RESEARCH PAPER

Students' Perceptions and Practices in Digitally Mediated Mathematics Learning: A Qualitative Study of Digital Competence and Problem Solving

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ABSTRACT

Digitally mediated and blended learning environments are increasingly common in mathematics education, yet there remains limited understanding of how students experience these environments in their everyday learning practices. This qualitative study examines students' perceptions and practices in digitally mediated mathematics learning, with particular attention to digital competence and problem solving. The study was conducted in two upper-secondary schools in Indonesia and involved eighteen Grade XI students. Data were collected through semi-structured interviews, classroom observations, and analysis of student-generated learning artifacts produced during technology-supported mathematics activities. The data were analyzed using an inductive thematic approach, with themes developed through iterative coding and constant comparison across data sources.

The analysis identified four central themes: the use of digital tools to support visualization of mathematical concepts, the role of technology in facilitating exploratory problem-solving strategies, the development of practical digital competence through routine learning tasks, and challenges related to access, connectivity, and off-task behavior. Students described digital tools as particularly helpful for testing ideas and revising solutions, while also noting that effective use depended on clear instructional guidance and structured tasks. The findings indicate that students experienced stronger support for problem solving and the development of digital competence in contexts where pedagogical design, technological resources, and learning conditions were coherently aligned. The study contributes insight into students' lived experiences of digitally mediated learning and highlights considerations for designing more effective and equitable blended mathematics learning environments.

Keywords: Digitally mediated learning, blended learning, digital competence, mathematics education, problem solving, qualitative study

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Introduction

Digital and blended learning environments have become a defining feature of contemporary education, reshaping how students encounter content, interact with peers, and engage in problem solving. In mathematics education, this shift is particularly visible. Interactive software, online platforms, and digital representations are now commonly integrated into instructional practice, often with the expectation that they will support deeper understanding and more flexible approaches to mathematical problems. As learning becomes increasingly mediated by digital tools, questions arise not only about instructional effectiveness but also about how students experience and navigate these environments in their everyday learning.

Within digitally mediated and blended learning contexts, **digital competence** has emerged as a critical dimension of learning. Students are expected to move beyond basic technical skills and demonstrate the ability to select, interpret, and use digital tools purposefully to support learning tasks. This includes managing information, engaging with dynamic representations, and making informed decisions while working in technology-rich environments. At the same time, mathematics education continues to emphasize problem solving as a central goal, requiring students to explore relationships, test ideas, and refine solutions rather than rely on routine procedures. When mathematics learning is digitally mediated, digital competence and problem solving become closely interconnected rather than separate learning outcomes.

The growing reliance on digital tools in mathematics learning also raises practical concerns that extend beyond pedagogy. Access to devices and stable connectivity remains uneven, shaping students' opportunities to participate fully in digitally mediated learning activities. Even when access is available, students may struggle to use digital tools productively without clear instructional guidance or well-designed tasks. Research on blended and digital learning consistently shows that technology alone does not guarantee meaningful engagement; rather, learning quality depends on how tools are embedded within instructional designs and classroom practices. These issues have implications for equity, engagement, and learning quality, particularly in settings where digital learning is introduced alongside traditional face-to-face instruction.

Existing research has documented both the potential and the limitations of digital tools in mathematics education. Studies suggest that dynamic visualization and interactive environments can support conceptual understanding and exploratory problem solving when they are integrated into coherent pedagogical approaches. Digital tools can allow students to manipulate representations, test conjectures, and receive immediate feedback, which may encourage active engagement with mathematical ideas. At the same time, other research highlights challenges related to distraction, superficial tool use, and uneven participation, especially when students lack guidance or experience with digital learning environments. Together, this body of work suggests that the impact of digitally mediated mathematics learning is highly context-dependent.

Despite these insights, **less attention has been given to students' own perspectives on learning mathematics in digitally mediated environments**, particularly in blended settings where digital and face-to-face activities are intertwined. Much of the existing literature focuses on instructional interventions, tool design, or measured learning outcomes. While such studies are valuable, they often provide limited insight into how students make sense of digital tools in practice, how they decide when and how to use them during problem solving, and what challenges they perceive as most significant. Understanding these lived experiences is especially important in digitally mediated learning contexts, where students are frequently expected to exercise greater autonomy and responsibility for their learning.

From a digital and blended learning perspective, examining students' perceptions and practices can help bridge the gap between intended instructional designs and actual learning experiences. Students' accounts of how digital tools support or constrain their problem-solving efforts can reveal tensions that are not always visible through performance data alone. These insights are critical for informing instructional design, teacher support, and institutional decision-making related to digital learning initiatives. They also contribute to broader discussions about how digital competence develops through everyday learning activities rather than through isolated skills training.

The present study addresses this gap by exploring **students' perceptions and practices in digitally mediated mathematics learning**, with a focus on digital competence and problem solving. Rather than evaluating a specific technological intervention or measuring predefined outcomes, the study adopts a qualitative approach to examine how students describe their experiences of learning mathematics through digital tools and how these tools shape their approaches to solving problems. This focus allows for a closer examination of the ways students engage with digital resources, interpret mathematical representations, and navigate challenges related to access and task design.

