ARTICLE

The digital–cognitive divide in quadratic function learning: evidence from Bloom's digital taxonomy

Thesa Kandaga [a]
Idha Novianti [b]
Suci Nurhayati [c]
Valeria Yekti Kwasaning Gusti [d]

Abstract

This research explores the disparity between students' digital proficiency and their cognitive performance within the framework of Bloom's Digital Taxonomy (BDT) in secondary school mathematics education. The study investigates how digital skills impact students' ability to attain cognitive outcomes across different BDT levels. Employing a quantitative descriptive design, it examines 127 students from four secondary schools in three major cities in Indonesia. Data were collected through cognitive tests and digital proficiency assessments, covering seven categories of digital tools: presentation, communication, interactive gamification, classroom management, mathematics & science, evaluation tools, and content creation. The results indicate that while students with strong digital skills perform well in lower-order cognitive tasks (remembering, understanding, applying), they face difficulties in achieving higher-order thinking skills (analyzing, evaluating, creating). This discrepancy highlights the necessity of aligning digital engagement with cognitive development goals, ensuring that

[a] Universitas Terbuka, Faculdade de Formação de Professores e Ciências da Educação, Programa de Estudos de Educação Matemática, Tangerang Selatan, Banten, Indonésia.

[b] Universitas Terbuka, Faculdade de Formação de Professores e Ciências da Educação, Programa de Estudos de Educação Matemática, Tangerang Selatan, Banten, Indonésia.

[c] Universitas Terbuka, Faculdade de Formação de Professores e Ciências da Educação, Programa de Estudos de Educação Matemática, Tangerang Selatan, Banten, Indonésia.

[d] Universitas Terbuka, Faculdade de Formação de Professores e Ciências da Educação, Programa de Estudos de Educação Matemática, Tangerang Selatan, Banten, Indonésia.

Received: Feb 23, 2025
Accepted: Oct 05, 2026

technology fosters critical thinking and creativity rather than merely supporting superficial knowledge acquisition.

Keywords: Digital Proficiency. Cognitive Levels. Bloom's Digital Taxonomy. Technology Integration, Descriptive Study.

1 Introduction

The advancement of digital technology over the past few decades has significantly influenced various aspects of life, particularly Education. Technology is no longer just a supporting tool but has become essential in enhancing students' critical thinking and problem-solving abilities. In this shift, Bloom's Taxonomy has been refined into Bloom's Digital Taxonomy (BDT) to evaluate cognitive skills within digital learning environments (Churches, 2008). This adaptation builds on Bloom's Taxonomy (Anderson & Krathwohl, 2001), incorporating technological competencies to meet the demands of the 21st century, where digital tools are deeply integrated into daily life. As Education evolves alongside technology, BDT has been widely used to assess students' cognitive abilities in digital-based learning. Research by Alaghbary (2021) on Web 2.0-based learning argues that integrating technology into Education plays a crucial role in developing students' critical thinking skills.

However, despite the extensive integration of technology in Education, a study by Zerényi and Mátrai (2022) found that while students' technical skills have improved, not all of them successfully develop higher-order thinking skills as expected. This finding aligns with the current educational landscape, where students have unrestricted access to digital tools, yet often face challenges in achieving advanced cognitive levels within BDT (Ortiz et al., 2020). The main problem that arises is that the implementation of digital technology often focuses too heavily on technical aspects without considering the substance needed to foster students' critical and creative thinking skills (Starkey, 2011; Sarıtaş, 2022). The use of technology in learning, such as Flipbooks, Quizizz, and Videos, although beneficial for technical skills, does not always ensure students achieve higher cognitive outcomes (Husain, 2021). For example, Lim (2021) found that digital collaborative tasks using the dictogloss method tend to make students focus solely on completing technical tasks without deeper consideration or analysis.

In this situation, students' cognitive skills at higher-order thinking levels, such as analyzing and evaluating, become more difficult to achieve because digital activities implemented often do not promote deep understanding.

Digital activities should be designed to challenge students to think more critically and reflectively (Akintolu et al., 2022). According to Goranova (2019), digital learning tools should be designed to support students in reaching higher-order thinking levels, such as analysis (C4) to creation (C6), by providing challenges that encourage them to think more critically and reflectively. Faraon et al. (2023) also support this view, noting that the use of technology like artificial intelligence can assist learning at the analysis level, but achieving higher-order thinking requires more profound interaction between students and technology.

This tension between digital activity and higher-order thinking is not unique to BDT; it echoes long-standing debates in learning theory and cognitive science. Vygotsky's (1978) concept of mediated learning holds that tools, including digital tools, only support higher psychological functions when a more capable other, typically a teacher, structures their use toward a specific cognitive goal; a tool used without this pedagogical mediation risks remaining at the level of mechanical operation rather than genuine cognitive development. This is compounded by cognitive load considerations: Sweller (1988) demonstrated that problem-solving activities which do not explicitly guide learners toward schema construction can consume working memory capacity without producing durable learning, which may help explain why digital tools that ease lower-order tasks do not automatically transfer into higher-order reasoning. Consistent with this, critical reviews of technology-integration frameworks such as SAMR (Hamilton, Rosenberg, & Akcaoglu, 2016) caution that classifying a digital activity by its technical sophistication says little about its actual cognitive demand, reinforcing the argument that the pedagogical design surrounding a tool, rather than the tool itself, determines whether it fosters deeper cognitive engagement.

Various studies (Alaghbary, 2021; Sarıtaş, 2022; Goronova, 2019) indicate that although digital technology can support learning, its effectiveness in achieving high cognitive levels often depends on instructional design, student engagement, and adequate mastery of digital tools. Kloos & Alario-Hoyos (2021) highlight that even though the use of frameworks like the DigCompEdu Framework has been adopted to support digital learning, its implementation still faces challenges in achieving higher cognitive outcomes. Research by Sayary *et al.* (2016) shows that the use of digital simulations is often insufficient to enhance students' critical thinking skills. While these simulations can help improve technical skills, achieving high cognitive outcomes such as analysis, evaluation, and creation remains difficult. Similarly, Ortiz *et al.* (2020) found that the use of open educational resources

(OER) has not fully supported the achievement of high cognitive goals, which are the focus of BDT.

