

Impact of Hybrid Learning on Digital Literacy and Mathematical Resilience in Master's Mathematics Education

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Abstract

Higher education in mathematics faces challenges in simultaneously building digital literacy and mathematical resilience. The limited number of studies integrating both aspects in a hybrid context remains a research gap. This study aims to evaluate the impact of hybrid learning on the digital literacy and mathematical resilience of master's students in mathematics education. A qualitative study with an instrumental case study design was conducted in the Master's Program in Mathematics Education at a university in Cirebon City, Indonesia. Data were collected through semi-structured interviews, observations of hybrid learning, and analysis of digital documents from nine students. Data analysis was conducted using Braun & Clarke's thematic analysis approach, which includes six stages: data familiarization, initial coding, theme identification, review, naming, and narrative writing, supported by method triangulation, inter-coder validation, and member checking to maintain credibility. Results showed improvements in digital literacy across technical (100%), evaluative (78%), and creative (67%) aspects. Mathematical resilience also improved through persistence (100%), cognitive flexibility (89%), and emotional regulation (78%). The hybrid environment was found to facilitate the simultaneous strengthening of students' technical, affective, and reflective skills. These findings contribute theoretically and practically to the development of a hybrid curriculum that promotes digital literacy while building students' mathematical resilience.

Keywords:

hybrid learning, digital literacy, mathematical resilience, mathematics education, qualitative research, higher education, case study

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INTRODUCTION

Global data shows that the global e-learning market value reached USD 227.3 billion in 2023 and is estimated to increase to USD 740.5 billion in 2032 with an annual growth rate of 14.0% (Suzianti & Paramadini, 2021). This trend aligns with the drastic increase in the adoption of online and hybrid learning during the COVID-19 pandemic. In 2020, more than 16.1 million students participated in online education, a tenfold increase compared to 2018 (Ganeshan & Vethirajan, 2022). Additionally, in 2022, global internet connectivity reached 66%, providing widespread access to digital learning across various levels of education (Hushin, 2025).

This development reflects a major shift towards hybrid learning models, which are now the primary approach in higher education worldwide. In the long



term, this trend not only changes students' learning patterns but also drives transformations in curriculum, quality assurance systems, and academic collaboration patterns across nations. For Indonesia, the implications include the need to strengthen digital infrastructure, prepare technology-savvy faculty members, and ensure equitable access to education in both urban and rural areas.

Although hybrid learning is becoming more widespread, a number of pressing issues have emerged. Students who lack adequate digital literacy often struggle to keep up with lectures, resulting in a decline in learning outcomes. Studies show that limited digital literacy has a negative impact on academic performance and learning motivation (Mohammadyari & Singh, 2015). At the individual level, students with low digital literacy and weak mathematical resilience tend to have low self-efficacy and are less engaged in academic activities (Chaerani et al., 2024). At the institutional level, this situation can reduce graduation rates and teaching effectiveness.

If this issue is not addressed, the long-term impact will be low readiness of graduates to face a technology- and research-based world of work, especially in the field of mathematics education, which requires strong analytical skills. Therefore, the results of this study will be applied in the form of a more adaptive hybrid curriculum model, which includes indicators of digital literacy and mathematical resilience as part of graduate learning outcomes (CPL).

Previous studies have addressed the issue of digital literacy in hybrid learning. Mohammadyari & Singh (2015) emphasize the importance of digital literacy in supporting the quality of blended learning. Other studies indicate that blended learning can enhance digital literacy skills among undergraduate students in Morocco (Idabdallah Abdelhadi & Brigui Hind, 2024). Additionally, digital literacy and academic self-efficacy have been proven to contribute to student engagement in hybrid learning in teacher education programs in Indonesia (Getenet et al., 2024). Digital literacy is an important foundation in preparing students for the challenges of a technology-based workplace (Gumelar et al., 2022; Nisa et al., 2024).

However, there are important limitations. Most studies focus on undergraduate students or general teacher education, rather than master's programs in mathematics education. In addition, many studies examine digital literacy and learning engagement separately, without considering their relationship to mathematical resilience.

State-of-the-art research in this field indicates that hybrid learning research is increasingly focused on the effectiveness of digital platforms, learning satisfaction, and the improvement of digital literacy. Few studies explicitly link it to mathematical resilience, especially at the master's level in mathematics education. This is where the novelty of this research lies: this study not only examines digital literacy but also how digital literacy can serve as an entry point for simultaneously building mathematical resilience. Its theoretical contribution is to expand our understanding of the mechanisms linking these two aspects in the context of hybrid learning, which has previously been rarely explored comprehensively. Thus, this research fills a gap in the literature that previous studies have not addressed.

