Nugraheni, 2021; Nurafni & Pujiastuti, 2019). Confidence is also one of the things that must exist in students because self-confidence plays a vital role in student achievement in a lesson (Amalia & Imami, 2021; Kawano, 2019). Thus self-confidence in students is essential because someone confident will be sure of his ability to solve a problem (Purwanda et al., 2020; Silitonga et al., 2019). Therefore, with self-confidence in students, students' mathematical communication skills can slowly develop (Wardhana & Lutfianto, 2018; Winarjo & Sulistyowati, 2022).

Based on field conditions taken from several previous studies, it was found that students' mathematical communication abilities still needed to be improved. Most of the difficulties students experience are in understanding and modeling a mathematical language problem and using appropriate formulas and symbols to solve the problem (K et al., 2021; Wijayanto et al., 2018). In addition, students' mathematical ideas have not been appropriately conveyed when facing mathematical problems, especially in questions related to images and using symbols or mathematical models. (Hikmawati et al., 2019). Research (Marniati et al., 2021) mentions that students still hesitate to express opinions or mathematical ideas in the learning process. When given word problems, students had difficulty solving questions in the language of mathematics or their language, and students also experienced difficulty in using appropriate mathematical symbols. Therefore, it is necessary to increase mathematical abilities, and one type of ability that students must improve is mathematical communication skills because apart from being trained to think mathematically, students must also be able to communicate.

Previously, research had been carried out on students' mathematical communication skills in solving problems in the set material about self-confidence. However, they must focus on solving challenging material problems regarding students' self-confidence. This study included students' mathematical communication skills in solving geometric cube and block problems, mathematical communication skills in terms of self-confidence, analysis of students' mathematical communication

abilities in circle material in terms of gender differences, analysis of students' mathematical communication abilities in ^{class} V. communication skills in set materials and mathematical communication skills of elementary school students in solving flat sided space problems (Afifah et al., 2022; Aminah et al., 2018; Dewi et al., 2021; Hikmawati et al., 2019; Zaditania & Ruli, 2022)

Based on the description above, it is not only mathematical communication skills that are important to have in learning mathematics. Confidence or self-confidence is also an essential ability for students because students with high self-confidence will be the basis for interacting with other students. Able to express opinions without hesitation and respect the views of other students; conversely, students with low self-confidence will find it challenging to communicate and debate. Therefore this study aims to describe students' mathematical communication abilities in solving HOTS questions about self-confidence.

This research introduces a novel approach by applying the TPACK framework to develop digital assessments specifically aimed at enhancing mathematical communication skills. A key aspect of this study is its exploration of the relationship between self-confidence and these skills through a mixed-methods approach. The innovation extends to recommending continuous teacher training to effectively integrate TPACK and develop robust digital platforms. This approach not only supports teachers in refining their educational methods but also ensures they are equipped to leverage technology for improved student outcomes. By doing so, the research provides a comprehensive strategy that enhances both teaching and learning experiences in mathematics education.

A distinctive feature of this research is the seamless integration of TPACK, digital assessment, and the analysis of self-confidence into a unified research design. Unlike previous studies that primarily concentrated on developing digital media or exploring the link between self-confidence and academic achievement, this research delves into how TPACK-based digital assessments can elevate the quality of educational assessment. It emphasizes the fusion of content knowledge, pedagogy, and technology, referencing NCTM standards for indicators of mathematical communication skills and Bandura's Self-Efficacy theory to explain the impact of self-confidence on academic performance. By incorporating elements such as digital portfolios and interactive simulations, the research underscores the importance of digital assessment innovation and technological integration in enhancing mathematics education.

RESEARCH METHOD

This study is designed to examine the application of the TPACK framework in digital assessment of elementary students' mathematical communication skills based on self-confidence levels. The method used is mixed-methods, integrating quantitative and qualitative data to gain a comprehensive understanding of the relationship between self-confidence and students' mathematical communication skills. The study also emphasizes the use of innovative digital media, such as online portfolios and interactive simulations, aligning with the goals of SDG 4 (Quality Education) and SDG 9 (Innovation and Infrastructure).

2.1 Research Design

The research design is mixed-methods with a convergent approach, where quantitative and qualitative data are collected in parallel and analyzed in an integrated manner. This approach is chosen to capture the dynamic relationship between self-confidence and mathematical communication skills more deeply, as well as to validate findings through data triangulation.