In this context, it is important for educators to not only focus on technological mastery but also develop students' deeper cognitive abilities (Gunarso *et al.,* 2024). Husain (2021) emphasizes that digital assessments should be designed to encourage students to think critically and creatively, rather than merely completing technical tasks mechanically. Educators must also ensure that digital activities align with the expected cognitive levels, creating a learning environment that supports students in exploring ideas in depth (Starkey, 2011). Although digital technology is often implemented in Education, many previous studies, such as those by Zawedde (2014), Sari (2014), Wedlock & Growe (2017), Sumartini (2022), and Lim (2021), have focused only on the general use of technology without thoroughly investigating whether students' digital skills truly support the achievement of higher cognitive levels, such as analysis, evaluation, and creation.

This study discusses how students' digital skills relate to achieving higher-order thinking levels (C4-C6) within BDT. It also proposes a more strategic approach to optimizing the use of digital technology, ensuring that it not only aids students in developing technical skills but also fosters the development of their critical and creative thinking skills.

This study aims to analyze the relationship between students' digital skills and cognitive achievement from the perspective of BDT. By mapping students' digital skills and cognitive levels in detail, this research is expected to provide deeper insight into how digital technology can be used not only for technical purposes but also to promote critical thinking abilities and higher cognitive development.

2 Method

This section describes the methodological procedures used to examine the relationship between students' digital proficiency and cognitive achievement. It outlines the research design and participants, data collection procedures and instruments, the operational definition of digital proficiency, and the descriptive data analysis used to identify patterns of alignment and misalignment across BDT levels.

2.1 Research design and subjects

This study employed a quantitative cross-sectional descriptive design to investigate the relationship between students' digital proficiency and their cognitive

achievement in mathematics. This design was chosen to systematically describe patterns across a defined sample using measurable indicators of digital proficiency and cognitive achievement. The sample consisted of 127 students from four secondary schools across three major Indonesian cities. Cognitive assessments were restricted to mathematics, establishing a clear research boundary. The 127 students were selected using convenience sampling based on pre-existing class structures across the four participating schools, reflecting the natural distribution of digital proficiency and cognitive ability within regular classroom settings. This approach was chosen to preserve ecological validity capturing how digital proficiency and cognitive achievement manifest under ordinary classroom conditions rather than through randomized assignment, which was not feasible given the schools' existing class arrangements.

This study was conducted in Indonesia, a country with one of the world's largest and most geographically diverse Education systems, encompassing significant disparities in digital infrastructure access between urban centers and underserved (3T) regions. Indonesia's basic Education system consists of six years of primary school (SD), three years of junior secondary school (SMP), and three years of senior secondary school (SMA/SMK), governed nationally by the Ministry of Education, Culture, Research, and Technology. The increasing integration of digital technology into Indonesian classrooms, accelerated further following the COVID-19 pandemic, makes it a relevant context for examining whether digital proficiency translates into higher-order cognitive achievement, particularly given ongoing national curriculum emphasis on digital proficiency (Kurikulum Merdeka).

2.2 Data collection

Data was collected through cognitive level tests used to measure students' cognitive achievement levels based on BDT. The six levels in Bloom's taxonomy were each represented by 1 question that represented each of those indicators. The cognitive indicators and digital activities in this study were adapted from Faraon *et al.* (2023) summary as presented in Table 1. The test was designed for mathematics with the topic of quadratic functions.

The cognitive test instrument underwent content validation by three categories of experts: a content/subject-matter expert, a methodological/evaluation expert, and an experienced teacher/practitioner. Following expert validation, the instrument was piloted with 28 twelfth-grade students in Bandung. Item validity testing showed that six of the eight items demonstrated significant item-total correlations ($r > .374$, $N = 28$), while two items fell below this threshold and were revised prior to final

administration. Reliability testing yielded a Cronbach's alpha of .821, indicating high internal consistency. The digital proficiency instrument was adapted from established digital proficiency piloted and reviewed for content validity.

Table 1 – Summary of Cognitive and Digital verbs adapted from as level indicators in this study

Taxonomy	Cognitive verbs	Digital verbs	Thinking Level
Remembering	Recognizing, listing, describing, identifying, naming, locating, finding	Bullet pointing, highlighting, bookmarking, social networking, social bookmarking, searching, googling	Lowest level
Understanding	Interpreting, summarizing, inferring, paraphrasing, classifying, comparing, explaining, exemplifying	Advanced and Boolean searching, blog journaling, categorizing and tagging, commenting and annotating, subscribing	Lower level
Applying	Implementing, using, carrying out, executing	Running and operating, playing, uploading and sharing, hacking, editing	Higher level
Analyzing	Comparing, organizing, detecting, monitoring, deconstructing, attributing, outlining, finding, structuring, integrating	Mashing, linking, reverse-engineering, cracking, mind-mapping	Higher level
Evaluating	Checking, hypothesizing, critiquing, experimenting, judging, testing, detecting, monitoring	Blog commenting and reflecting, posting, moderating, collaborating and networking, testing, validating	Higher level
Creating	Designing, constructing, planning, producing, inventing, devising, making	Programming, filming, animating, videocasting, podcasting, mixing and remixing, directing and producing, publishing	Highest level

Source: Anderson & Krathwohl (2001) and Churches (2008)

To identify the gap between students' cognitive abilities and digital proficiency, this study employed an instrument that required students to solve problems using technology. However, the use of technology was limited to specific parts of the overall cognitive process, ensuring that students still relied on fundamental reasoning skills.

Table 2 – Question grid of Cognitive and Digital Proficiency

Question number	Cognitive Indicators	Digital proficiency	Taxonomy Level
1	Classifying domain, codomain, and range of a function	Annotating the domain, co-domain, and range of a function	C1-C2
2	Determining composite function of two functions	Operating technology to obtain a composition of two functions	C3
3	Deconstructing composite function to obtain the former function	Reversing technology to obtain former function from a composite function	C4
4	Structuring composite function from several functions	Mind-mapping composite function using technology	C4
5	Hypothesizing composite function from contextual problem	Testing composite function into contextual problem using technology	C5
6	Constructing inverse function from a composite function	Constructing inverse function from a composite function	C6

Source: Own elaboration (2025)

This study also employed a technology-to-analytics conversion table, similar to the approach used in Kandaga (2022), to systematically translate digital-assisted problem-solving into non-digital analytical processes. By mapping students' use of technology to equivalent manual cognitive steps, this method allowed for a clearer identification of cognitive gaps. The table served as a framework to pinpoint where students struggled, highlighting moments when reliance on technology failed to translate into deeper cognitive engagement. This approach enabled a comparative assessment, revealing specific phases of problem-solving where students exhibited disconnects between digital proficiency and cognitive mastery in mathematics.

