




# Exploring game-based learning to enhance mathematics teaching and learning: A case study of year 6

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## ABSTRACT

The integration of online learning games in mathematics education is a rapidly growing area, driven by ongoing technological progress and the recognized potential to improve student learning experiences. Effective technological support is essential for enhancing students' understanding and engagement in mathematics. This study critically assesses the effectiveness of MangaHigh, an online game-based learning (GBL) resource featuring adaptive learning technology, in an Australian primary school setting. Using a mixed-methods case study approach, data were gathered through surveys completed by 72 year 6 students and a semi-structured interview with their classroom teacher. The results show that the teacher viewed MangaHigh as a tool that encourages student engagement and helps in understanding specific mathematical concepts, aligning with recent research indicating GBL can increase motivation and conceptual understanding. Survey data showed that most students believed MangaHigh assisted their understanding of mathematical concepts. Notably, gender-based differences in perceptions were observed, with more boys than girls perceiving MangaHigh as a helpful tool that makes learning mathematics enjoyable, boosts confidence, and simplifies concepts. However, statistical analysis revealed that these differences were not significant. These findings are placed within current research on digital skills and attitudes. Overall, the results suggest that mathematics teachers should think about incorporating technology into their teaching. The study also emphasizes the need for further research, as current studies on the impact of GBL tools like MangaHigh on primary school mathematics education are still limited.

**Keywords:** game-based learning, online mathematics resources, primary school, digital technology, MangaHigh

## INTRODUCTION

The use of digital technologies in mathematics education is widespread in Australia and around the world. The Australian mathematics curriculum clearly encourages the integration of information and communication technology (ICT) to enhance student learning across various mathematical areas (Schmidt & Williamson-Kefu, 2020). Recent systematic reviews and studies regularly confirm the positive impact of digital tools on improving student learning outcomes, developing problem-solving skills, and boosting engagement in mathematics (e.g., Bright et al., 2024; Hui & Mahmud, 2023). Game-based learning (GBL), in particular, has received notable attention for its ability to motivate students and make complex mathematical concepts more understandable (Hui & Mahmud, 2023).

Despite these promising trends, the effective integration of digital technologies remains a complex endeavor, filled with challenges. Teachers' careful selection and pedagogical use of these tools require thoughtful consideration and ongoing professional development (Loong & Herbert, 2018). Ongoing issues include equitable resource access, the digital divide, and the need for continuous support for educators (Akpalu et al., 2025). Many students often find mathematics challenging (Kasim & Deringöl, 2025), highlighting the need for innovative pedagogical strategies, including the thoughtful use of technology, to foster deeper conceptual understanding. Ersozlu (2024) found that digital tools and GBL can reduce mathematics anxiety and enhance learning, emphasizing the importance of collaborative efforts between educators and administrators. Additionally, the rise of adaptive learning technologies and artificial intelligence in education offers new opportunities for personalizing learning experiences and creating more interactive and engaging mathematical environments (Akpalu et al., 2025).

Although the body of research on educational technology is expanding, there remains a need for more detailed investigations into how specific technologies influence primary school students' attitudes, engagement, and learning in mathematics (Hilton, 2018; Howard & Crotty, 2017). In-depth exploration of teachers' and students' perspectives on GBL platforms such as MangaHigh is still relatively limited within the context of Australian primary mathematics education (Akçay et al., 2021). As digital technologies continue to develop rapidly (Koehler et al., 2013), understanding their practical applications and perceived effectiveness is crucial.

This study aims to contribute to this understanding by examining the effectiveness of MangaHigh, a prominent GBL platform for mathematics, within an Australian primary school. MangaHigh employs adaptive learning technology to tailor task difficulty, a feature increasingly central to personalized learning approaches. The research involved surveys of year 6 students and an in-depth interview with their mathematics teacher. This evidence-based investigation is significant as it provides specific insights into the use of the GBL platform, MangaHigh, which offers instructional games across various mathematical strands, including number, algebra, measurement, geometry, statistics, and probability.

The research questions (RQs) guiding this study are:

1. **RQ1.** What role does MangaHigh play in enhancing year 6 students' understanding of mathematics?
2. **RQ2.** How do the year 6 teacher and students perceive the influence of MangaHigh in the teaching and learning of mathematics?

This study seeks to contribute to the field by providing empirically grounded evidence on the use of GBL technology in a primary school context. Specifically, it provides an in-depth examination of students' and teachers' experiences with the MangaHigh platform in an Australian primary school. The findings extend prior studies by identifying gendered perceptions of GBL participation and highlighting the critical role of teacher-mediated technology use in shaping students' mathematical learning. By offering practical, context-specific evidence, this study enriches the literature on the implementation and impact of GBL in classroom settings. It also aims to illuminate how such tools can influence student engagement and conceptual understanding. Ultimately, this research underscores the critical importance of thoughtful technology integration in mathematics pedagogy and calls for continued inquiry into the multifaceted impacts of these evolving digital resources.

## LITERATURE REVIEW

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The literature review examines current insights into the role of digital technologies in enhancing understanding of mathematics and their perceived influence on teaching and learning. It is divided into two main sections: the first section explores the use of digital technologies in teaching mathematics and addresses the challenges related to their use in classrooms, including the significance of technological pedagogical content knowledge (TPACK). The second section explores how digital technology supports and improves mathematics learning.