The study is situated in upper-secondary school settings where mathematics learning involves regular use of digital tools as part of instructional practice. These settings reflect broader trends toward blended and digitally mediated learning, in which online platforms, digital resources, and technology-supported activities

complement face-to-face instruction. By examining students' experiences in such contexts, the study seeks to contribute to understanding how digitally mediated learning is enacted in practice and how it supports—or complicates—students' development of digital competence and problem-solving practices.

The study is guided by the following research questions:

1. How do students describe their experiences of learning mathematics in digitally mediated environments?
2. What practices do students report using when digital tools support mathematical problem solving?
3. What conditions do students perceive as enabling or constraining their development of digital competence in mathematics learning?

To address these questions, the study draws on interview data, classroom observations, and student-generated learning artifacts to develop an in-depth account of students' perspectives and practices. The emphasis is on analytical insight rather than statistical generalization, with the goal of illuminating how digitally mediated mathematics learning is experienced by learners in a specific educational context.

The remainder of the paper is organized as follows. The next section reviews relevant research on digital competence, digitally mediated mathematics learning, and problem solving, and outlines the conceptual framework guiding the study. This is followed by a description of the research methodology, including the study design, participants, data sources, analytic procedures, and ethical considerations. The findings section presents the key themes that emerged from the analysis. The discussion interprets these findings in relation to existing research and considers their implications for digitally mediated and blended mathematics learning. The paper concludes by summarizing the study's contributions and identifying directions for future research.

Literature Review and Conceptual Framework

Digitally mediated and blended learning environments have increasingly reshaped how mathematical knowledge is accessed, represented, and constructed (Attard & Holmes, 2020; Okoye et al., 2023). In such environments, learning extends beyond physical classrooms and static representations to include sustained interaction with digital tools, platforms, and resources that mediate students' engagement with mathematical ideas (Trouche et al., 2020; Wu, 2024). Consequently, research in digital and blended learning has shifted attention not only to learning outcomes, but also to the processes through which learners interact with technology while developing conceptual understanding (Quigley et al., 2020; Romero-García et al., 2020).

Digital competence in learning contexts

Digital competence is widely understood as more than technical proficiency. Contemporary perspectives define it as a combination of skills, knowledge, and dispositions that enable learners to use digital technologies effectively, critically, and purposefully within specific contexts (Calvani et al., 2012; Laar et al., 2017). In educational settings, digital competence includes the ability to select and use appropriate tools, interpret and evaluate digital representations, manage information, and reflect on one's own technology-supported learning processes (Blayone et al., 2018; Mattar et al., 2022). Importantly, these competencies are developed through situated use and participation rather than acquired as isolated skills (Nouri et al., 2020; Romero-García et al., 2020).

To address definitional variation, this study anchors the concept of digital competence in the European Commission's Digital Competence Framework (DigComp), which conceptualizes digital competence as a multidimensional construct encompassing (1) information and data literacy, (2) communication and collaboration, (3) digital content creation, (4) safety, and (5) problem solving in digital environments (Laar et al., 2018; Mattar et al., 2022). In the present study, these dimensions are interpreted in a subject-specific manner for mathematics learning. Information and data literacy refer to locating, interpreting, and evaluating digital mathematical representations; communication and collaboration involve sharing screens, articulating tool-mediated reasoning, and coordinating work through digital platforms; digital content creation includes producing, revising, and organizing digital learning artifacts such as annotated screenshots or submitted files; safety is understood as responsible, focused, and appropriate use of digital tools in classroom contexts; and the problem-solving dimension is operationalized as selecting suitable tools, troubleshooting technical or representational issues, and adapting digital resources to task demands (Sari et al., 2021; Sari et al., 2023).

Research on digital competence in education indicates that students' capabilities are strongly shaped by the learning tasks they encounter and the expectations embedded in instructional design (Fraile et al., 2018; Guillén-Gámez & Mayorga-Fernández, 2020). When digital tools are integrated into authentic learning activities aligned with disciplinary goals, students are more likely to develop practical and transferable competence (Blayone et al., 2018; Nouri et al., 2020). Conversely, when technology use is peripheral or poorly aligned with learning objectives, students may engage in surface-level interactions that offer limited support for conceptual understanding (Stephen & Rockinson-Szapkiw, 2021). In blended learning environments, where digital and face-to-face activities intersect, the development of digital competence often emerges unevenly, influenced by factors such as access, prior experience, and instructional support (Laar et al., 2019; Okoye et al., 2023).

Despite growing scholarly attention to digital competence, much existing research emphasizes assessment frameworks or large-scale indicators of skill (Guillén-Gámez & Mayorga-Fernández, 2020; Laar et al., 2019). Less attention has been paid to how students experience the development of digital competence through everyday learning activities, particularly in subject-specific contexts such as mathematics (Sari et al., 2021). This gap is significant because digital competence is enacted differently across disciplines and cannot be fully understood without examining how learners perceive and use digital tools while engaging in disciplinary practices (Trouche et al., 2020).