2.3 Operational definition of digital proficiency

This study uses the term "digital proficiency" to specifically denote students' practical, task-based ability to operate digital tools across defined categories (e.g., presentation, communication, evaluation tools), as measured through direct performance-based indicators. This is distinguished from "digital literacy," which more broadly encompasses critical and reflective engagement with digital

information, and from "digital competence," which typically integrates attitudinal and contextual dimensions of technology use (Ferrari, 2013). While these terms are sometimes used interchangeably in the literature, this study restricts its measurement and claims specifically to proficiency, that is, the demonstrated capacity to operate digital tools, rather than the broader constructs of literacy or competence.

2.4 Data analysis

The data were analyzed using descriptive statistical procedures to examine the gap between students' digital proficiency and cognitive indicators in BDT. Students' cognitive test scores were classified according to the six BDT levels, and performance scores were systematically categorized. Simultaneously, students' digital proficiency was assessed across seven categories of digital tools: presentation, communication, interactive gamification, classroom management, mathematics & science, evaluation tools, and content creation. Frequencies, percentages, means, and standard deviations were calculated for each category. Cross-tabulation and a heatmap visualization were then used to illustrate the distribution of cognitive achievement across digital proficiency levels, highlighting patterns of alignment and misalignment between digital reliance and cognitive mastery in mathematics. The technology-to-analytics conversion table (Kandaga, 2022) was also used descriptively to track cognitive gaps, pinpointing specific stages where students struggled to transition from digital-assisted problem-solving to analytical reasoning.

3 Results

In general, the results shows a clear gap between students' digital proficiency and their cognitive achievement across the levels of BDT. Participants with more developed digital skills exhibited proficiency in lower-order cognitive domains such as recalling and comprehending information (Gui & Argentin, 2011). However, they often struggle with higher-order skills like analyzing, evaluating, and creating. This difficulty may be attributed to the limitations in applying digital skills in more complex contexts. While strong digital skills often indicate technical proficiency, higher-order cognitive skills require critical and creative application of knowledge, involving problem-solving and deep reflection. This suggests the need for a more strategic approach in integrating digital technology, ensuring it serves as a tool not just for basic tasks but for fostering higher-level thinking.

3.1 Profiling students' digital proficiency

This study measured students' digital proficiency by surveying 127 secondary school students in Indonesia. Before delving into the detailed categories of students' digital proficiency, it is essential to provide an overview of the overall proficiency levels measured in this study. Table 2 below summarizes the students' proficiency levels, offering a general perspective on how students perform in digital tasks before breaking down specific tools and competencies.

Table 3 – Students' Digital Proficiency based on Digital Tools Categories

Proficiency Level	n	(%)
Very high	57	45%
High	29	23%
Moderate	34	27%
Low	6	5%
Very low	1	1%

Source: Own elaboration (2024)

Table 3 shows that 45% of students exhibited very high digital proficiency, and another 23% had high proficiency, indicating that a significant portion of students are well-equipped with digital skills. However, there is still a portion of students (5%) with low proficiency and even 1% with very low proficiency, which suggests that while the majority are capable of digital tasks, additional support may be required for those less proficient.

In this study, digital proficiency assessment divided digital tools into several categories: presentation tools, communication tools, interactive games, classroom management tools, mathematics & science tools, evaluation tools, and digital content creation tools. The survey results showed that students generally had good proficiency in using digital tools for presentation, evaluation, and communication. Table 3 presents the data on students' digital proficiency, it shows that most students have good proficiency in using various types of digital devices.

Table 4 – Students' Digital Proficiency based on Digital Tools Categories

	Information	Communication	Interactive Gamification	Competencies	Evaluation Tools	Content	TOTAL
MIN	1	1	1	1	1	1	7
MAX	5	5	5	5	5	5	35
AVERAGE	4.42	3.92	3.31	3.09	4.85	3.09	25.72
STDEV	0.859	0.922	1.263	1.202	0.656	1.439	6.870

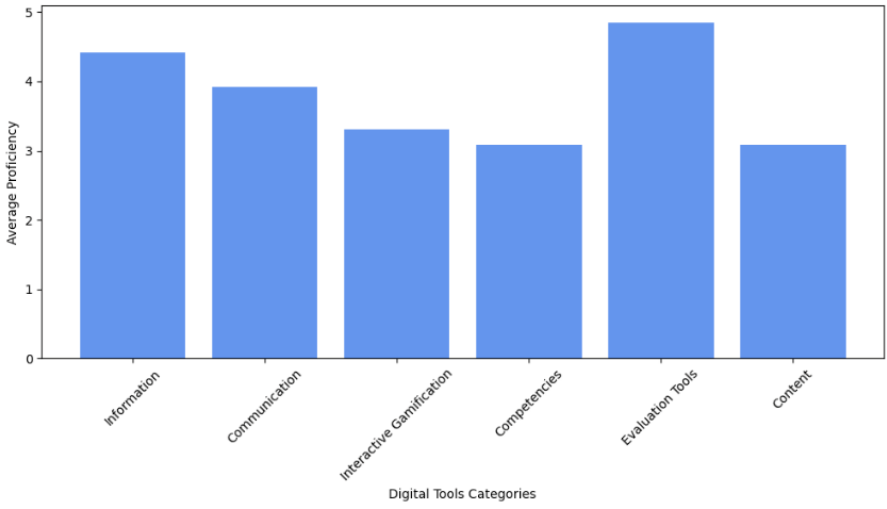
Source: Own elaboration (2024)

The results presented in Table 4 provide an overview of students' digital skills based on the category of digital tools. The highest average skill level is found in the Evaluation Tools category (4.85), indicating that students generally have good proficiency in using digital evaluation tools. This could suggest that students are already familiar with assessment tools such as Quizziz, WordWall, and similar applications.

On the other hand, the Competencies and Content categories have the lowest average (3.09), showing that although students generally possess basic skills in using digital tools, their proficiency in tools that support content creation or enhance their comprehension skills is still limited. This may indicate a need to emphasize improving students' skills in using these tools for more creative and complex learning purposes.

The Interactive Gamification category also shows a relatively low average (3.31), with some students demonstrating a lack of familiarity with or usage of digital gamification in learning. The high standard deviation in some categories, such as Interactive Gamification (1.263) and Content (1.439), indicates considerable variation among students in these categories.

Figure 1 – Average Digital Proficiency by Categories



Source: Own elaboration (2024)

The following section analyzes students' cognitive achievement levels based on Bloom's Taxonomy. This analysis illustrated how well students perform in different cognitive domains, from basic recall to more complex tasks such as analysis and creation, providing deeper insights into the relationship between their digital skills and cognitive development.