## Using Digital Technology to Enhance Understanding of Mathematics

Research indicates that teachers require an understanding of the purpose of technology in teaching mathematics to effectively integrate any technology-based methods (Schmitz et al., 2023), as well as an awareness of the school culture where they teach (Yean, 2024). Orlando and Attard (2016) found that other factors are also significant. These include

- (1) the teacher's knowledge and beliefs, including their technical skills,
- (2) the professional context, which covers curriculum demands, access to hardware and software, technical support, and students' prior experiences, and
- (3) sources of assistance such as the teacher's university education and professional development.

Teachers' knowledge and beliefs are crucial in integrating digital tools into mathematics teaching. Educators need to identify the most suitable technologies for achieving learning objectives when teaching mathematics to enhance students' understanding (McCulloch et al., 2018). TPACK is a framework for teacher knowledge in technology integration (Koehler et al., 2013). It is suggested that the overlap between content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) creates a flexible knowledge base that supports effective technology-based teaching. The benefits of the TPACK framework include helping students with learning difficulties, identifying their prior knowledge, and reinforcing it. TPACK measurement methods include self-reports, open-ended questionnaires, interviews, and observations. Researchers are still working to assess TPACK levels in teachers to understand their knowledge and evaluate the effects of interventions and professional development programs (Tondeur et al., 2020). A discussion on the knowledge teachers need to use technology in mathematics education, particularly the development of the TPACK framework in mathematics, was presented in Getenet's (2017) study.

Moreover, TPACK assists teachers in integrating technology into mathematics teaching. First, a teacher recognizes the importance of TK. The next step is for educators to accept technology in mathematics learning and teaching. Then, educators can effectively incorporate the teaching and learning of mathematics with appropriate technology. Finally, teachers prefer to use technology during lessons and regularly evaluate the outcomes (Aldemir Engin et al., 2023). Loong and Herbert (2018) conducted a cross-case analysis of two teachers' use of digital technologies in Australian classrooms, applying the stages of the TPACK framework: recognizing (knowledge), accepting (persuasion), adapting (decision), exploring (implementation), and advancing (confirmation). In their first case study, students used iPads and cameras to record two lessons, and afterwards, the teacher and two students were interviewed. In the second case study, a classroom with twelve computers for twenty-one students had students taking turns using the computers. In this research, the participating teacher effectively employed the TPACK framework to guide lesson planning and instruction, thereby improving understanding and meeting the needs of diverse learners. By applying TPACK principles, the teacher created engaging learning experiences in the classroom. This literature offers insights into factors influencing technology integration but highlights a need for further research into mathematics education in Australian primary settings schools.

Furthermore, one framework that has been successful in integrating technology into the mathematics classroom is to view technology as a master, servant, partner, or an extension of the self (Goos et al., 2003). If a teacher's knowledge and beliefs align more with technology as a partner, then the teacher uses it to support learning. For example, if students solve learning exercises faster using technology to explore different approaches to current tasks, enhance understanding, or discover multiple perspectives, then technology is regarded as a partner. Knowledge areas related to technology integration are closely linked and mutually reinforce each other in mathematics education (Koehler et al., 2013). When technology is combined with effective pedagogy, it can assist students in classifying information, explaining relationships in representations, and applying mathematical knowledge (Van de Walle et al., 2019). Grandgenett et al. (2011) also proposed seven types of technology-based practices that support mathematical understanding, such as interpreting concepts, evaluating student work, and applying mathematics to real-world situations. The frameworks discussed explore technological and pedagogical outcomes within mathematics education in Australia.

Besides teachers' knowledge and beliefs, various other factors influence the adoption of technology in mathematics education. Previous research also highlights gender differences in students' attitudes towards using technology to learn mathematics (Abidin et al., 2018). While technology can increase the complexity of teaching (Koehler et al., 2013), teachers must understand the connection between the technology and its purpose, then clearly explain its features to students (Admiraal et al., 2017). However, teachers who graduated before technology became widespread in education often do not fully see its relevance and value in teaching and learning. The key challenge for teachers when integrating technology is organising classroom discussions with students (Goos et al., 2017). Teachers need to evaluate not only the technology itself but also the resources available for both teacher and student support. When assessing internet resources, criteria such as currency, relevance, authority, accuracy, and purpose are vital (Fielding, 2019). They must judge the quality of online materials and increase awareness of the technologies used to understand mathematics education; this is especially important given the many resources now available online (Anshari et al., 2016; Harrison & Lee, 2018).

Curriculum requirements and access to hardware and software resources are also significant factors in integrating technology into mathematics education. The digital content used to teach mathematics depends on the curriculum, such as the year, the topics covered, and the technology that supported students at that time. Technology, pedagogy, and content are reflected in specific teaching and learning contexts. Devices like tablets and laptops may be essential in some schools, while not endorsed in others. For example, if each student in a class had a computer or an iPad connected to the internet, whereas another class had only one computer, the types of educational activities the teacher could use would differ. Similarly, schools that permit or block certain websites influence how teachers plan their lessons. Online learning presents capabilities and limitations that make it more suitable for particular tasks and impact how teachers teach (PK) (Gore et al., 2021).

### Using Game-Based Technology to Learn Mathematics

One of the new interactive learning methods for primary school students is GBL applications. Darragh (2021) discussed the rise of online mathematics learning platforms. Online platforms enable students to access educational materials at any time, overcoming geographical barriers. They feature interactive tools, videos, and quizzes, which enhance engagement and provide immediate feedback. GBL can take the form of mini-lessons, and these mathematics educational games can be used alongside traditional classroom or at-home instruction, such as videos (Jahnke et al., 2020). GBL employs digital games to support educational goals. It emphasizes learning through interactive play, where participants face challenges that develop skills and improve knowledge retention while remaining motivated and engaged (All et al., 2015). Games offer strong motivation, allowing people to strive for victory or to replay the game until they succeed (Buckley et al., 2018). Students learn while having fun, either individually or in groups.