Table 1. Mixed-Methods Research Design

Data Type	Data Source	Instrument	Analysis
Quantitative	Self-confidence questionnaire	20-item Likert scale	Descriptive statistics, correlation
Qualitative	Digital assessment scores	Portfolio/simulation scores	Descriptive statistics
	Students' digital portfolios	Artifact analysis	Content analysis, coding
	Structured interviews	Interview guide	Thematic, narrative

Explanation: This table summarizes the integration of quantitative and qualitative data used to address research objectives and support the validity of results.

2.2 Research Subjects and Location

The research subjects are fifth-grade students at the Assyfa Learning Center Pasuruan Foundation, grouped based on self-confidence levels (high, medium, low) using questionnaire results. Subject selection is done purposively to ensure representation of each self-confidence category, with two students per category, totaling six students.

Table 2. Research Subject Categorization

Self-Confidence Category	Number of Students	Questionnaire Score Criteria
High	2	> 62.19
Medium	2	44.61 – 62.19
Low	2	< 44.61

Explanation: This categorization refers to Rizki et al. (2022) and is used for analyzing the relationship between self-confidence and mathematical communication skills.

2.3 Research Instruments

The instruments used include:

1. **Mathematical Communication Skills Test:** Three HOTS descriptive questions on plane geometry, referring to NCTM and Ontario Ministry of Education indicators, namely: (1) written explanation, (2) visual/pictorial representation, (3) mathematical/symbolic expression.
2. **Self-Confidence Questionnaire:** 20-item Likert scale, measuring students' self-confidence dimensions in solving math problems.

3. **Digital Portfolio:** A collection of students' digital artifacts (answers, drawings, explanation videos) uploaded to an online platform.
4. **Structured Interviews:** Interview guide to explore students' understanding and experiences after completing digital assessments.

Table 3. Mathematical Communication Skills Indicators

Indicator	Assessment Description
Written Explanation	Conveying mathematical ideas narratively
Visual Representation	Drawing/diagramming to explain solutions
Mathematical Expression	Using symbols/formal mathematics in answers

Explanation: These indicators are adapted from NCTM and used in TPACK-based digital assessments.

2.4 Data Collection Procedure

Data collection is conducted in several stages:

1. Online distribution of the Self-Confidence Questionnaire to group students.
2. Implementation of Digital Tests: Students complete HOTS questions through digital portfolio platforms and interactive simulations.
3. Collection of Digital Artifacts: All student work (answers, drawings, videos) is collected in digital portfolios.
4. Structured Interviews: Conducted with selected students from each self-confidence category to delve into their thinking processes and experiences.



Figure 1. Data Collection Procedure Flowchart

Explanation: This flowchart illustrates the data collection process from questionnaires to interviews, ensuring data integration of quantitative and qualitative aspects.

2.5 Data Analysis Techniques

Data analysis is conducted in three main stages:

1. **Data Reduction:** Questionnaire and test results are categorized according to scores and mathematical communication skills indicators.
2. **Data Presentation:** Reduced data is presented in narrative, table, and visualization forms.
3. **Conclusion Drawing:** The analysis of the relationship between self-confidence and mathematical communication skills is conducted integratively.

Table 4. Data Analysis Stages

Analysis Stage	Activity Description	Visualization (Script)
Data Reduction	Categorization of questionnaire & test scores	Bar chart of score distribution
Data Presentation	Narrative, table, and result visualization	Heatmap/Scatter plot
Conclusion Drawing	Synthesis of quantitative & qualitative data	Relationship/correlation diagram

2.6 Validity, Reliability, and Research Ethics

The validity of the instruments is ensured through adaptation of indicators from NCTM and expert validation. The reliability of the questionnaire is tested with internal consistency testing. Ethical aspects are maintained with informed consent from parents/guardians of the students, as well as confidentiality of participant data.

2.7 Linkage to SDGs and Research Impact

This research contributes to SDG 4 by improving the quality of mathematics assessment through digital innovation, and SDG 9 by promoting the use of technology in education. Additionally, it supports SDG 5 and SDG 17 through inclusive and collaborative practices, as well as the development of gender-friendly learning media and fostering partnerships among schools, teachers, and parents.