Digital tools and mathematical problem solving

Problem solving occupies a central position in mathematics education, reflecting an emphasis on reasoning, exploration, and sense-making rather than routine application of procedures (Goethals, 2013; Cevikbas & Kaiser, 2020). Digital tools have long been associated with the potential to support mathematical problem solving by enabling dynamic representations, immediate feedback, and iterative exploration (Borkulo et al., 2015; Su et al., 2022). Visualization software, interactive simulations, and computer-based algebra systems allow students to manipulate mathematical objects, test conjectures, and examine patterns in ways that are difficult to achieve using static media (Chivai et al., 2022; Sebsibe & Abdella, 2025).

Empirical research suggests that digital tools can support mathematical problem solving when they are embedded within coherent pedagogical designs (Trouche et al., 2020; Wu, 2024). Dynamic representations, for example, can help students connect symbolic, graphical, and numerical forms, thereby supporting conceptual understanding (Borkulo et al., 2015; Cirneanu, 2024). Other studies highlight the role of technology in facilitating exploratory strategies, encouraging students to experiment with multiple solution paths and revise their thinking (Quigley et al., 2020; Su et al., 2022). However, these benefits are not automatic. Without clear task structures and instructional guidance, students may use digital tools in ways that prioritize efficiency or visual appeal over mathematical reasoning (Attard & Holmes, 2020; Collie et al., 2019).

In blended and digitally mediated learning environments, problem solving often spans online and offline spaces (Cevikbas & Kaiser, 2020; Okoye et al., 2023). Students may begin exploring a problem using digital tools outside class, refine their understanding through discussion, and return to digital representations to test revised ideas. This movement across learning spaces places new demands on learners, who must decide how, when, and why to use digital resources effectively (Stephen & Rockinson-Szapkiw, 2021). Understanding these decisions requires attention to students' practices and perceptions, not only to performance outcomes.

Access, participation, and learning conditions

Research on digital and blended learning consistently highlights structural conditions that shape students' experiences (Okoye et al., 2023; Wahyudin et al., 2024). Access to devices, reliable internet connectivity, and technical support influences how students participate in digitally mediated learning activities (Klochkova & Sadovnikova, 2019a; Okoye et al., 2023). Even within a single classroom, opportunities to engage with digital tools may vary considerably, affecting both learning processes and outcomes (Calvani et al., 2012; Laar et al., 2019). Such disparities are particularly salient in secondary education contexts, where institutional resources and home learning environments differ (Kemendikbudristek, 2022).

Beyond access, participation is shaped by how digital tools are positioned within instruction. When digital activities are framed as integral to learning, students are more likely to invest effort and maintain engagement

(Collie et al., 2019; Quigley et al., 2020). When they are perceived as supplementary or optional, students may disengage or use tools superficially (Attard & Holmes, 2020). Prior research suggests that students' perceptions of relevance and usefulness play an important role in shaping engagement with digitally mediated learning tasks, yet these perceptions are often inferred rather than examined directly (Stephen & Rockinson-Szapkiw, 2021).

Conceptual framework guiding the study

Drawing on this literature and anchored in DigComp's conceptualization of digital competence, this study adopts a framework that conceptualizes digitally mediated mathematics learning as an interaction among three interrelated elements: **digital tools**, **learning practices**, and **contextual conditions**. Within this framework, digital competence is treated as an enacted, practice-based capability that develops through repeated engagement with digital tools in meaningful mathematical tasks, rather than as a fixed set of skills (Nouri et al., 2020; Trouche et al., 2020). Problem solving is conceptualized as a process of exploration, representation, testing, and revision, in which digital tools shape the availability of feedback and the ease of iteration but do not determine mathematical reasoning (Borkulo et al., 2015; Wu, 2024).

This framework informs the study in several ways. First, it guides the design of interview prompts, which focus on how students describe selecting and using digital tools during problem-solving activities, managing and producing digital work, and responding to challenges such as technical issues or distractions. Second, it shapes the focus of classroom observations by directing attention to how digital tools are embedded within tasks, how students interact with representations, and how instructional guidance supports or constrains competent participation. Third, it informs the analytic process, with coding attending to tool-mediated mathematical practices, iterative problem-solving strategies, and contextual conditions such as access and instructional support, while using DigComp dimensions as sensitizing concepts for interpretation.

Identifying the research gap

Although prior research has documented the potential of digital tools to support mathematical problem solving and emphasized the importance of digital competence in contemporary education (Borkulo et al., 2015; Laar et al., 2017), there remains limited qualitative insight into how students experience digitally mediated mathematics learning in practice, particularly in blended settings (Attard & Holmes, 2020). Much existing research focuses on intervention effectiveness, tool design, or measured outcomes, leaving students' lived experiences underexplored (Trouche et al., 2020). As a result, a gap persists between the intentions of digitally mediated learning designs and how learners actually engage with them.

Qualitative research is well suited to addressing this gap because it enables close examination of students' perspectives, practices, and sense-making processes (Lutz et al., 2016). By foregrounding students' voices, qualitative inquiry can illuminate how digital competence develops through routine learning activities, how problem-solving practices are shaped by digital mediation, and how contextual conditions enable or constrain meaningful engagement (Sari et al., 2023). Addressing this gap is essential for informing more responsive and equitable designs for digitally mediated and blended mathematics learning.