Teachers with high TPACK knowledge should assess the design, motivation, support, ease of use, engagement, practicality, and feedback of mathematics GBL to help students learn and understand mathematics (Attard & Northcote, 2011; Darragh, 2021; Gocheva et al., 2022; Hilton, 2018; McCulloch et al., 2018). Harrison and Lee (2018) reviewed an effective mathematics application that guides students through step-by-step interactive lessons, helping them learn to solve similar problems independently. Conversely, they discussed a less effective application that provides feedback on students' answers without showing where errors occurred or what the correct solutions are.

One such game-based technology for learning mathematics is MangaHigh, an internet-based program designed for children aged 5 to 16 years. MangaHigh's adaptive learning technology adjusts the difficulty of tasks based on each student's performance, providing a personalized learning experience (Winthrop et al., 2019). The activities are intended to be fun and foster a positive attitude towards mathematics. It offers a comprehensive digital mathematics curriculum for primary school students, covering a variety of topics through engaging, interactive activities. The curriculum includes number sense and operations, where students learn basic arithmetic, place value, fractions, and decimals. Geometry and measurement topics help students recognize shapes, understand symmetry, and measure length, area, volume, and mass. Data handling and probability introduce students to collecting and organising data, interpreting graphs, and basic probability concepts. Algebraic thinking is also included, focusing on recognizing patterns and simple

equations. Additionally, problem-solving and reasoning skills are developed through real-world applications and logical reasoning exercises (Kriswandani & Kusuma, 2025).

One feature of MangaHigh is that each lesson focuses on one educational topic. Challenges provide exercises that can be assigned to an individual student or to an entire class. Games or lessons can be set up as challenges with a tutorial that provides directions for the student. The videos include animation and sound. In challenges, the timer and due dates may be edited. The admin tab allows users to add teachers, add students, and modify student information. Students' login requires a username and a password. The activities tab allows the teacher to analyze the students' results. Next, the teacher identifies gaps in students' learning and assigns follow-up exercises. Medals are awarded to motivate students, each worth a set number of points. Note that the MangaHigh platform examined in this study is no longer operational as of 2026. However, the platform served as a research context rather than the object of evaluation, and the findings focus on transferable pedagogical practices and principles of technology integration in mathematics education. As such, the insights remain relevant beyond the lifespan of the specific platform.

In 2021, the participating school in the study had integrated MangaHigh into its mathematics instruction, particularly as a supplementary and engaging resource. Teachers used it to serve as interactive homework, differentiated instruction, and a platform for competitive activities. Additionally, teachers at the school utilize it to track students' mathematics progress, conduct review sessions, and set up independent learning stations.

## METHODOLOGY

This study aimed to assess the experience of students of MangaHigh as a tool for teaching mathematics, specifically by investigating how it can be utilized to enhance mathematics learning in primary schools. The investigation employs a case study research design and includes a student survey and a teacher interview to address a specific RQ (Queirós et al., 2017). During the 2023 school year, the study focused on a group of students in an Australian setting to explore the impact of MangaHigh on their understanding of mathematics.

### Participants

The participants in this study were 72 year 6 students (45 girls and 26 boys) and their mathematics teacher from a nongovernmental school in New South Wales. These participants were selected from a total of 120 year 6 students across four classes. Only students whose parents provided consent took part in the survey. The teacher who was interviewed holds a Bachelor of Arts in informatics and a Master of Teaching, with 10 years of experience teaching year 6. The school was selected for its suitability, and the necessary permissions were secured. It uses a balanced approach to teaching mathematics, with about half of the instruction delivered through technology and the other half through traditional paper-based methods. While the technology of interest in this study was MangaHigh, other technological tools were also discussed. Smartboards are used to display PowerPoint slides, YouTube videos, Mathletics activities, and MangaHigh tasks. Students solve questions on the Smartboard and sometimes visit the computer lab to complete exercises, such as those related to geometry. The teacher also mentioned that PowerPoint slides are printed as a backup in case of issues with the Smartboard. This group included high-achieving students, as shown by the consistently high NAPLAN test scores in the school. There is strong parental involvement, with parents who are very supportive and respectful of education, ensuring students complete their homework.

The deputy executive principal of the school distributed the invitation to participate. Information sheets and consent forms were distributed to parents and collected with the assistance of the teacher. To ensure confidentiality, participants' identities were protected by de-identifying the interview audio recording and survey data.

### Data Collection Methods

Previous researchers have used mixed-methods approaches to examine the impact of technology, especially GBL, on primary school students' understanding of mathematics. For example, Hilton (2018) used surveys to gauge students' attitudes towards using technology for understanding mathematics in Australia, followed by interviews with teachers. Additionally, Howard and Crotty (2017) investigated the opinions and perspectives of thirty high-achieving mathematics students, enabling them to assess MangaHigh's

motivational features. Data were gathered through open-ended questions posed by the teacher. Hilton's (2018) study highlighted the advantages of using digital technologies, such as iPad applications, for teaching and learning mathematics. Conversely, Loong and Herbert (2018) found that most students and their teachers did not favor digital technologies. However, Howard and Crotty (2017) underscored the value of MangaHigh as a game-based educational tool.

In this study, consistent procedures and steps were applied across data collection methods (interviews, questionnaires) to ensure result reliability. Effective interview and questionnaire questions were developed, and the questionnaire was carefully designed to answer the RQs. Both sets of questions were based on similar sources discussed earlier, which are further described in the section titled Students survey. The data's reliability in both methods depended on the participants' responses (Queirós et al., 2017).