Explicitly, compared to (Hamzaoui et al., 2024) study in Morocco, which focused on undergraduate students, this study examined master's students with more complex academic demands. Compared to (Amiruddin et al., 2023) study in

Indonesia, which only looked at learning engagement, this study linked it to mathematical resilience. This underscores that this study provides a more in-depth theoretical contribution on how hybrid learning not only enhances digital competencies but also students' cognitive and affective resilience. The main difference between this study and previous ones is its focus on master's students with more complex academic demands, as well as the simultaneous analysis of digital literacy and mathematical resilience. This adds novelty not found in undergraduate studies or general teacher education.

Based on this research gap, this study aims to answer the question: How does hybrid learning affect the digital literacy and mathematical resilience of master's students in mathematics education? This study uses a qualitative approach to evaluate the impact of hybrid learning in depth.

The conceptual framework of this study is based on the integration of hybrid learning, digital literacy, and mathematical resilience in the context of higher education. Hybrid learning is understood as the complementary integration of face-to-face and online learning, not merely the addition of technology (Eyal & Gil, 2022; O'Byrne & Pytash, 2015). This model offers flexibility, interactivity, and personalization, and has been proven to enhance motivation, engagement, and academic achievement when supported by effective instructional design (Aini & Yasid, 2022). However, its effectiveness heavily depends on the technological readiness and digital competencies of both students and faculty (Helsa et al., 2022).

In this context, digital literacy plays a key role. Digital literacy encompasses not only technical skills, but also critical thinking, problem solving, and ethical understanding in the use of digital information (Audrin & Audrin, 2022; Eshet-alkalai, 2004). This literacy is related to students' motivation, attitudes, and learning satisfaction (Gutiérrez-Ángel et al., 2022), and is an important prerequisite for effective hybrid learning (Vangani et al., 2023). Furthermore, digital literacy prepares students for a technology-based workplace and narrows the digital skills gap in society (Reddy et al., 2023).

In addition, mathematical resilience is an important aspect that cannot be separated from student success in hybrid learning. Mathematical resilience reflects the ability to persevere in the face of learning challenges and is closely related to growth mindset, emotional regulation, and self-efficacy (Yeager & Dweck, 2012). Research indicates that students with high resilience exhibit better problem-solving skills, greater self-confidence, and perseverance in tackling complex tasks (Maarif & Fitriani, 2023; Toromade et al., 2024). Social support, coping strategies, and a supportive learning environment further strengthen this resilience (Eyal & Gil, 2022).

Thus, the conceptual framework of this study emphasizes that hybrid learning serves as the main vehicle, digital literacy is a key prerequisite, and mathematical resilience is a non-cognitive outcome that determines student success. The relationship between the three is complementary: hybrid learning enhances digital literacy through the use of technology and online activities, digital literacy strengthens self-efficacy and academic engagement, while mathematical resilience ensures that students are able to persevere and succeed in facing the complexities of master's-level learning. This framework implies that strengthening digital

literacy through an appropriate hybrid learning design will directly and indirectly build students' mathematical resilience.

This study theoretically expands the understanding of the dual impact of hybrid learning, namely the strengthening of digital literacy and mathematical resilience, and offers a conceptual model of the relationship between the two as a framework for further research. Practically, these findings are useful for lecturers and program managers in designing hybrid curricula that promote holistic competencies, for example, through project-based integrative assessments that evaluate students' digital literacy and mathematical resilience. From a methodological perspective, this study presents an integrative framework with performance assessments, self-reports, and process evaluations to identify effective learning mechanisms. The outcome framework maps inputs such as students' digital readiness, processes through hybrid experiences, and outputs such as improvements in digital literacy and mathematical resilience, making it transferable to various higher education contexts in Indonesia.

This research is not only relevant to the global development of hybrid education but also directly contributes to the development of a sustainable hybrid learning system in Indonesia. The long-term impact is the creation of master's degree graduates in mathematics education who not only master technology but also possess strong academic resilience to face the challenges of the digital era and Society 5.0.