Research Questions

Guided by the literature and conceptual framework outlined above, this study addresses the following research questions:

1. How do students describe their experiences of learning mathematics in digitally mediated environments?
2. What practices do students report using when digital tools support mathematical problem solving?
3. What conditions do students perceive as enabling or constraining their development of digital competence in digitally mediated mathematics learning?

Method

Research Design

This study employed a qualitative research design to explore students' perceptions and practices in digitally mediated mathematics learning. A qualitative approach was appropriate because the study sought to understand how students experienced and made sense of learning activities mediated by digital tools, rather than to measure predefined outcomes or test causal relationships. This design allowed for close attention to students'

perspectives, decision-making processes, and contextual influences shaping their engagement with mathematical problem solving.

Setting and Learning Modality

The study was conducted in two upper-secondary schools where mathematics instruction incorporated regular use of digital tools as part of a blended, digitally mediated learning design. Instruction combined face-to-face classroom teaching with structured technology-supported activities, both during lessons and, in some cases, beyond scheduled class time. Digital tools were not used sporadically, but were embedded within routine instructional practices, particularly for problem-solving activities, visualization, and submission of student work. This combination of in-person instruction and planned digital engagement constituted the digitally mediated learning context examined in the study.

Digital tools and platforms used

Across both schools, mathematics instruction involved the use of several categories of digital tools. Interactive mathematics software, primarily dynamic graphing and visualization applications (e.g., graphing tools and geometry visualization software), was used to support exploration of functions, graphs, and geometric relationships. An online learning platform was used to distribute learning materials, assign tasks, and collect student submissions. In addition, students commonly used personal or school-provided devices (smartphones, tablets, or laptops) to access digital worksheets, view instructional materials, and produce learning artifacts such as screenshots or annotated solutions. While specific software interfaces varied slightly between classrooms, the functional roles of the tools were comparable across settings.

Frequency and integration pattern of digital tool use

Digital tools were used regularly rather than occasionally. In the observed classrooms, technology-supported activities occurred in most mathematics lessons during the study period, typically at least once per week and often multiple times within a single lesson. A common instructional pattern involved an initial teacher-led explanation or demonstration, followed by student engagement with digital tools to explore problems, visualize concepts, or test solutions. In some cases, students continued working with the same tools outside class to complete assignments or revisit concepts. Digital tool use was therefore integrated into ongoing instructional sequences rather than treated as isolated enrichment activities.

Typical digitally mediated task structure

Technology-supported mathematics activities followed a relatively consistent structure. Tasks typically began with a mathematically focused prompt, such as exploring the behavior of a function, identifying relationships between variables, or solving a non-routine problem. Students were instructed to use a digital tool to manipulate representations, test values, or generate visual outputs. During this phase, students were encouraged to experiment, revise inputs, and observe changes in real time. Tasks often required students to save or submit digital artifacts—such as screenshots of graphs, step-by-step digital solutions, or brief written explanations—through the online platform. Teacher support during these activities included clarifying task goals, guiding attention to relevant features of the tools, and addressing technical or conceptual difficulties as they arose. This structure positioned digital tools as integral to sense-making and problem solving rather than as presentation aids.

Participants and Sampling

Participants were eighteen Grade XI students enrolled in mathematics courses at the participating schools. Purposive sampling was used to select students who had regular experience using digital tools as part of their mathematics learning. Inclusion criteria included active enrollment in the relevant course and participation in technology-supported learning activities during the study period. The sample included students with varied levels of access to personal devices and prior experience with digital tools, allowing for examination of diverse learning conditions. Participation was voluntary, and students were recruited with the support of their teachers after the study was introduced and explained.

Data Sources and Instruments

Data were collected from three primary sources: semi-structured interviews, classroom observations, and student-generated learning artifacts. Interviews were designed to elicit students' perspectives on learning mathematics through digital tools, their problem-solving practices, and perceived challenges and supports. The interview protocol included open-ended questions focused on how students used digital tools during learning activities, how these tools influenced their thinking, and how they navigated access and task demands. Classroom observations focused on how digital

tools were integrated into instruction, how students interacted with these tools during problem-solving activities, and how teachers structured and supported digitally mediated tasks. Learning artifacts included students' digital work products, such as screenshots, submitted assignments, and notes generated through digital platforms, which provided insight into enacted practices and complemented self-reported data.

Procedures and Timeline

Data collection took place over a six-week period during the academic term. Classroom observations were conducted during scheduled mathematics lessons that involved digital tool use. Interviews were conducted after observations to allow students to reflect on recent learning experiences. Interviews were audio-recorded with consent and transcribed verbatim. Observational notes were recorded during and immediately after lessons to capture contextual details. Digital artifacts were collected with permission and anonymized prior to analysis. Care was taken to minimize disruption to regular instructional activities throughout the study.

Data Analysis

Data analysis followed an inductive thematic approach. Interview transcripts, observation notes, and learning artifacts were read repeatedly to develop familiarity with the data. Initial codes were generated to capture meaningful units related to tool use, problem-solving strategies, perceptions of learning, and contextual conditions. Codes were compared across data sources and refined through iterative analysis. Related codes were grouped into broader categories and further developed into themes that captured patterns across participants' experiences. Analytic decisions were documented throughout the process to support transparency and coherence.