### **Teacher interview**

In qualitative research, non-numeric data such as words and narratives are gathered to explore feelings, thoughts, and perceptions related to a specific concept. Interviews are especially valuable for examining the limitations and advantages of particular tools or techniques (Patton, 2003).

After coordinating with the deputy executive principal and the teacher, the teacher reviewed the information sheet and signed a consent form. The teacher was given the opportunity to ask questions both before and after the interview. The interview was conducted outside of teaching hours and took place in a single session at the school, scheduled at a convenient time for the teacher. The face-to-face interview lasted approximately 30 minutes and was audio-recorded.

The interview questions were designed based on Hilton's (2018) study and included open-ended questions about the teacher's technological and pedagogical choices when teaching mathematics, as well as student learning and engagement with MangaHigh. The interview questions include: "Does the use of technology in teaching mathematics affect student engagement?"; "How do you use MangaHigh?"; "What does the student think of the use of MangaHigh?"; "Is MangaHigh effective and useful in learning and teaching mathematics?"

### **Students survey**

A survey instrument was selected to assess the effectiveness of game-based technology, employing a mixed-methods research approach. However, one limitation of the survey instrument is its depth, as it collects data by asking participants about their experiences and opinions (Polkinghorne, 2005). The participants had been using MangaHigh for approximately two years to learn mathematics.

The researcher initially drafted the survey questions, which were then refined based on feedback from supervisors, as the study was originally developed as part of a master's thesis project. Once finalized, the survey was sent to the teacher for comments. The survey questions were designed based on previously identified sources (Ghavifekr & Rosdy, 2015; Lowerison et al., 2006; Muir, 2014; Shin, 2015). For example, questions rating statements on a scale of "always," "sometimes," or "not at all" included: "I find it easier to learn mathematics using MangaHigh", and "MangaHigh enables me to work with other children in my learning," adapted from Ghavifekr and Rosdy (2015) and Lowerison et al. (2006). The student survey responses were analyzed using descriptive statistics (frequency and percentages), consistent with prior studies (Ghavifekr & Rosdy, 2015; Muir, 2014; Shin, 2015). In addition, gender comparisons were explored using crosstabs and chi-square tests of independence.

Parents received information sheets and signed consent forms before their children participated in the project. Participants had the opportunity to ask questions before and after the survey. Participation was voluntary, and students could choose not to complete or submit their survey if they no longer wished to participate. Completion of the survey implied consent.

A total of 72 year 6 students (45 girls and 26 boys), representing 86.4% of the total cohort, completed a deidentified survey. The survey consisted of seven multiple-choice questions, ten Likert scale questions, and five open-ended questions. It was administered on paper, took approximately 15 minutes to complete, and was returned with the teacher's help at a time chosen by the teacher to minimize disruption to student learning.

## Data Analysis Methods

To ensure the reliability and validity of the research, it is necessary to collect long-term data, use multiple data sources (interviews and surveys), and accurately transfer responses to interview and survey questions without modification (Creswell, 2009). Quantitative data were collected from the student survey questionnaire and analyzed using SPSS. Responses were summarized using frequencies and percentages. Gender comparisons were examined using crosstabs, and chi-square tests of independence were conducted to identify potential differences between boys and girls across selected survey variables, with statistical significance set at  $p < .05$ .

The qualitative data collected from the teacher interview were analyzed using the six steps of thematic analysis suggested by Braun and Clarke (2012). The qualitative data from the student survey (responses to open-ended questions) were also coded. In the current study, the first step was familiarization and organization of the data. The researcher transcribed the recorded interview, reviewed it, and noted initial impressions. For the student survey, the researcher read some responses to understand the context. The second step involved coding data by highlighting and describing the text. Third, the codes were broken down into themes that addressed the RQs and grouped relevant codes. NVivo software was used to manage and code data into themes. Fourth, the themes were reviewed to ensure they accurately represented the data. Fifth, the themes were defined and linked to the RQs. For example, the theme “understanding” was defined. Finally, the most frequent themes were discussed, the frequency of each theme was identified, and examples were included from the collected data (Braun & Clarke, 2012). When analyzing the data, the participants’ words and beliefs were compared to those in the current literature.

## RESULTS AND DISCUSSION

This section details the findings and discussions from the teacher interview and student surveys, structured to address the RQs about MangaHigh’s role in enhancing mathematical understanding and the perceptions of its influence on teaching and learning.

### Teacher Interview

Responses from the teacher interview were coded to address the following RQs: What role does MangaHigh play in enhancing year 6 students’ understanding of mathematics? How do the year 6 teacher and students perceive the influence of MangaHigh in the teaching and learning of mathematics? The analysis revealed two main themes: “Understanding” and “Technological pedagogical selections”. A “benefits” sub-theme emerged across both main themes, including building skills (5), meeting students’ needs (5), engagement (9), and enhancing online teaching (12) and learning (10). An overlapping “affect” sub-theme highlighted motivation (3). A third sub-theme, “negative effects”, included limited topic coverage (2), and technical issues (2).

### Understanding

The teacher emphasized that MangaHigh supports understanding through staged skill developments, a view reinforced by student comments. One girl noted that the tasks provided useful information for building mathematics skills. In addressing **RQ1**, the teacher indicated that MangaHigh supports understanding of selected concepts (e.g., addition, multiplication, and division), although it does not cover all areas of mathematics. The first subtheme, “**building skills**,” is illustrated in the following teacher comment:

You’re developing a skill within them, then they can apply that skill. They get one or two tasks of addition, multiplication, or division. It starts very basic, it entices them to come back to it, then as they go through each question, it just builds up their skills, challenging them more and more.