METHODS

This study uses a qualitative approach with an instrumental case study design to gain an in-depth understanding of the influence of hybrid learning on the digital literacy and mathematical resilience of master's students in mathematics education. Lectures were conducted using a hybrid model for semesters 1 and 2. Each semester consisted of eight face-to-face sessions and eight synchronous online sessions, as well as the use of an LMS for asynchronous assignments.

The population of this study is Master of Mathematics Education students for the 2024/2025 academic year who have completed two semesters of study. The research subjects consisted of nine students who were selected through purposive total sampling with inclusion criteria: active students, have participated in hybrid learning for at least two semesters, have experience using digital technology in learning, and are willing to participate. This number is considered adequate because in qualitative research, the emphasis is not on statistical generalization, but on the depth of exploration until information saturation is achieved. The selection of all class members is considered relevant because the population is small and homogeneous, thus allowing for a comprehensive exploration of learning experiences, increasing the validity of findings, and minimizing the potential for selection bias (Etikan et al., 2016; Patton, 2015). This approach is in line with the design of qualitative case studies that emphasize a complete understanding of the phenomena experienced by a particular group (Creswell, 2014).

This approach was chosen because it allows researchers to explore phenomena contextually and in depth through various data sources (Laelasari et al.,

2022; Murni & Juandi, 2023). Qualitative research aims to explore an in-depth understanding of social phenomena through the experiences and perspectives of individuals (Creswell & Poth, 2018).

Instrumental case studies were used to provide broader theoretical insights from the cases studied. This research was conducted over one semester with a focus on observing specific courses conducted in a hybrid model. The research setting was in a mathematics education master's program at a university in Cirebon, with a hybrid learning context that combined face-to-face and online learning, both synchronous and asynchronous. This provides an authentic picture of how students interact with digital technology while maintaining mathematical resilience in a flexible learning situation.

Three main techniques were used for data collection: (1) semi-structured interviews, (2) observation of hybrid learning, and (3) analysis of documents such as videos, reflections, and digital portfolios. Interviews lasted 60–90 minutes, were conducted individually, recorded, and transcribed for analysis. Observations were conducted during eight learning sessions, while documents were analyzed thematically. Instrument development involved creating interview protocols and observation sheets based on prior literature and research objectives. The instruments were validated for content by involving experts in mathematics education and qualitative research methodology, then pilot-tested before being used for primary data collection. This process aimed to ensure the clarity of questions, the relevance of indicators, and the measurability of the observed phenomena.

Subject recruitment was based on purposive criteria, followed by interviews and observations during hybrid learning sessions. Documentary data were collected throughout the semester. After data collection, the researchers conducted transcription, initial coding, and thematic analysis based on the (Braun & Clarke, 2019) approach. Validity was maintained through method triangulation, source triangulation, and member checking. Ethical considerations were also strictly observed, including obtaining approval from the university's research ethics committee, providing informed consent to participants, maintaining the confidentiality of subjects' identities using anonymous codes, and ensuring participants' rights to withdraw at any time without consequences. All stages took place over one academic semester. Analysis was conducted using thematic analysis following the six stages of Braun & Clarke: data familiarization, coding, theme identification, theme review, naming, and narrative writing. Emphasis was placed on exploring the meaning of students' experiences, not on statistical significance. Triangulation techniques and subject confirmation were used to enhance the credibility of the research.

RESULTS & DISCUSSION

All participants in this study were students who had completed their second semester of the mathematics education program with relatively equivalent academic backgrounds in terms of previous achievements. A total of nine mathematics education students participated in this study, consisting of five females and four males aged 21–23 years. All participants were final-year students who had

participated in hybrid learning for at least two semesters. All students had experience using the institutional Learning Management System (LMS) and video conferencing platforms (Zoom/Google Meet). No significant differences were found regarding digital technology usage backgrounds between male and female participants, nor between groups with high and low technology access.

Table 1. Baseline Characteristics of Participants

Variable	Total (N=9)	Female (n=5)	Male (n=4)
Mean age (years)	22.1 ± 0.7	22.2 ± 0.6	22.0 ± 0.9
Experience with LMS	100%	100%	100%
Video conference use	100%	100%	100%
Digital content creation	78%	80%	75%

As shown in Table 1, all students had similar experiences in using LMS and video conferencing, which formed the basis for developing digital technical skills.

Data analysis shows that the impact of hybrid learning on students' digital literacy can be classified into three main themes:

1. *Improved digital technical skills.*

All participants reported improved skills in using LMS, video conferencing, and digital math tools such as GeoGebra and Desmos. They also became accustomed to creating learning videos independently.