Trustworthiness

Several strategies were used to enhance the trustworthiness of the study. Triangulation across interviews, observations, and artifacts supported the credibility of the findings. Reflexive memos were maintained during analysis to document assumptions, emerging interpretations, and analytic decisions. An audit trail of coding iterations and theme development was preserved. Where appropriate, participants were invited to clarify or elaborate on interview responses to ensure accurate representation of their perspectives.

Ethical Considerations

The study was conducted in accordance with recognized ethical standards for educational research. Institutional approval was obtained prior to data collection. Informed consent was secured from all participants, and parental consent was obtained where required. Participants were informed of the study's purpose, their right to withdraw at any time, and the measures taken to protect confidentiality. All data were anonymized and securely stored, and identifying information was removed from transcripts and artifacts.

Methodological Limitations

Several limitations should be acknowledged. The study was conducted in a limited number of schools, which may constrain the transferability of findings to other contexts. Although digitally mediated learning was a routine part of instruction, the specific tools and platforms reflected local practices and available resources. The qualitative design emphasizes depth of understanding rather than generalization, and students' accounts may have been influenced by differences in comfort with reflection and verbal expression. These limitations are considered when interpreting the findings.

3. Result and Discussion

Result

Findings (Results)

This section reports the findings of the study in relation to the research questions guiding the inquiry: (1) how students experience digitally mediated mathematics learning, (2) what practices they adopt when digital tools support mathematical problem solving, and (3) what conditions shape the development of digital competence in this learning context. The findings are drawn from semi-structured interviews, classroom observations, and student-generated learning artifacts. Following qualitative reporting conventions, the results are presented descriptively, organized around four themes that emerged through inductive thematic analysis. Interpretation and engagement with prior research are reserved for the Discussion section.

Overview of Emergent Themes

Analysis of the data resulted in four interrelated themes: (1) digital tools as supports for visualization and conceptual exploration, (2) iterative problem-solving practices enabled by digital mediation, (3) development of practical digital competence through routine learning

activities, and (4) constraints related to access, connectivity, and sustained focus. These themes align with the research questions and reflect patterns observed consistently across data sources. An overview of the relationship between research questions, themes, and evidence sources is presented in Table 1.

Table 1

Alignment of Research Questions, Themes, and Evidence Sources

Research Question	Theme	Evidence Sources
RQ1	Visualization and conceptual exploration	Interviews, observations, artifacts
RQ2	Iterative problem-solving practices	Interviews, artifacts, observations
RQ3	Development of digital competence	Interviews, observations
RQ3	Access, connectivity, and focus constraints	Interviews, observations

Note. Themes were generated through inductive coding and constant comparison across data sources (Braun & Clarke, 2006).

Theme 1: Digital Tools as Supports for Visualization and Conceptual Exploration

Students consistently described digital tools as supporting their understanding of mathematical concepts by making abstract ideas more visible and manipulable. Visualization emerged as a prominent feature of students' experiences, particularly during tasks involving graphs, functions, and geometric representations. Students reported that dynamic visual displays allowed them to observe changes in real time, which supported exploration and sense-making.

Several participants explained that adjusting values or parameters helped them understand relationships between variables. One student noted, "When I change the value, the graph moves immediately, so I can see what is happening. It is easier than imagining it." During classroom observations, students were frequently seen adjusting digital graphs, zooming in on specific sections, and comparing different representations. These actions were often accompanied by brief discussions with peers or quiet verbal reasoning.

Learning artifacts further illustrated this pattern. Screenshots and saved files showed multiple versions of the same task, reflecting exploratory activity rather than a single finalized product. In some cases, students added short annotations explaining why a particular visual configuration was useful or incorrect. These artifacts indicated that students used visualization not only to confirm answers but also to test ideas during problem solving.

However, students also reported that visualization tools could be overwhelming when first introduced. Several participants described uncertainty about which features were relevant. One student explained, "At first I just clicked many things, but I did not know which one was important." Observational notes confirmed that students initially relied on trial-and-error before identifying functions aligned with the task. These accounts indicate that visualization supported learning but required guidance and task structure to be effective.

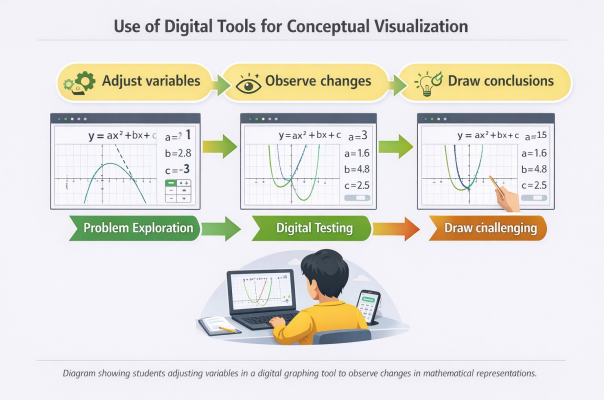

Figure 1

Use of Digital Tools for Conceptual Visualization

Caption.