RESULTS AND DISCUSSION

Results

3.1. Description of Quantitative and Qualitative Data

This study involved six fifth-grade students from Assyfa Learning Center Pasuruan Foundation, grouped based on their level of self-confidence (high, medium, low) using a 20-item self-confidence questionnaire. Each category was represented by two students. Quantitative data were obtained from self-confidence questionnaire scores and digital assessment results (online portfolios and interactive simulations), while qualitative data were derived from digital portfolio artifact analysis and structured interviews. The quantitative data analysis revealed a clear pattern: students with high self-confidence consistently achieved higher scores across all mathematical communication indicators—written explanations, visual

representations, and mathematical expressions—compared to their peers with medium or low self-confidence. These students demonstrated a robust understanding of mathematical concepts and were able to articulate their thoughts effectively through digital platforms.

On the qualitative side, digital portfolio analysis and interviews provided deeper insights into students' cognitive processes. High self-confidence students exhibited a more organized and detailed approach in their digital artifacts, highlighting their ability to integrate knowledge and communicate effectively. In contrast, students with medium self-confidence showed potential but often hesitated in their explanations, suggesting a need for supportive interventions to build confidence. Meanwhile, those with low self-confidence struggled to fully engage with the tasks, often requiring additional encouragement and guidance to express their ideas.

Overall, the combination of quantitative and qualitative data underscores the pivotal role of self-confidence in enhancing students' mathematical communication skills. This finding aligns with the broader educational goal of fostering an environment where students can confidently engage with and express complex ideas, ultimately contributing to their overall academic success.

3.2. Quantitative Results: The Relationship Between Self-Confidence and Mathematical Communication Skills

The analysis of scores revealed a clear pattern concerning the relationship between self-confidence and mathematical communication skills. Students who exhibited high levels of self-confidence consistently achieved top scores across all three key indicators of mathematical communication: written explanation, visual representation, and mathematical expression. This suggests that a strong sense of self-confidence can significantly enhance a student's ability to articulate and represent mathematical ideas effectively. Furthermore, these students demonstrated a comprehensive understanding of mathematical concepts, which allowed them to excel in various forms of communication.

In contrast, students with medium self-confidence levels managed to meet only two of the three indicators effectively. While they showed proficiency in certain areas, such as written explanation and visual representation, they often struggled with mathematical expression. This indicates that while moderate self-confidence can support some aspects of mathematical communication, it may not suffice to achieve excellence across all areas. It points towards the need for targeted interventions to bolster their confidence and improve their overall communication skills.

Students with low self-confidence generally met only one of the three indicators, often limited to basic written explanations. This group faced significant challenges in translating their understanding into visual and expressive mathematical forms, which hindered their overall performance. Descriptive statistical analysis further supported these findings, highlighting a positive correlation between self-confidence levels and scores on digital assessments. These results underscore the importance of fostering self-confidence in educational settings to enhance students' mathematical communication abilities and overall academic success.

Table 5. Average Scores of Mathematical Communication Skills Based on Self-Confidence Levels

Self-Confidence Category	Written Explanation	Visual Representation	Mathematical Expression	Number of Indicators Met
High	2/2	2/2	2/2	3
Medium	1/2	2/2	1/2	2
Low	1/2	1/2	0/2	1

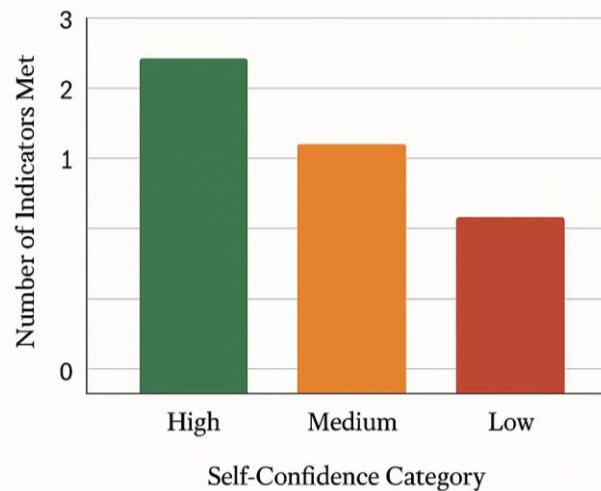


Figure 2. Relationship Between self-confidence and mathematical communication indicators

3.3. Qualitative Results: Digital Artifact Analysis and Interviews

Digital portfolio analysis highlighted distinct differences in students' abilities based on their self-confidence levels. Students with high self-confidence were capable of composing systematic written explanations, crafting accurate diagrams, and using mathematical symbols correctly, showcasing a robust understanding of the content. In contrast, those with medium self-confidence exhibited some hesitation, often struggling with written explanations and occasionally making errors in symbol usage, despite being able to produce good visual representations. Students with low self-confidence primarily recorded known information without developing comprehensive solutions or visual aids.