P3: “At first, I only knew how to log into Zoom and upload assignments on the LMS, but after the hybrid program, I can now create my own videos using GeoGebra to explain function graphs.”

2. *Strengthening information evaluation skills.*

Students demonstrated a shift in how they evaluate the credibility of digital sources. Previously, they often cited blogs, but now they prefer scientific journals or official websites as references.

P6: “I used to take material from blogs, but now I’m more careful—I check scientific journals or official websites first before using them for assignments.”

3. *Development of digital creativity.*

Students are beginning to develop learning products such as animated videos, infographics, and digital simulations to explain mathematical concepts. This creativity reflects the integration of subject mastery and technological innovation.

P1: “I tried making an infographic about probability, and it turned out to be easier for my friends to understand than a long written explanation.”

A deeper analysis shows a shift in the role of students from passive users to producers of digital content. Technical skills develop alongside critical evaluation of information, while creativity emerges as a more complex dimension that requires the integration of mathematical content understanding with media innovation.

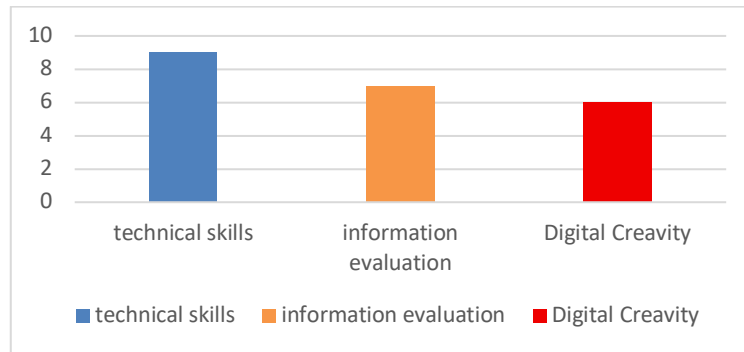


Figure 1: Distribution of student digital literacy themes

As shown in Figure 1, the distribution of digital literacy themes shows the dominance of technical skills, followed by digital creativity. This graph reinforces the finding that access to technology is related to the level of digital creativity.

Students with better access to technology (devices and stable internet connections) more frequently demonstrate digital creativity compared to those with limited access. A reanalysis eliminating two subjects with minimal involvement shows that the three main themes still emerge, although the frequency of digital creativity decreases slightly.

These findings indicate that hybrid learning contributes significantly to the improvement of digital literacy among mathematics education students, encompassing: 1) technical skills (mastery of LMS, GeoGebra, Zoom), 2) evaluative abilities (filtering digital information), and 3) creativity (creation of interactive media).

The basic characteristics of the participants are presented in Table 2. The data show that most students reported having difficulty learning mathematics (67%), nearly half had failed a mathematics exam (44%), but all actively participated in both face-to-face and online discussion forums.

Tabel 2. Baseline Characteristics of Participants

Variable	Total (N=9)	Female (n=5)	Male (n=4)
Self-reported math struggle	6/9 (67%)	4/5	2/4
Never failed a math test	4/9 (44%)	3/5	1/4
Engage in discussion forum	9/9 (100%)	5/5	4/4

Data analysis shows an increase in students' mathematical resilience through three main aspects, namely persistence, cognitive flexibility, and emotional regulation. These three aspects appeared consistently in interviews, observations, and student reflections. A summary of the findings is shown in Table 3.

Tabel 3. Thematic Summary and Cross-Source Agreement

Resilience Theme	Meaning Units	Agreement ≥ 2 Source	Percentage (%)	Consistency
Persistence	13	9/9	100	Very High
Cognitive Flexibility	10	8/9	89	High
Emotional Regulation	8	7/9	78	Fairly High

The visualization of mathematical resilience distribution is presented in Figures 1 and 2. The results show that students who have experienced failure in exams are more prominent in terms of emotional regulation and persistence, while students who have never failed are more prominent in terms of cognitive flexibility.