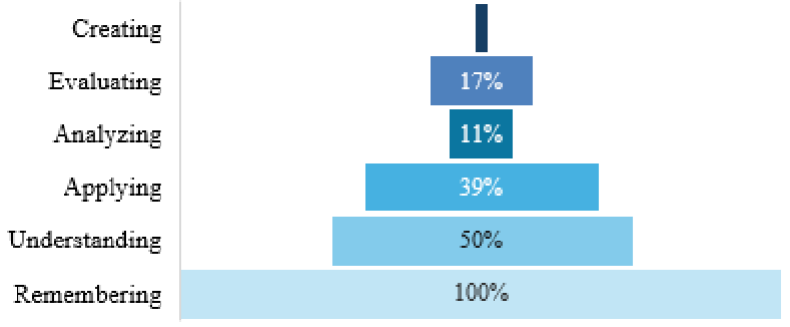
3.2 Students' achievement on Bloom's Digital Taxonomy indicators

The analysis of students' mathematics learning outcomes in this study was based on the indicators proposed by Churches (2008). In general, BDT does not differ from Bloom's Taxonomy and its revision proposed by Anderson & Krathwohl, but BDT is more specific in accommodating students' digital abilities. The student activities grouped in this study correspond to the verbs that were presented earlier in Table 1. Specifically, for each level of BDT in this study, the activities that students must perform to achieve a certain cognitive level were determined. This classification can be seen in Table 1.

Based on the analysis between the BDT activities formulated and the student's cognitive level tests, it was found that all students achieved the C1 level. Unsurprisingly, technology indeed provides great assistance in facilitating

activities at this level. Cognitive abilities of remembering and understanding are facilitated by digital activities such as googling and bookmarking through the use of online search engines (Kurniasih *et al.,* 2018; Shariman *et al.,* 2012). Student achievement was generally lower at higher cognitive levels. At the analyzing level, this pattern became particularly evident, as high digital proficiency did not correspond to similarly high cognitive achievement. Figure 2 presents students' cognitive achievement across the levels of BDT.

Figure 2 – Student's Cognitive Level Tests Based on The BDT Level



Source: Own elaboration (2024)

The findings suggest that students with more developed digital skills tend to excel at the lower cognitive levels (C1 to C3) of Bloom's Digital Taxonomy. These levels involve recalling, comprehending, and applying knowledge, which is facilitated by the diverse interactive digital technologies used. As shown in Table 5, students with high and higher digital proficiency demonstrate good achievement in remembering, understanding, and applying domains. This pattern suggests that mastery of digital technology may be associated with an advantage in building the foundational cognitive skills that are crucial for more complex learning and problem-solving, although the descriptive nature of this analysis does not establish a causal relationship. Proficiency in leveraging digital technology appears to co-occur with students' ability to effectively engage with and apply their knowledge at the basic cognitive levels.

The results showed that students performed relatively well at the C1–C3 levels, where the cognitive demands were lower than those required at higher

levels. However, this pattern should not be interpreted as evidence that digital technology directly improved their cognitive performance. The implementation of technology at these levels tends to be straightforward and practical, making it easier for students to benefit from it. Specifically, for the Remembering (C1) level, activities such as searching and googling information using online search engines provided strong support for students in recalling information quickly. This observation shows that technology simplifies the process of accessing and remembering information.

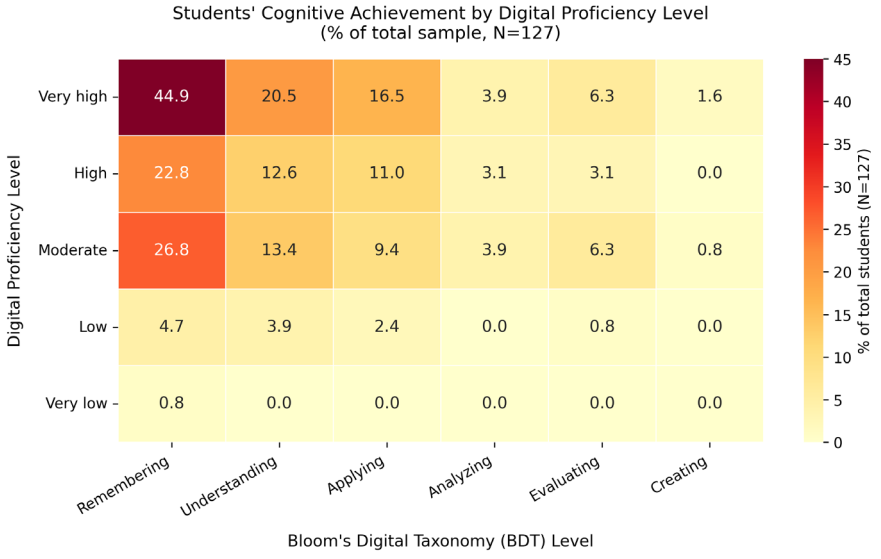
Table 5 – Students' Cognitive Achievements Based on Their Digital Proficiency

Digital Proficiency	Bloom's Digital Taxonomy					
	Remembering	Understanding	Applying	Analyzing	Evaluating	Creating
Very low	1%	0%	0%	0%	1%	0%
Low	4%	4%	2%	0%	3%	0%
Moderate	27%	13%	9%	3%	4%	0%
High	23%	13%	11%	4%	5%	0%
Very high	45%	20%	17%	4%	4%	2%
TOTAL	100%	50%	39%	11%	17%	2%

Source: Own elaboration (2024)

At the Understanding (C2) level, applications like GeoGebra and Maple offered effective support by allowing students to visualize and better comprehend mathematical concepts. These tools provided interactive simulations that helped bridge the gap between abstract concepts and practical understanding. For the Applying (C3) level, tools such as Photo math, Maple, POM-QM, and ChatGPT facilitated students in applying mathematical and problem-solving skills in an accessible manner. The instructions or commands required to use these tools at this level were relatively simple, without involving complex or nested commands. Students could complete tasks without needing to integrate multiple applications or engage in complex ways of thinking. Therefore, at these levels, higher cognitive achievement coincided with students' generally high digital proficiency.