Interviews reinforced these observations, revealing that students with high self-confidence felt more comfortable using digital media and were more confident in expressing mathematical ideas, both orally and in writing. They were more engaged and proactive in their learning. Conversely, students with low self-confidence tended to be passive and less assured, often requiring additional motivation and support from teachers to actively participate and express their thoughts. These findings suggest that fostering self-confidence is essential for improving educational outcomes in digital learning environments, emphasizing the importance of encouragement and support from educators to help bridge the confidence gap.

4. Effectiveness of TPACK-Based Digital Assessment

The implementation of TPACK-based digital assessment through online portfolios and interactive simulations proved effective in identifying the strengths and weaknesses of students' mathematical communication skills. Teachers could provide real-time feedback, and students could reflect on their thought processes through digital artifacts. The use of digital media also increased student motivation and engagement, particularly in groups with medium and high self-confidence.

The study explored the effectiveness of TPACK-based digital assessment, focusing on online portfolios and interactive simulations. This approach successfully highlighted students' strengths and weaknesses in mathematical communication skills. By leveraging digital platforms, teachers were able to offer immediate feedback, which facilitated students' ability to reflect on their reasoning and understanding through digital artifacts. This real-time interaction not only enhanced the learning experience but also allowed for more personalized guidance.

Moreover, the integration of digital media in assessments significantly boosted student motivation and engagement. This was especially evident among students who exhibited medium to high levels of self-confidence. These students appeared more enthusiastic and participatory, likely due to the interactive and dynamic nature of the digital tools employed. The use of technology in assessments created an environment that encouraged active learning and self-assessment.

Overall, the TPACK-based digital assessment method demonstrated substantial potential in improving educational outcomes. It provided a comprehensive framework that not only assessed student capabilities effectively but also promoted a deeper understanding of mathematical concepts. By fostering an interactive and reflective learning environment, this approach could serve as a model for future educational assessments aiming to harness the benefits of digital technology.

Table 5. Effectiveness of TPACK-based Digital Assessment

Key Findings	Details
Effectiveness	Highlighted students' strengths and weaknesses in mathematical communication skills.
Feedback	Enabled real-time feedback and reflection on reasoning and understanding.
Motivation and Engagement	Boosted particularly among students with medium to high self-confidence.
Educational Outcome	Promoted deeper understanding and provided a comprehensive assessment framework.

5. Challenges and Implications

Identified challenges include limited access to technology at home, variations in students' digital literacy, and teachers' readiness to optimally integrate TPACK. However, with continuous training and the selection of child-friendly platforms, these challenges can be minimized. This study impacts the achievement of SDG 4 (Quality Education) and SDG 9 (Innovation and Infrastructure) by promoting technology-based assessment and learning innovations in mathematics. Additionally, the inclusive and collaborative practices applied support SDG 5 (Gender Equality) and SDG 17 (Partnerships).

Discussion

The study underscores that self-confidence is pivotal in elementary students' mathematical communication success. Students with high self-confidence meet all mathematical communication indicators and are more active and reflective in digital learning environments. This aligns with findings by Rudianto et al. (2022) and Rizki et al. (2022), which highlight confidence as a significant contributor to students' communication skills and mathematics achievement. Confident

students participate actively, ask questions, and explore problem-solving strategies, leading to enhanced learning outcomes. This confidence not only boosts academic performance but also positively influences students' attitudes towards learning, equipping them to tackle challenges effectively. Thus, self-confidence sets a solid foundation for lifelong learning.

The integration of the TPACK (Technological Pedagogical Content Knowledge) framework in digital assessments marks a notable shift in educational strategies. TPACK helps teachers design assessments that are authentic, interactive, and adaptive, fostering a deeper understanding of students' learning processes. Portfolio-based digital assessments and interactive simulations effectively evaluate students' thinking processes rather than just their final answers. This approach enables more personalized feedback, helping students identify their strengths and areas for improvement. Empirical studies have shown these assessments to promote critical thinking and creativity, as they shift the focus from rote memorization to a more holistic understanding of mathematical concepts, contributing to a more engaging learning experience.