This figure illustrates how students used digital tools to manipulate variables and visualize mathematical relationships during learning activities.

Alt text.

"Diagram showing students adjusting variables in a digital graphing tool to observe changes in mathematical representations."

Theme 2: Iterative Problem-Solving Practices Enabled by Digital Mediation

A second theme concerned how digital tools supported iterative approaches to mathematical problem solving. Students described problem solving as a process of

testing, revising, and refining ideas rather than following a fixed linear sequence. This pattern was evident across interviews, observations, and learning artifacts.

Students emphasized that digital tools made it easier to revise work without restarting tasks. One participant explained, "If the answer is wrong, I can just change it and try again. I don't need to erase everything." During observations, students were frequently seen revising solutions multiple times within a single session, comparing different outputs before deciding which response to submit.

Artifacts provided further evidence of iterative practices. Many digital assignments contained multiple saved versions or visible revision histories, showing incremental adjustments over time. In tasks involving simulations or dynamic graphs, small changes produced immediate visual feedback, prompting additional revisions. Students often retained earlier versions as reference points rather than deleting them, suggesting ongoing evaluation of their work.

Students also described informal collaboration as part of problem solving. Although tasks were typically assigned individually, participants reported brief exchanges with peers, such as sharing screens or asking focused questions. Observations confirmed that these interactions were common when students encountered difficulties. These exchanges were usually short and centered on specific steps or tool functions rather than complete solutions.

Despite these affordances, some students reported that time pressure limited exploration. One student remarked, "Sometimes I just want to finish quickly because there are many tasks." This indicates that while digital tools enabled iterative practices, contextual factors influenced the extent to which students engaged in them.

Figure 2 Observed Iterative Problem-Solving Cycle

Caption.

This figure represents the recurring cycle of exploration, testing, revision, and confirmation observed in students' digitally mediated problem-solving practices.

Alt text.

"Flow diagram showing a cycle of problem exploration, digital testing, revision of solutions, and confirmation."

Theme 3: Development of Practical Digital Competence Through Learning Activities

The third theme relates to how students developed digital competence through repeated engagement with digitally mediated mathematics tasks. Students described digital competence as emerging gradually through use, rather than as a separate or explicitly taught skill. Competence was associated with increased confidence, efficiency, and independence when navigating digital tools and platforms.

Many participants reflected on changes in their abilities over time. One student stated, "Before, I always asked the teacher how to use the application. Now I can do it by myself." Similar accounts appeared across interviews, with students noting that tasks that initially felt difficult became routine with practice. Observational data supported these accounts, as students required less assistance and accessed relevant tool features more quickly as the study progressed.

Digital competence was also evident in how students managed files, submissions, and platforms. Learning artifacts showed consistent naming conventions, organized folders, and timely submissions. In interviews, students described learning how to address minor technical issues independently, such as reconnecting to the internet or restarting applications.

However, development of digital competence was uneven. Differences were often linked to prior experience and access to devices outside school. Students with regular access to personal devices described greater ease in transferring skills across contexts, while those relying on shared devices reported slower progress. One student explained, "At home I cannot practice because I share the phone with my brother, so I only learn at school."

Table 2

Observed Indicators of Developing Digital Competence

Indicator	Evidence Source	Example
Independent tool navigation	Observations	Students accessed functions without assistance

Indicator	Evidence Source	Example
Efficient task completion	Artifacts	Reduced number of revisions over time
Digital file management	Artifacts	Organized folders and consistent naming
Troubleshooting behaviors	Interviews	Restarting applications, reconnecting internet

Note. Indicators reflect observed practices rather than measured proficiency levels.

Theme 4: Constraints Related to Access, Connectivity, and Focus

Alongside the affordances of digitally mediated learning, students consistently identified constraints affecting their engagement. Issues related to device access, internet connectivity, and sustained focus appeared across interviews and observations.

Access to devices varied across participants. While some students used personal smartphones or laptops, others relied on shared devices provided by the school or family members. Students who shared devices described difficulties completing tasks outside scheduled class time. One participant noted, "If my friend is using the laptop, I have to wait, so sometimes I submit late."

Connectivity issues were also frequently reported. Students described unstable internet connections, particularly during peak usage times. Observational notes documented interruptions during lessons when students lost connection and needed to reconnect, reducing time available for task completion.

Students also acknowledged challenges related to focus. Digital devices made it easier to shift attention away from learning tasks. One student commented, "When I use my phone, notifications appear, and sometimes I check them." Observations confirmed that off-task behavior occasionally occurred, especially during independent work periods. However, this behavior varied across students and appeared influenced by task structure and classroom management.

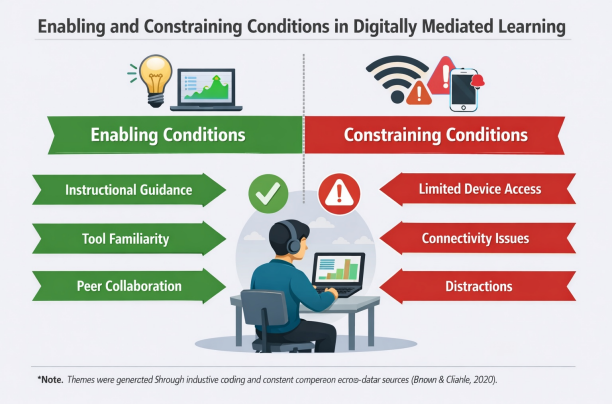

Figure 3

Enabling and Constraining Conditions in Digitally Mediated Learning

Caption.