Figure 3 – Heatmap of Students' Cognitive Achievement by Digital Proficiency Level (% of total sample, N = 127)



Source: (Own elaboration, 2024)

4 Discussion

The results of this study were consistent with findings from earlier research, reinforcing the notion that digital technology is instrumental in enhancing student learning. Wedlock and Growe (2017) highlighted the pivotal role that digital tools play in helping students cultivate essential cognitive skills. They pointed out that these technologies can support the processes of remembering and understanding information, particularly at the C1 and C2 cognitive levels. Furthermore, Lin (2021) explored the impact of specific simulation technologies, including GeoGebra and Maple, on student learning outcomes. His research demonstrated that these tools were particularly effective in enhancing students' comprehension at the C2 level. However, Lin argued that advancing to the Applying (C3) level and beyond requires a more profound integration of technology alongside a critical and reflective learning approach. This deeper engagement is essential for students to develop the necessary competencies to navigate more complex problems effectively. Moreover, Sumartini (2022) emphasized that while applications such as Photomath and Maple have the potential to bolster basic cognitive skills at the Applying (C3) level, they do not inherently ensure that students can transfer their knowledge to more intricate and varied contexts. This

observation underscores a crucial gap in the educational process and highlights the necessity for implementing targeted learning strategies. Such strategies should focus on fostering critical thinking skills, thereby enabling students to ascend to higher levels of understanding and application as defined by BDT. By prioritizing these efforts, educators can better prepare students to tackle complex tasks and challenges in their academic and real-world endeavors.

At the same time, this finding should be read alongside a broader body of international scholarship that has questioned the assumption that digital access or proficiency straightforwardly translates into improved learning outcomes. Analyzing PISA data across dozens of Education systems, the OECD (2015) found no consistent positive relationship between students' computer use at school and their performance in mathematics and reading, and cautioned that heavy technology use was in some cases associated with weaker outcomes. Kirschner and De Bruyckere (2017) similarly challenged the popular assumption that students who have grown up with digital technology automatically possess stronger digital or cognitive capabilities as a result, arguing that such assumptions are not supported by cognitive science. Selwyn (2016) extends this critique further, arguing that the presumed benefits of educational technology are often driven by commercial and policy interests rather than robust evidence of cognitive gains, and calling for more critical scrutiny of what digital tools actually contribute to learning. Read together, these international, critical perspectives support the present study's central finding: digital proficiency alone, without deliberate pedagogical structuring, does not reliably produce higher-order cognitive achievement.

The condition was different from that faced by students with low and very low digital proficiency. These students did not show good cognitive achievement at the cognitive levels C1 to C3, with only 5% of students accomplishing the remembering and understanding indicators, and just 2% reaching the applying level. This indicates that at the lower and middle-order thinking levels (C1–C3), insufficient digital skills become an obstacle in supporting students' cognitive development. The detailed overview of students' cognitive achievements based on their digital proficiency is presented by a crosstab in Table 5 above.

While the previous analysis highlights several advantages, it was also identified that students with moderate to very high digital skills still do not benefit from their digital proficiency to support their ability to apply, analyze, and evaluate information at higher cognitive levels. Based on the descriptive data, students' generally high digital proficiency was not accompanied by comparable achievement at the C4, C5, and C6 levels of BDT. This is reflected in the low percentage of

student achievement at these levels, even though students have high levels of digital proficiency. For example, students with very high digital proficiency only achieved 4% at the Analyzing and Evaluating levels, and only 2% at the Creating level. Even students with high digital proficiency only achieved 4% at the Evaluating level and showed no achievement at all at the Creating level. Students with medium digital proficiency also show a similar trend, with very low achievement at the Analyzing and Evaluating levels, and zero at the Creating level. This data indicates that although students have good digital proficiency, this does not automatically help them achieve indicators at higher cognitive levels, such as analyzing, evaluating, and creating.

Digital proficiency serves as a valuable asset in the pursuit of higher-order cognitive skills, but it is essential to recognize that it is just one element of a broader educational strategy. Current digital tools have limitations, often concentrating on procedural and technical tasks that are suitable for lower-order cognitive activities. By enhancing these tools to encourage deeper, reflective thinking, we can create more meaningful learning experiences that enable students to engage in complex tasks such as analysis and evaluation (Haleva *et al.,* 2020; Herrmann, 1996). To foster higher-order thinking, such as analysis and evaluation, it is crucial to implement effective instructional design (Kandaga, 2023). While tools like GeoGebra and Photomath can provide answers, it is essential to integrate these resources with teaching methods that promote critical thinking and understanding of core concepts. This approach will better equip students with the analytical skills necessary for comprehensive learning. When it comes to the Creating (C6) level, which involves generating innovative ideas or products, it is important to acknowledge that digital tools alone may not be sufficient. Fostering creativity requires students to synthesize information from varied sources and engage in open-ended exploration. Encouraging independent exploration and reflection can heighten the effectiveness of these tools, enabling students to innovate.

Finally, achieving higher-order cognitive outcomes relies on several non-digital factors that enhance the learning experience. A strong conceptual understanding, the ability to identify relationships among different concepts, and engaging activities that inspire reflective thought are all vital (Kandaga, 2023). While digital proficiency is important, it is most effective when paired with foundational skills, critical thinking, and a supportive learning environment. By focusing on these interconnected elements, educators can empower students to reach a deeper understanding and develop the critical and creative thinking skills essential for success.

4.1 Gap Between Digital Activities and Cognitive Indicators in the BDT

The research findings indicate that merely possessing digital skills is insufficient for students to successfully achieve more advanced cognitive outcomes. As we progress to the higher levels of BDT (C4 to C6), the impact is no longer solely dependent on students' digital proficiency, but also on the way technology is utilized. While interactive digital technology can be an effective tool, cognitive abilities at higher levels require a more holistic approach. As Kandaga *et al.* (2023) suggests, although interactive digital technology can provide visualization and simulation that facilitates conceptual understanding, it will be less effective if not supported by appropriate learning strategies and techniques. Achieving cognitive indicators at the Analyzing, Evaluating, and Creating levels should emphasize the development of appropriate modes of thinking, rather than simply relying on the features available in the technology (McDougall, 2005; Chinien & Boutin, 2003; Serafín *et al.,* 2014).

For example, the use of simulation software that enables students to explore and manipulate variables can indeed support analysis and evaluation (Smetana & Bell, 2012; Price *et al.,* 2019). However, this is effective only when students are guided to critically and reflectively examine the results they obtain (Price *et al.,* 2019). Without clear direction or prompting questions that encourage further exploration, the technology will be utilized merely as a passive tool, failing to stimulate the higher-order thinking skills required at these cognitive levels (Pineteh, 2014).