The teacher noted that MangaHigh creates a challenging environment, which encourages students to strive for the correct answers. The following response reflects the subtheme of “**motivation**” in terms of understanding:

The more you get right the more challenging it becomes. They keep going until they kind of get through it, that's what I love about it.

The following comments addresses the role of MangaHigh in understanding mathematics, specifically the subthemes of “**information retention**” and “**activation of prior knowledge**”. The teacher explained that MangaHigh helps students review and consolidate classroom learning at home, while in class it engages students by activating prior knowledge. These subthemes are illustrated in the teacher's response below:

Through MangaHigh, we ask students to go home and review what we've taught them to consolidate their learning and retain the information. Sometimes it's pulling out a times tables lesson as a wake-up lesson to engage them. Or a simple game for activating prior knowledge.

These findings align with research suggesting that online mathematics games can enhance student engagement and reinforce learning (Attard & Northcote, 2011). Similarly, technology integration in mathematics classrooms can support students' engagement with mathematical tasks and help them recognize the usefulness of mathematics (Attard & Holmes, 2020).

The next subtheme addresses the limitations of MangaHigh. The teacher noted that students primarily use it for homework, because it does not cover all year 6 mathematics topics. This subtheme is referred to as “**limited topic coverage**”. The following response illustrates this concern:

Students use MangaHigh only for homework because it doesn't complete the stage outcome for year 6. For perimeter, area, composite shapes, or order of operations, we use worksheets, for example, K5 Learning online or Mathletics. The activity isn't challenging as we want, and some questions don't have explanation, it would be good to have that.

Consistent with findings from other technology-enhanced learning environments, this study suggests that MangaHigh is utilized within specific teaching and learning contexts. As a result, the types of educational resources a teacher employs may vary (Koehler et al., 2013).

### **Technological pedagogical selections**

This section outlines subthemes related to teachers' perceptions of MangaHigh's influence on mathematics teaching. The teacher reported that Smartboard use increased student engagement and supported conceptual understanding. The importance of balancing online and paper-based learning was also emphasized. These findings are consistent with Hilton (2018), who found that teachers believe iPad applications should not be used exclusively in mathematics lessons and that students require multiple ways to demonstrate understanding. Similarly, Attard and Northcote (2011) argued that effective ICT integration in mathematics education requires a balance that enhances engagement without distracting from learning.

In addressing **RQ2**, the teacher described MangaHigh as an influential tool in teaching mathematics and learning, particularly for supporting challenging topics and exam preparation. During exam periods, targeted tasks were assigned to address specific learning needs, and one participating girl also reported that MangaHigh was beneficial when studying for examinations. This subtheme is referred to as “**enhance online teaching**.” The following statements from the teacher exemplify this subtheme:

We use problem-solving strategies to engage the kids using PowerPoint and the Smartboard, getting them to answer questions on the board and then in their books. Using YouTube clips is effective, and they must take down notes and understand what they are doing. I especially get the quiet ones up because sometimes they don't know how to do it but won't say it.

The work we do in the classroom is paper-based and hands-on. There should be strong integration between online and paper-based learning, but not one more than the other. The programs are customized and reflected in their workbooks to support whole student development. MangaHigh is as effective as other online programs.

My students struggle with problem-solving, multiplication, and addition using formal algorithms. I call MangaHigh my little helper in the background, especially during exam time.

This finding is consistent with Muir's (2014) study, which found that online mathematics resources can support independent revision and exam preparation. In this context, the teacher's comment suggested that MangaHigh serves as a metaphorical partner in learning (Goos et al., 2003).

The teacher observed that MangaHigh supports differentiated learning, reflected in the subthemes "**meeting students' needs**" and "**enhance online learning**". These subthemes are illustrated in the following statement:

The homework we assign is through MangaHigh. A lot of students say they enjoy it. Every child goes at their own pace, which is a good thing. Differentiated learning is what we must provide, and we can meet students' needs through an online numeracy program. Even though they're in year 6, they could learn year 7 content. MangaHigh is open to all stages.

These responses highlight the impact of technological pedagogical choices on student engagement in mathematics. The teacher emphasized that technology is essential in the digital world and that MangaHigh promotes engagement through GBL. This sub-theme is referred to as "**engagement**" and is illustrated in the following statements:

Technology keeps students engaged because we're living in a tech-savvy world. We need to embed that in teaching and learning. If we distance technology from learning, students won't see education and technology working hand in hand. These kids may find picking up a book foreign, but put it digitally and they'll read it. It must be in every classroom.

Especially in math, many of my students are kinesthetic, visual learners. Through our online program, we allocate games. Game-based learning gets students engaged and responding. When students are stressed, or during exams, I change my approach and put on two math games, they think it's homework, but it's a game.