This study distinguishes itself by explicitly linking the TPACK framework to digital assessment design and the relationship between self-confidence and mathematical communication skills. While previous research mainly focused on digital media development or the correlation between self-confidence and academic achievement, this study offers a comprehensive analysis of how digital tools can enhance communication skills through tailored assessments. Findings indicate that incorporating self-confidence as a variable in assessment design can lead to more effective teaching strategies and improved student outcomes. This approach enriches existing research and offers practical guidelines for educators aiming to leverage technology to enhance educational practices.

The study's practical implications stress the importance of continuous teacher training in TPACK adoption, development of child-friendly digital platforms, and collaboration among schools, teachers, and parents to support equitable and inclusive mathematics assessments. These initiatives are crucial for preparing students for the demands of the 21st century and aligning educational practices with the Sustainable Development Goals (SDGs). By fostering environments that build student self-confidence, educators can cultivate a generation of learners equipped with skills necessary to thrive in a rapidly changing world. Furthermore, the study lays the foundation for developing educational policies that prioritize digital assessment innovation and recognize self-confidence as integral to educational success.

Incorporating TPACK into digital assessments not only enhances the assessment process but also contributes to developing critical thinking and creativity in students. This innovative approach shifts the focus from traditional memorization techniques to a deeper understanding of mathematical concepts. By engaging students in interactive simulations and portfolio-based assessments, teachers can provide feedback that is both personal and meaningful. This method allows students to reflect on their learning journey, fostering a more engaging and comprehensive educational experience. As a result, students become more adept at problem-solving and critical analysis, skills that are essential in today's fast-paced world.

The study highlights the need for educational policies that support digital assessment innovation and the enhancement of student self-confidence. Policymakers must recognize the importance of integrating technology in assessments to foster a more dynamic and inclusive learning environment. By prioritizing the development of child-friendly digital platforms and ensuring continuous teacher training in TPACK, educational systems can create a supportive atmosphere that encourages student growth. Collaborative efforts between schools, teachers, and parents are essential to ensure that all students have

access to equitable and inclusive learning opportunities, ultimately contributing to the achievement of the SDGs.

Overall, the research affirms that self-confidence is key to success in mathematical communication among elementary students. By integrating the TPACK framework into digital assessments, educators can design more authentic and interactive assessments that cater to students' individual needs. This approach not only enhances communication skills but also contributes to improved learning outcomes and fosters a deeper understanding of mathematical concepts. As education continues to evolve, embracing technology and self-confidence as integral components of the learning process will be crucial for preparing students for future challenges. This study provides a roadmap for educators and policymakers to harness the power of technology and self-confidence in shaping the future of education.

CONCLUSION

The study underscores the pivotal role self-confidence plays in the development of elementary students' mathematical communication skills within the TPACK framework during digital assessments. By examining the relationship between self-confidence and students' proficiency in articulating mathematical concepts through digital means, the research reveals several key insights:

1. The study highlights the significant influence of self-confidence on the mathematical communication skills of elementary students within the TPACK framework during digital assessments.
2. A positive correlation is evident between self-confidence and students' proficiency in articulating mathematical concepts digitally.
3. Students with high self-confidence consistently met all communication indicators, demonstrating strong understanding and expression.
4. Those with moderate to low self-confidence require personalized support to improve their skills.
5. TPACK-based digital assessments enhanced both the evaluation process and data quality.
6. The findings underscore the importance of fostering self-confidence and utilizing digital tools to advance math education.

To improve educational outcomes, it is crucial for teachers to receive continuous training in the TPACK framework, enabling them to integrate technology effectively in their teaching practices. Schools should develop child-friendly digital platforms that engage students and support differentiated learning. Additionally, implementing targeted interventions for students with moderate and low self-confidence, such as personalized feedback and strategies to boost self-efficacy, is essential. Collaborative efforts among educators, parents, and the community should be encouraged to support student confidence and digital engagement. Lastly, educational policymakers need to prioritize technology integration in assessments and recognize the significance of self-confidence in student success, aligning policies with the Sustainable Development Goals for quality education and innovation.

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