At the Creating level, where students are tasked with generating novel ideas or products, relying solely on technology for presentation or modeling is grossly inadequate in facilitating intended innovation. To truly empower students to create something innovative, technology must be integrated with learning strategies that encourage active knowledge construction and deep conceptual understanding, such as inquiry-based or project-based approaches. Fostering the appropriate modes of thinking must be the foundation when incorporating technology into learning (Onyango & Gitonga, 2017). Failing to utilize appropriate technology results in learning that is dull and ineffective, unable to help students achieve the expected cognitive indicators at the higher levels of C4 through C6.

The findings of this study challenge the prevailing assumption that digital activities directly correlate with students' cognitive achievements in BDT. This study contrasts with previous research by Zawedde (2014) and Lin (2021), which presented digital practices as an effective means to support higher-order thinking skills. While those studies highlighted the successful achievement of

high order thinking indicators through digital activities, the current analysis casts doubt on this direct connection. The crux of the matter lies in the need to look beyond the mere execution of digital tasks and instead evaluate the substantive content and cognitive processes they reflect. For instance, creating a podcast may ostensibly align with the Creating level of BDT, but the assessment should focus on the critical thinking, depth of understanding, and originality of ideas expressed, rather than just the technical aspects of production. This distinction becomes particularly crucial in contexts where technical proficiency, rather than cognitive development, is the primary learning objective, such as in broadcasting courses. This study suggests that the relationship between digital activities and cognitive achievement is more nuanced than previously portrayed, necessitating a more holistic and discerning approach to evaluating the cognitive impact of technology-mediated learning.

This research presents a compelling counterargument to the notion that students' engagement in digital activities directly corresponds to their achievement of higher-order thinking skills within BDT. The findings reveal that even when students undertake digital activities that ostensibly align with advanced BDT levels, such as creating a podcast at the C6 level, this does not automatically guarantee their achievement of the associated cognitive indicators. Contrary to findings from other studies, this study suggests a skeptical perspective that a student's involvement in interactive digital experiences does not necessarily translate to their cognitive indicator achievements matching those digital endeavors.

However, it must be acknowledged that in certain contexts, digital activities can closely align with BDT. For example, Kandaga's research shows how using GeoGebra in Transformation Geometry supports cognitive achievement at the C6 level (Kandaga, 2023). Creating a GeoGebra applet to simulate geometric transformations represents the cognitive indicators at C6. Students who can create such an applet demonstrate not just the ability to apply, analyze, or evaluate, but also the skills to create based on deep knowledge. This example suggests that, in certain contexts, successfully creating a GeoGebra applet may reflect a high cognitive level, capable of not only applying, analyzing, or evaluating but also creating something based on their understanding.

Faraon *et al.* (2023) research is another example that provides a compelling case for the alignment between digital activities and the cognitive levels of BDT. In their study, they implemented the Analyzing level (C4) through the task of "Handling errors in web development code." This activity challenged students to deeply engage with error codes, requiring them to sort, organize, and

comprehend the emerging patterns. Notably, the students then leveraged artificial intelligence to devise effective resolution strategies, demonstrating not merely the ability to identify problems, but also to develop appropriate solutions. This digital experience, therefore, powerfully reflects the complex problem-solving process associated with the Analyzing level, where students exhibit high cognitive capabilities supported by technological tools.

The research by Zawedde (2014), Lin (2021), Kandaga (2023), and Faraon *et al.* (2024) suggests that the disconnect between digital activities and cognitive achievement levels in BDT may stem from the inappropriate selection of concepts and technologies. Specifically, choosing digital activities that are irrelevant or misaligned with the targeted cognitive objectives can be a crucial factor in creating the gap between students' cognitive achievements and their use of digital technology.

This study's findings highlight a persistent disconnect between students' engagement in digital activities and their corresponding cognitive achievements within BDT framework. It is crucial to recognize that the digital activities outlined in BDT are not inherently tied to specific cognitive levels. Rather, they serve as illustrative examples of strategies that can be employed to promote the meaningful integration of technology into the learning process. Fundamentally, the realization of desired cognitive outcomes depends not solely on the implementation of these digital activities, but also on the purposeful and thoughtful integration of technology within the relevant learning context, ensuring its alignment with the targeted cognitive objectives.

5 Limitations

This study has several limitations. First, the sample was drawn using convenience sampling from four schools in three cities, which may limit the generalizability of findings to the broader Indonesian student population, particularly those in rural or under-resourced (3T) regions with different technology access conditions. Second, the cross-sectional, descriptive design captures a single point in time and does not establish causal or developmental relationships between digital proficiency and cognitive achievement; the patterns reported here should be read as descriptive associations rather than evidence of effect. Third, the study focused exclusively on mathematics, specifically quadratic functions, and findings may not generalize to other subject domains or topics. Future research should consider longitudinal designs, inferential statistical testing, and broader sampling across diverse educational contexts to strengthen the robustness of these conclusions.

6 Conclusion

This study presents a compelling counterargument to the widely held assumption that students' engagement in digital activities directly correlates with their attainment of higher-order cognitive skills within BDT. The findings challenge this prevailing notion, revealing a disconcerting gap between students' mastery of digital proficiencies and their substantive cognitive understanding. While digital tools and resources can indeed serve as powerful enablers of advanced cognition, their mere implementation does not automatically guarantee the desired cognitive outcomes. Specifically, the research suggests that even when students undertake tasks that ostensibly align with the higher levels of BDT, such as creating a podcast, this does not necessarily translate to their achievement of the associated cognitive indicators. The crux of the issue lies in the need to move beyond simply evaluating the execution of digital tasks and instead focus on assessing the substantive content and cognitive processes they reflect. Ultimately, this study emphasizes the urgent need for a more thoughtful and intentional approach to integrating technology in the learning process, one that prioritizes the alignment between digital activities and the targeted cognitive objectives, rather than solely focusing on the execution of digital tasks. Educators must carefully select digital activities that are closely matched to the desired cognitive outcomes, ensuring a meaningful integration of technology that supports the development of students' substantive understanding and advanced thinking skills.