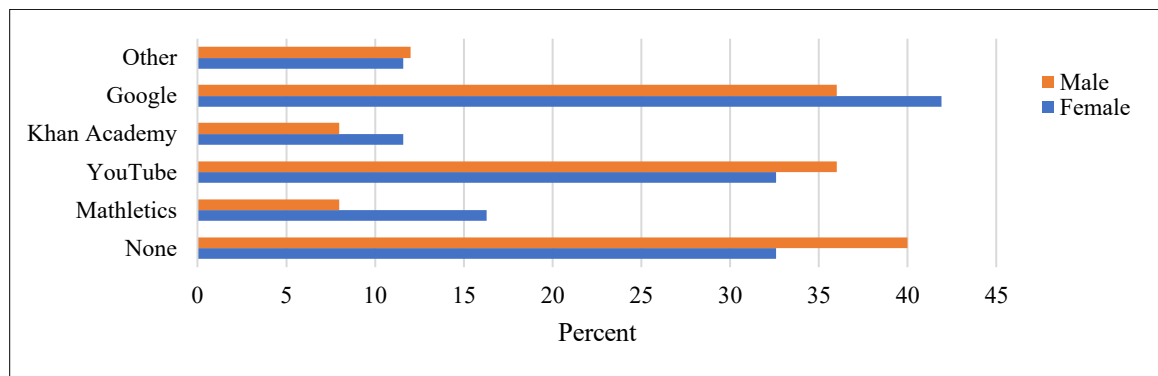
These findings align with Hilton (2018), who suggested that iPad applications can positively influence students' engagement and attitudes towards mathematics. However, Darragh (2021) argued that online programs can result in either highly engaged or weak learners in mathematics.

The data generated by MangaHigh provide feedback and detailed progress reports on students' understanding, which can be shared with parents. The teacher explained that after assigning tasks, students are given time to complete them, and the resulting data are used to monitor achievement. This subtheme is referred to as "**collecting data for educators**," and is illustrated in the following teacher responses:

Once you allocate the task, you give them time to do it. That data tells you how many times they attempted it. We need them to do their homework, to make sure they do well in class. When students don't complete it, this online component falls behind. It also pulls out the top students by giving them recognition; you did this four times and earned a gold.

These findings are consistent with Goos et al. (2017), who indicated that technology could provide instant feedback that supports learning. Additionally, Van de Walle et al. (2019) emphasized the importance of integrating technology with effective pedagogy to evaluate mathematical understanding.

These responses highlight challenges associated with using technology. The teacher reported login difficulties and technical issues that prevented students from accessing MangaHigh. One participating boy described unexpected system errors that required restarting tasks, while another girl reported being logged out during use. The teacher also identified limited control over online content as a potential source of distraction. These issues form the subthemes "**technical issues**" and "**topics cannot be controlled online**," illustrated in the following teacher responses:



**Figure 1.** Online mathematics learning resources by gender (Source: Created by the authors)

We've had multiple issues where students can't log in to MangaHigh because the server was down, or their username and password weren't working. That's a big challenge, along with technical issues when the website doesn't open, especially when it's important to work.

When they get a question, they're a bit alarmed. Just because I didn't tell you about it doesn't mean it doesn't exist. These kinds of questions cannot be controlled. Students are exposed to a lot online, and we want to protect them. That's what throws them off; they sit on it and ask, 'but why?'

### Student Survey

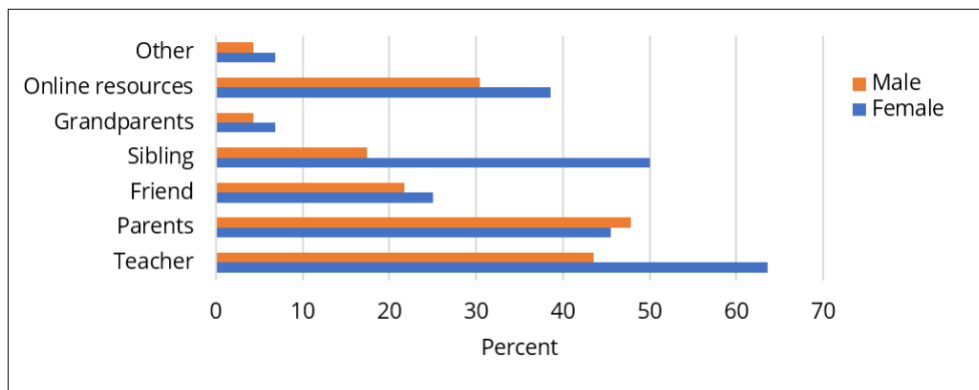
Survey responses from 45 female and 26 male students were analyzed in relation to the following RQs: What role does MangaHigh play in enhancing year 6 students' understanding of mathematics? How do the year 6 teacher and students perceive the influence of MangaHigh in the teaching and learning of mathematics? The results included both quantitative and qualitative data, with comparisons between girls and boys.

#### Quantitative data

All students reported having internet access at home. The results showed a small gender difference in the devices used to access MangaHigh, including tablets (e.g., Samsung, Lenovo, and Google) and desktop/laptop computers. Only 4.3% of participants ( $n = 3$ ) reported using smartphones. Although a higher proportion of boys (64%) preferred online mathematics homework than girls (41.9%), the difference was not statistically significant,  $\chi^2(1, N = 68) = 3.10, p = .078$ .

Most students reported using MangaHigh for 0-1 hour daily (70.5% of girls; 76% of boys), consistent with its primary use for homework. Two girls reported not using MangaHigh, suggesting incomplete homework and a need for additional support. A smaller group used MangaHigh for 2-3 hours per day (25% of girls; 24% of boys). Overall, there was a small descriptive difference between girls and boys in daily usage time. A chi-square test of independence showed no significant difference between gender and daily MangaHigh usage,  $\chi^2(2, N = 69) = 1.20, p = .549$ . Due to small frequencies in some categories, "more than 3 hours" and "not using MangaHigh" were combined for the chi-square analysis.