This figure summarizes conditions that supported or constrained students' engagement in digitally mediated mathematics learning.

Alt text. "Diagram showing enabling conditions such as instructional guidance and tool familiarity, and constraining conditions such as limited access, connectivity issues, and distractions."

Summary of Findings

Overall, the findings portray digitally mediated mathematics learning as a situated experience shaped by interactions among digital tools, instructional practices, and learning conditions. Students used digital tools to visualize concepts, engaged in iterative problem-solving practices, and developed practical digital competence through repeated participation in learning activities. At the same time, access limitations, connectivity challenges, and issues related to focus influenced how these practices unfolded in everyday classroom settings. These findings directly address the research questions and provide a descriptive foundation for the Discussion section that follows.

Discussion

This study set out to examine how students experience digitally mediated mathematics learning, the practices they adopt when digital tools support problem solving, and the conditions that shape the development of digital competence within this context. The findings offer a detailed account of students' lived experiences, highlighting both the pedagogical affordances of digital mediation and the practical constraints that shape

everyday learning. Taken together, the results suggest that digitally mediated mathematics learning is not defined solely by the presence of technology, but by how tools, tasks, and conditions interact to support or limit meaningful engagement.

Interpreting Students' Experiences of Digitally Mediated Mathematics Learning

The first research question focused on how students experience mathematics learning when it is mediated through digital tools. The findings indicate that students largely perceive digital mediation as enhancing conceptual access, particularly through visualization and dynamic representation. Students' descriptions of adjusting parameters, observing immediate graphical changes, and revisiting representations suggest that digital environments make abstract mathematical ideas more tangible. Rather than replacing mathematical reasoning, these tools appear to externalize thinking processes, allowing students to explore relationships that might otherwise remain implicit.

At the same time, the findings show that students' experiences are shaped by the degree of structure provided. When tasks clearly guided attention toward relevant features of digital tools, students reported greater clarity and confidence. In contrast, when tools presented multiple features without sufficient scaffolding, students described initial confusion and uncertainty. This tension highlights that digital mediation alone does not guarantee productive learning experiences; instructional design plays a critical role in shaping how students perceive and engage with digital environments.

Importantly, students did not describe digitally mediated learning as fundamentally separate from mathematics learning itself. Instead, digital tools were woven into routine classroom practices, becoming part of how students approached problems, tested ideas, and communicated understanding. This finding underscores the need to conceptualize digital learning not as an add-on, but as an integrated learning modality with its own pedagogical demands.

Problem-Solving Practices in Digitally Mediated Contexts

The second research question examined the practices students adopt when digital tools support mathematical problem solving. The findings point to a shift toward more iterative and exploratory approaches. Students described problem solving as a process of testing, revising, and refining ideas rather than following a fixed linear pathway. Digital tools enabled this process by lowering the cost of error; students could quickly modify inputs, explore alternatives, and compare outcomes without erasing or restarting their work.

This iterative cycle was visible not only in students' accounts but also in observational data and learning artifacts, which documented multiple solution attempts and version histories. These patterns suggest that digitally mediated environments can support forms of productive trial and revision that are less accessible in static, paper-based settings. In practice, students appeared more willing to experiment when digital tools allowed immediate feedback.

However, the findings also indicate that iterative problem solving was unevenly enacted. Time pressure, assessment expectations, and task volume influenced the extent to which students engaged in exploration. Some students prioritized efficiency over experimentation, particularly when tasks were perceived as routine or when deadlines were tight. These observations suggest that while digital tools afford iterative practices, institutional and instructional conditions strongly shape whether those affordances are realized.

Development of Digital Competence Through Participation

The third research question addressed how students develop digital competence within digitally mediated mathematics learning. Rather than describing digital competence as a predefined skill set, students framed it as something that emerged gradually through participation. Repeated engagement with digital tasks fostered familiarity, confidence, and independence. Over time, students required less assistance, navigated tools more efficiently, and demonstrated greater control over their digital work.

This finding aligns with the view that digital competence develops through use rather than instruction alone. Students learned how to manage files, troubleshoot minor technical issues, and adapt tools to task requirements as part of their everyday learning practices. Digital competence, in this sense, was closely tied to mathematical activity rather than separate from it.

At the same time, development of digital competence was shaped by access conditions beyond the classroom. Students with regular access to personal devices reported greater continuity in their learning, while those relying on

shared devices described fragmented opportunities for practice. These differences suggest that digital competence is not only an individual attribute but also a socially and materially situated outcome.

Enabling and Constraining Conditions

Across all research questions, the findings point to a set of enabling and constraining conditions that shape digitally mediated learning. Access to devices, internet connectivity, and classroom management practices emerged as particularly influential. While digital tools supported visualization and iterative problem solving, disruptions caused by unstable connections or limited access interrupted learning flow and reduced available time for engagement.