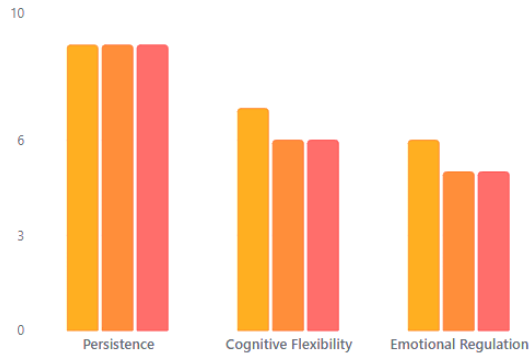


Figure 1. Distribution of Mathematical Resilience Aspects of Students

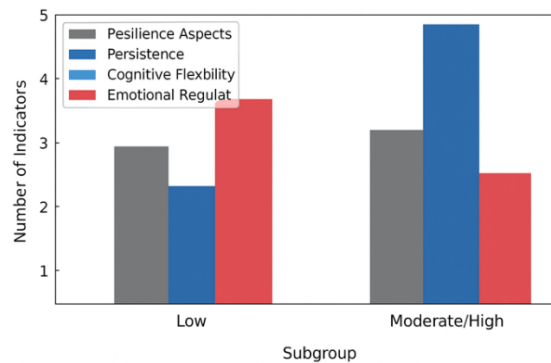


Figure 2. Aspects of Resilience Based on Academic History

The following interview results provide a clear picture of how hybrid learning experiences shape student resilience.

1. Persistence

P3: “In the past, when I encountered difficulties, I would quickly give up. But because there are lecture recordings and discussion forums, I can review the material and try other approaches. It feels more reassuring knowing that I can study anytime.”

2. Cognitive flexibility

P6: “I usually prefer reading the modules, but when I get stuck, I try searching for videos on YouTube or asking in the class WhatsApp group. It turns out that other methods can be easier to understand.” (Student 6, reflection).

3. Emotional Regulation

P2: “Before the hybrid system, I often panicked before exams. Now, I can manage my study time on my own. If I feel overwhelmed, I take a break and then continue later. This helps me better manage stress.”

The quote shows how students integrate various learning resources, manage their pace, and build emotional calmness in facing academic challenges. The findings of this study confirm that hybrid learning plays a positive role in strengthening students' mathematical resilience. A flexible learning environment

allows students to develop perseverance in facing difficult problems, try various learning strategies, and manage stress more adaptively.

Within the framework of the Mathematical Resilience Framework (Johnston-Wilder & Lee, 2010). Improvements were observed in the dimensions of confidence in mathematical learning abilities, connection to the learning community, and coping strategies in the face of difficulties. Interestingly, no patterns of resistance or regression were found, indicating consistency in findings across all participants.

These results expand on the research of Ramirez et al. (2022), which emphasizes the role of technology in building resilience. This study further demonstrates that hybrid instructional design can facilitate emotional regulation and cognitive flexibility, even among students with low initial self-confidence. Thus, unlike Martin & Marsh (2008), who emphasize personality as the primary factor, this study emphasizes the instructional context as an equally important factor.

Thus, this study expands the Mathematical Resilience Framework by incorporating time and space flexibility as important factors in shaping resilience. Mathematical resilience is not solely the result of cognitive ability but rather the product of the interaction between learning strategies, social support, and emotional control within a digital ecosystem.

CONCLUSION

This study confirms that hybrid learning plays an important role in strengthening the digital literacy and mathematical resilience of master's students in mathematics education. Through this learning design, students not only develop technical, evaluative, and creative skills in the digital field, but also learn to build perseverance, cognitive flexibility, and the ability to manage emotions when facing challenges in mathematics learning. These findings enrich our understanding of the Digital Literacy Framework and Mathematical Resilience Framework by adding the context of hybrid pedagogy as a mediating factor, thereby contributing new insights into the study of dynamic and complex learning ecosystems.

However, this study has limitations. The relatively small sample size and focus on a single institution mean that the results of this study cannot be fully generalized. In addition, the use of qualitative data without long-term measurements has not been able to describe the continuous development of digital literacy and mathematical resilience.

Further research needs to involve a more diverse range of participants, establish cross-institutional collaboration, and use a longitudinal approach. A combination of quantitative and qualitative methods should also be employed to ensure more valid and comprehensive research outcomes. For education practitioners, these findings offer actionable recommendations, such as designing a hybrid curriculum that incorporates structured reflection activities, collaborative digital tasks, and ongoing support to enhance students' digital skills while fostering their emotional resilience.

From a policy perspective, the research findings underscore the importance of commitment from higher education institutions and policymakers to provide adequate hybrid learning infrastructure, develop faculty competencies through

professional training, and formulate policies that support competency-based education. With these steps, hybrid learning can become an effective strategy for improving the quality of teacher education in the digital age.

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