**Figure 1** presents gender-based data on the use of online resources, including MangaHigh, for learning mathematics. The resources included "Mathletics," "YouTube," "Khan Academy," "Google," and other platforms. Google (39.7%,  $n = 27$ ; 18 girls, 9 boys) and YouTube (33.8%,  $n = 23$ ; 14 girls, 9 boys) were the most frequently used resources. The teacher also reported using YouTube clips in class, consistent with Grandgenett et al. (2011), who emphasized offering a range of technologies to support mathematical understanding. However, Google was not mentioned in the interview. The results showed that Mathletics was used by 13.2% of students ( $n = 9$ ; 7 girls, 2 boys). One boy reported valuing its explanations, while seven girls highlighted its strategies and engaging learning approach. The teacher indicated that Mathletics was used when topics were unavailable on MangaHigh, demonstrating strong TPACK through the integration of technology as a learning partner (Goos et al., 2003). Similarly, Muir (2014) found that students accessed Mathletics with teacher guidance, particularly when they experienced difficulty.



**Figure 2.** Comparison of responses to assistance with mathematics by gender (Source: Created by the authors)

As students could select multiple resources, percentages exceeded 100%. Some students reported using Google and YouTube to check answers and access alternative explanations, often valuing their ease of use. Two female students reported using TikTok for its entertainment value. In contrast, 24 students (14 girls, 10 boys) reported not using any additional online resources for learning mathematics.

**Figure 2** presents gender-based percentages of where students sought help in mathematics (multiple-response question). The options included: “teacher,” “parents,” “friend,” “sibling,” “grandparents,” “online resources,” and “other.” Among girls, the teacher was the most common source of help ( $n = 28$ ), followed by siblings ( $n = 22$ ), parents ( $n = 20$ ), and online resources ( $n = 17$ ). The gender of the sibling was not collected and could be explored in future research. Among boys, parents were the most selected source ( $n = 11$ ), followed by the teacher ( $n = 10$ ) and online resources ( $n = 7$ ). A larger proportion of girls selected the teacher compared to boys.

Overall, more students sought help from the teacher ( $n = 38$ ) than from online resources ( $n = 24$ ), consistent with Muir (2014), who found that students preferred teacher support before turning to online support. In total, 97.8% of girls and 88.5% of boys reported seeking help with mathematics. Students who selected “other” mentioned a tutor or a calculator.

**Figure 3** compares students’ Likert scale responses regarding how helpful MangaHigh was for understanding specific mathematics topics by gender. The topics included: “whole numbers,” “integers,” “addition,” “subtraction,” “multiplication,” “division,” “geometry,” and “other.” Not all students indicated that they had used each topic, resulting in varying response numbers (girls: 9-44; boys: 9-23).

Most students reported that MangaHigh was very helpful for addition (22 girls, 10 boys), subtraction (24 girls, 13 boys), and multiplication (26 girls, 11 boys). In contrast, geometry and other topics were rated as least helpful, which may reflect the one-time survey administration.

**Figure 4** presents students’ Likert-scale responses about their views of MangaHigh’s impact on learning mathematics by gender. Most students said they always used MangaHigh for homework (31 girls, 15 boys), in line with the teacher’s requirement.

To explore part of **RQ2**, gender differences in students’ perceptions of MangaHigh were analyzed. Overall, boys in this sample reported greater enjoyment, confidence, and ease of learning with MangaHigh than girls. However, a chi-square test of independence on the statement “I enjoy using MangaHigh to learn mathematics” showed that this difference was not statistically significant,  $\chi^2(2, N = 69) = 4.57, p = .102$ . This outcome contrasts with some previous research suggesting that boys might report more positive attitudes towards technology in mathematics learning (Abidin et al., 2018).

### Qualitative data

In the survey, students provided open-ended responses about what they liked or disliked about MangaHigh and how it helped them understand mathematics. Analysis revealed different themes for boys and girls.