A divisão digital-cognitiva na aprendizagem de funções quadráticas: evidências da taxonomia digital de Bloom

Resumo

Este estudo investiga a relação entre a proficiência digital dos estudantes e suas habilidades cognitivas na aprendizagem de funções quadráticas, utilizando a Taxonomia Digital de Bloom como estrutura analítica. Adotou-se uma abordagem quantitativa descritiva, envolvendo 127 estudantes de quatro escolas de ensino médio localizadas em três grandes cidades da Indonésia. Os dados foram coletados por meio de testes cognitivos e avaliações de proficiência digital, abrangendo diferentes níveis cognitivos e o uso de ferramentas digitais na aprendizagem da matemática. Os resultados revelaram que os estudantes apresentaram níveis relativamente elevados de proficiência digital, especialmente no uso operacional de tecnologias. Entretanto, esse domínio não foi acompanhado por um desempenho cognitivo igualmente elevado. O desempenho diminuiu substancialmente nos níveis cognitivos superiores, particularmente em analisar, avaliar e criar. Os resultados evidenciam, portanto, uma divisão digital-cognitiva: a capacidade de utilizar ferramentas digitais não implica necessariamente a capacidade de mobilizá-las para raciocínio matemático de ordem superior. Esses achados indicam a necessidade de práticas pedagógicas que ultrapassem o desenvolvimento de habilidades operacionais e integrem intencionalmente a tecnologia a atividades que promovam análise, avaliação, criação e justificativa matemática. O estudo contribui para a discussão sobre a integração significativa das tecnologias digitais na Educação matemática, destacando a importância de alinhar a proficiência digital às demandas cognitivas da aprendizagem matemática.

Palavras-chave: *Taxonomia Digital de Bloom. Proficiência Digital. Funções Quadráticas. Pensamento de Ordem Superior. Educação Matemática.*

La brecha digital-cognitiva en el aprendizaje de funciones cuadráticas: evidencia desde la taxonomía digital de Bloom

Resumen

Este estudio investiga la relación entre la competencia digital de los estudiantes y sus habilidades cognitivas en el aprendizaje de funciones cuadráticas, utilizando la Taxonomía Digital de Bloom como marco analítico. Se adoptó un enfoque cuantitativo descriptivo, con la participación de 127 estudiantes de cuatro escuelas secundarias ubicadas en tres grandes ciudades de Indonesia. Los datos se recopilaron mediante pruebas cognitivas y evaluaciones de competencia digital, que abarcaron diferentes niveles cognitivos y el uso de herramientas digitales en el aprendizaje de las matemáticas. Los resultados revelaron que los estudiantes presentaron niveles relativamente altos de competencia digital, especialmente en el uso operativo de las tecnologías. Sin

embargo, este dominio no estuvo acompañado de un rendimiento cognitivo igualmente alto. El rendimiento disminuyó sustancialmente en los niveles cognitivos superiores, particularmente en analizar, evaluar y crear. Por lo tanto, los resultados evidencian una brecha digital-cognitiva: la capacidad de utilizar herramientas digitales no implica necesariamente la capacidad de movilizarlas para el razonamiento matemático de orden superior. Estos hallazgos indican la necesidad de prácticas pedagógicas que trasciendan el desarrollo de habilidades operativas e integren intencionalmente la tecnología en actividades que promuevan el análisis, la evaluación, la creación y la justificación matemática. El estudio contribuye al debate sobre la integración significativa de las tecnologías digitales en la Educación matemática, destacando la importancia de alinear la competencia digital con las demandas cognitivas del aprendizaje matemático.

Palabras clave: *Taxonomía Digital de Bloom. Competencia Digital. Funciones Cuadráticas. Pensamiento de Orden Superior. Educación Matemática.*

References

AKINTOLU, M.; DLAMINI, N.; LETSEKA, M. Bloom's taxonomy for the digital age student in a rural African context. *EUREKA: Social and Humanities*, n. 6, p. 39–47, 2022. Disponível em: https://doi.org/10.21303/2504-5571.2022.002472. Acesso em: 24 set. 2026.

ALAGHBARY, G. S. Integrating technology with Bloom's revised taxonomy: Web 2.0-enabled learning designs for online learning. *Asian EFL Journal*, v. 28, n. 2.3, p. 10–37, 2021.

CHINIEN, C.; BOUTIN, F. Bridging the cognitive divide in ICT-mediated learning. In: IEEE INTERNATIONAL CONFERENCE ON ADVANCED LEARNING TECHNOLOGIES, 3., 2003, Athens. *Proceedings [...]*. Athens: IEEE, 2003. p. 422–423. Disponível em: https://doi.org/10.1109/ICALT.2003.1215154. Acesso em: 12 dez. 2024.

CHURCHES, A. Bloom's digital taxonomy. 2008. Disponível em versão arquivada online. Acesso em: 24 set. 2026.

FARAON, M.; GRANLUND, V.; RÖNKKÖ, K. Artificial intelligence practices in higher education using Bloom's digital taxonomy. In: INTERNATIONAL WORKSHOP ON ARTIFICIAL INTELLIGENCE AND EDUCATION (WAIE), 5., 2023, Tokyo. *Proceedings [...]*. IEEE, 2023. p. 53–59. Disponível em: https://doi.org/10.1109/WAIE60568.2023.00017. Acesso em: 24 set. 2026.

FERRARI, A. DIGCOMP: a framework for developing and understanding digital competence in Europe. Luxembourg: Publications Office of the European Union, 2013.

GORANOVA, E. Creation of electronic learning objects for the high cognitive levels of Bloom's Digital Taxonomy. *Knowledge International Journal*, v. 31, n. 2, p. 585–590, 2019. Disponível em: https://doi.org/10.35120/kij3102585g. Acesso em: 24 set. 2026.

GUI, M.; ARGENTIN, G. Digital skills of internet natives: different forms of digital literacy in a random sample of northern Italian high school students. *New Media & Society*, v. 13, n. 6, p. 963–980, 2011. Disponível em: https://doi.org/10.1177/1461444810389751. Acesso em: 24 set. 2026.

GUNARSO, G.; SYAMSUDIN, M. S.; NURSALMAN, M.; NURDIN, E. A.; FITRI, A. Computational bibliometric analysis of research on Bloom Digital Taxonomy and critical thinking. *AL-ISHLAH: Jurnal Pendidikan*, v. 16, n. 1, 2024.

HALEVA, L.; HERSHKOVITZ, A.; TABACH, M. Students' activity in an online learning environment for mathematics: the role of thinking levels. *Journal of Educational Computing Research*, v. 59, n. 4, p. 686–712, 2021. Disponível em: https://doi.org/10.1177/0735633120972057. Acesso em: 24 set. 2026.

HAMILTON, E. R.; ROSENBERG, J. M.; AKCAOGLU, M. The Substitution Augmentation Modification Redefinition (SAMR) model: a critical review and suggestions for its use. *TechTrends*, v. 60, n. 5, p. 433–441, 2016.