Students were also aware of challenges related to focus and distraction. The presence of notifications and non-academic applications created competing demands for attention, particularly during independent work. However, students did not frame these challenges as inherent flaws of digital learning. Instead, they viewed them as practical issues that required clearer norms, better infrastructure, or more purposeful task design.

These findings suggest that digitally mediated learning environments are best understood as ecosystems in which tools, policies, and practices interact. Productive learning depends not only on what tools are available, but on how learning conditions support sustained engagement.

Practical Implications for Instruction and Design

The findings offer several implications for instructional practice and learning design. First, tasks should leverage the strengths of digital tools by encouraging exploration and iteration rather than simply digitizing traditional worksheets. Structured prompts that direct attention to key features of digital representations can help students move beyond surface interaction.

Second, opportunities for reflection on iterative processes may strengthen learning. Encouraging students to retain and compare multiple solution attempts can support metacognitive awareness and deepen understanding. Digital platforms that allow version tracking and annotation are particularly well suited to this purpose.

Third, attention to access and infrastructure remains essential. Equitable digitally mediated learning requires reliable connectivity and consistent device access, both within and beyond the classroom. Where access is uneven, instructional strategies may need to account for limited opportunities for practice outside scheduled learning time.

Finally, classroom norms and task structures can support focus by clarifying expectations for digital tool use. Rather than restricting devices, clear guidance on when and how tools are used for learning may help students manage distractions more effectively.

Study Limitations

Several limitations should be acknowledged. The study was conducted within a specific educational context, and findings may not generalize to settings with different curricular structures, technological resources, or student populations. The qualitative design provides depth of insight but does not allow for claims about prevalence or causal impact.

In addition, data relied on self-reported experiences, observations, and artifacts collected over a defined period. While triangulation strengthened credibility, students' accounts may have been influenced by social desirability or familiarity with the researcher. Finally, digitally mediated learning was examined within a particular configuration of tools and practices; different platforms or instructional models may yield different experiences.

Directions for Future Research

Future research could build on these findings in several ways. Longitudinal studies may offer insight into how digital competence develops over extended periods and how it transfers across subjects. Comparative research across different digital learning models could clarify how specific design features shape problem-solving practices. Further work might also examine how assessment practices influence students' willingness to engage in iterative exploration. Understanding how evaluation criteria interact with digital affordances could inform more aligned instructional approaches. Finally, research that foregrounds students' perspectives across diverse access contexts may contribute to more equitable designs for digitally mediated learning.

Conclusion of the Discussion

In sum, the findings suggest that digitally mediated mathematics learning supports visualization, iteration, and the gradual development of digital competence, while also presenting practical challenges related to access, connectivity, and focus. Students' experiences are shaped not simply by technology itself, but by the conditions under which digital tools are embedded in everyday

learning. These insights provide a grounded basis for rethinking how digitally mediated environments are designed, supported, and sustained in mathematics education.

4. Conclusion

This study contributes a grounded account of how students experience and enact digitally mediated mathematics learning, with particular attention to visualization, problem-solving practices, and the development of digital competence. By foregrounding students' voices, observed classroom activity, and learning artifacts, the findings clarify how digital tools become embedded in everyday mathematical work rather than functioning as add-ons to instruction. The study shows that digitally mediated learning supports conceptual exploration and iterative problem solving while simultaneously shaping students' growing confidence and independence in using digital tools. At the same time, it highlights how these experiences are situated within concrete conditions of access, connectivity, and classroom organization.

These findings matter for digitally mediated and blended learning practice because they point to the importance of intentional design rather than technological presence alone. When digital tools are paired with clear task structures and opportunities for exploration, they can support meaningful mathematical engagement and the gradual development of digital competence. Conversely, uneven access, unstable connectivity, and competing demands on students' attention can limit these benefits if left unaddressed. Together, the results underscore that effective digitally mediated learning depends on aligning tools, pedagogy, and learning conditions in ways that are responsive to students' lived experiences. This alignment offers a practical foundation for designing learning environments that are both pedagogically purposeful and attentive to equity and participation.

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Ethics Statement

This study was conducted in accordance with established ethical standards for research involving human participants. Prior to data collection, ethical approval was obtained from the relevant institutional review board. Informed consent was secured from all participants, and, where applicable, assent and parental consent were obtained. Participants were informed of the voluntary nature of the study and their right to withdraw at any time. All data were anonymized, and confidentiality was maintained throughout data collection, analysis, and reporting.

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Conflict of Interest Statement

The authors declare no conflicts of interest related to the research, authorship, or publication of this study.

Data Availability Statement

Due to the qualitative nature of the study and the need to protect participant confidentiality, the interview transcripts, observational notes, and learning artifacts are not publicly available. De-identified excerpts supporting the findings are included within the article. Additional information about the data and analytic procedures may be made available upon reasonable request to the corresponding author, subject to ethical approval.

Author Contributions

All authors contributed to the conception and design of the study. Data collection and analysis were conducted collaboratively. The first author led the drafting of the manuscript, and all authors contributed to critical revision for intellectual content. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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