HERRMANN, J. Different ways to support intelligent assistant systems by use of machine learning methods. *International Journal of Human–Computer Interaction*, v. 8, n. 3, p. 287–308, 1996. Disponível em: https://doi.org/10.1080/10447319609526153. Acesso em: 24 set. 2026.

HUSAIN, F. N. Use of digital assessments: how to utilize digital Bloom to accommodate online learning and assessments? *Asian Journal of Education and Training*, v. 7, n. 1, p. 30–35, 2021. Disponível em: https://doi.org/10.20448/journal.522.2021.71.30.35. Acesso em: 24 set. 2026.

KANDAGA, T. Analisis proses berpikir geometri mahasiswa calon guru matematika dalam perspektif way of thinking dan way of understanding pada implementasi desain didaktis berbantuan GeoGebra. 2022. Tese (Doutorado) – Universitas Pendidikan Indonesia, Bandung, 2022.

KANDAGA, T.; ROSJANUARDI, R.; JUANDI, D. How DGS integrated learning in geometric transformation drives students' way of thinking and way of understanding. In: INTERNATIONAL SEMINAR ON MATHEMATICS, SCIENCE, AND COMPUTER SCIENCE EDUCATION (MSCEIS), 2021. *AIP Conference Proceedings*, v. 2734, 090005, 2023. Disponível em: https://doi.org/10.1063/5.0156651. Acesso em: 24 set. 2026.

KIRSCHNER, P. A.; DE BRUYCKERE, P. The myths of the digital native and the multitasker. *Teaching and Teacher Education*, v. 67, p. 135–142, 2017.

KLOOS, C. D.; ALARIO-HOYOS, C. Educational pyramids aligned: Bloom's Taxonomy, the DigCompEdu framework and instructional designs. In: WORLD ENGINEERING EDUCATION FORUM/GLOBAL ENGINEERING DEANS COUNCIL (WEEF/GEDC), 2021. *Proceedings.* IEEE, 2021. p. 110–117. Disponível em: https://doi.org/10.1109/WEEF/GEDC53299.2021.9657335. Acesso em: 24 set. 2026.

KURNIASIH, N. et al. The utilization of search engines by students of the Library and Information Science Program at Universitas Padjadjaran. *Journal of Physics: Conference Series*, v. 1114, 012085, 2018. Disponível em: https://doi.org/10.1088/1742-6596/1114/1/012085. Acesso em: 24 set. 2026.

LIM, Y. Analysis of dictogloss tasks using Bloom's Digital Taxonomy based on digitalized collaborative work. *Language Research*, v. 57, n. 3, p. 307–328, 2021. Disponível em: https://doi.org/10.30961/lr.2021.57.3.307. Acesso em: 24 set. 2026.

MCDOUGALL, A. Issues in the assessment of real-life learning with ICT. In: VAN WEERT, T. J.; TATNALL, A. (ed.). *Information and communication technologies and real-life learning: new education for the knowledge society.* Boston: Springer, 2005. p. 13–20. Disponível em: https://doi.org/10.1007/0-387-25997-X_3. Acesso em: 24 set. 2026.

OECD. Students, computers and learning: making the connection. Paris: OECD Publishing, 2015. (PISA).

ORTIZ, A.; BARRERA, F.; VALDÉS, D. Open educational resources: an analysis of the learning objectives referenced by Bloom's Digital Taxonomy. *International Review of Research in Open and Distributed Learning*, v. 21, n. 2, p. 85–99, 2020.

SELWYN, N. Is technology good for education? Cambridge: Polity Press, 2016.

SWELLER, J. Cognitive load during problem solving: effects on learning. *Cognitive Science*, v. 12, n. 2, p. 257–285, 1988.

VYGOTSKY, L. S. Mind in society: the development of higher psychological processes. Cambridge, MA: Harvard University Press, 1978.

ZERÉNYI, K.; MÁTRAI, Z. Taxonomies from a cognitive to a digital revolution, focusing on transferable skills. *Andragoške Studije*, n. 2, p. 91–104, 2022. Disponível em: https://doi.org/10.5937/AndStud2202091Z. Acesso em: 24 set. 2026.

CC BY

Information about the authors

Thesa Kandaga: Dr. in Mathematics Education. Associate Professor and Researcher at Universitas Terbuka, Jakarta, Indonesia. Research experience in Mathematical Thinking and Educational Technology. Contact: thesa.official@ecampus.ut.ac.id

Idha Novianti: Dr. in Mathematics Education. Associate Professor and Researcher at Universitas Terbuka, Jakarta, Indonesia. Head of Mathematics Education Program. Contact: anti@ecampus.ut.ac.id

Suci Nurhayati: M.Pd. in Mathematics Education. Lecturer at Universitas Terbuka, Jakarta, Indonesia. Lecture and research interests in statistics and curriculum evaluation. Contact: suci.nurhayati@ecampus.ut.ac.id

Valeria Yekti Kwasaning Gusti: M.Pd. in Mathematics Education. Lecturer at Universitas Terbuka, Jakarta, Indonesia. Lecture and research interests in Mathematics Learning Media. Contact: valeria.gusti@ecampus.ut.ac.id

Authors´ contributions: All authors participate in diverse processes including the literature review (data collection, data analysis, and discussion of results), manuscript preparation, and text writing.

Data Availability: The data that support the findings of this study, including students' raw digital proficiency and cognitive achievement scores, are available from the corresponding author, Thesa Kandaga, upon reasonable request. Requests may be directed to thesa.official@ecampus.ut.ac.id.

Declaration on the Use of Artificial Intelligence: The authors used ChatGPT and Grammarly to assist with grammar checking, language editing, some figures, structure writing like references, and consistency checking. All content has been reviewed and revised by the authors. The authors take full responsibility for the accuracy and originality of the work.

Conflict of interest: The authors declare that he has no commercial or associative interest that represents a conflict of interest concerning the manuscript.

Financing: This research was funded by the Indonesian Ministry of Education, Culture, Research, and Technology through the Fundamental BIMA Research Scheme in 2024.

Acknowledgements: The authors would like to express their gratitude to the participating schools, students, and teachers who made this study possible. We also thank our colleagues and collaborators for their invaluable insights and feedback throughout the research process. Special thanks are extended to our institution for providing the support and resources necessary to carry out this study.

Responsible Editor:
Érika Dias

Associate Editor:
Ana Ivenicki
Cristiano Calisto (*Ad hoc reviewer)*