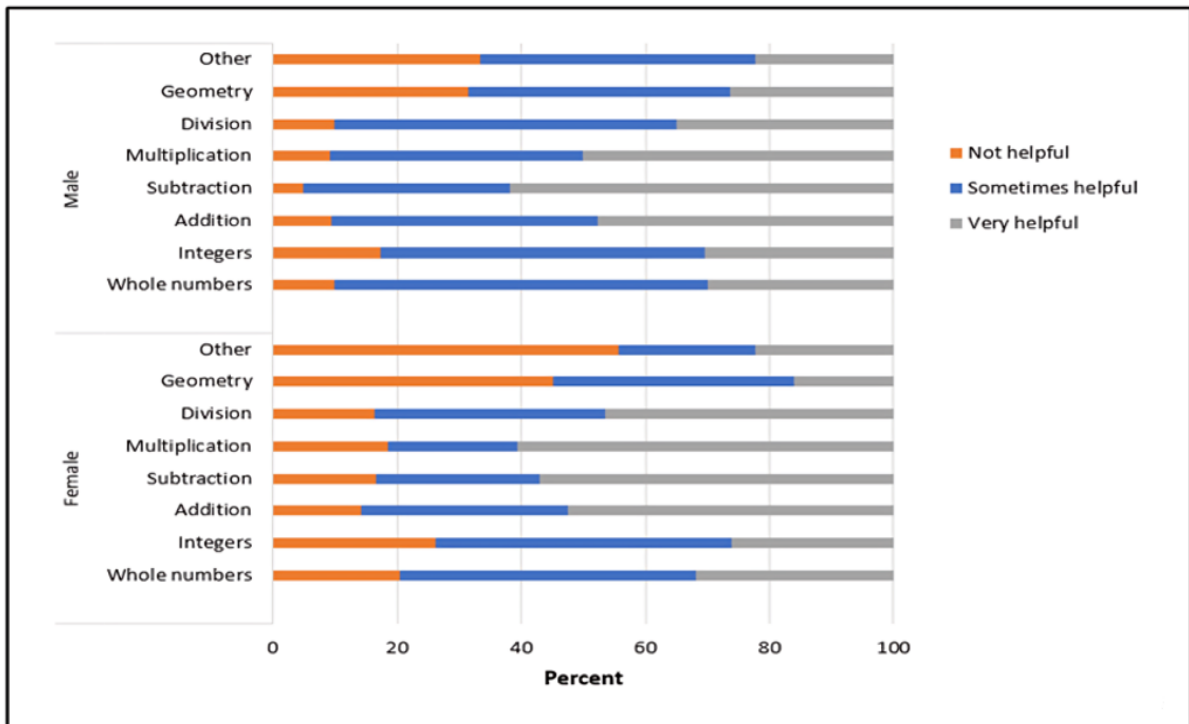


Figure 3. Helpful topics in MangaHigh to understand mathematics by gender (Source: Created by the authors)

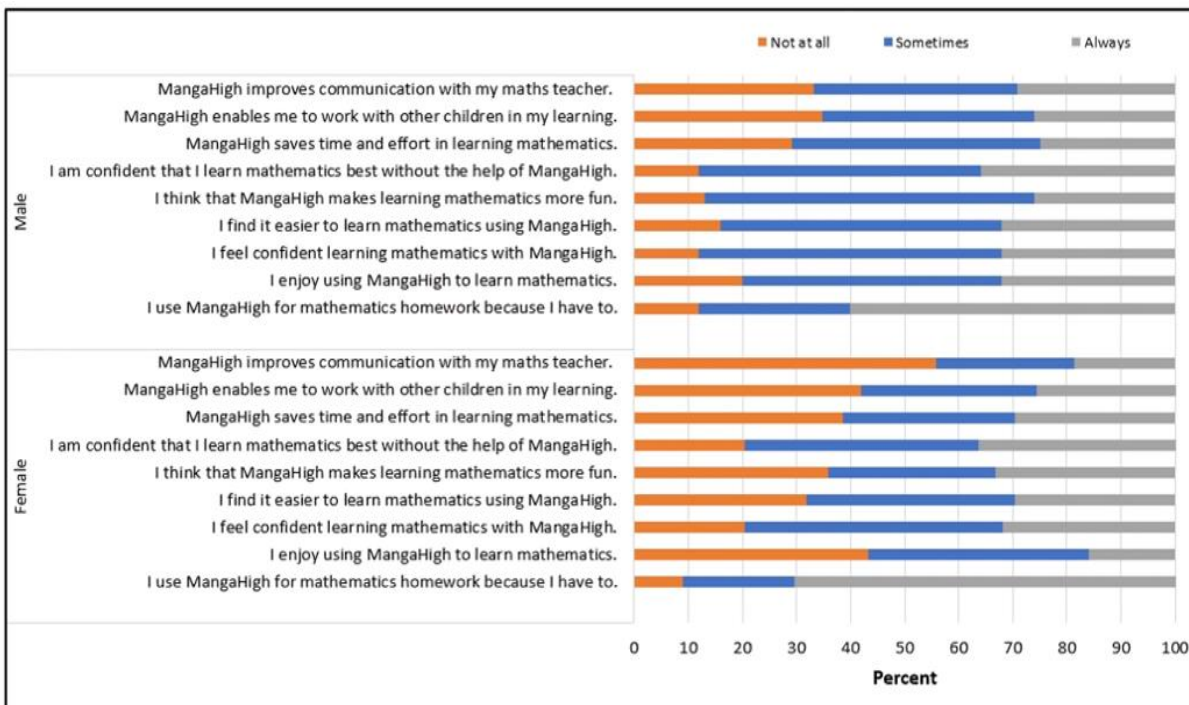


Figure 4. Students' perceptions of MangaHigh's impact on mathematics learning by gender (Source: Created by the authors)

Table 1 summarizes boys' perspectives on using MangaHigh for learning mathematics. Some boys reported that it helped them understand topics such as integers and subtraction. Most boys (n = 19) enjoyed learning through games, while others (n = 8) felt it primarily allowed them to review class material. Approximately half (n = 13) indicated that MangaHigh was not always useful, citing confusing or time-consuming questions.

**Table 1.** Common themes of the survey analysis: numbers indicate how often themes were referred to and some responses for boys (n = 26)

Theme	F	Examples
Understanding	9	<ul style="list-style-type: none"> <li>The integers and subtraction were most helpful because they would help me throughout the activity.</li> <li>It is very helpful because sometimes I do not know a specific topic, and it could help me to acknowledge it.</li> </ul>
Learn with fun mathematics games	19	<ul style="list-style-type: none"> <li>MangaHigh provides interactive, educational games that help me excel in basic mathematics. They are very fun, so I am more engaged in them than in normal worksheets.</li> </ul>
Motivation	6	<ul style="list-style-type: none"> <li>It helps encourage you to do more and get a better medal.</li> </ul>
School recommendation	6	<ul style="list-style-type: none"> <li>It is a school-mandatory homework.</li> </ul>
Revision/no explanation	8	<ul style="list-style-type: none"> <li>The topics didn't help me to learn things; it was just a great website to revise the topics learned at school.</li> </ul>
Confusing questions/time-consuming	13	<ul style="list-style-type: none"> <li>They would sometimes get me mixed up.</li> <li>It is not too helpful because the questions sometimes are non-understandable for me. Questions take too long.</li> </ul>
Teaching mathematics	3	<ul style="list-style-type: none"> <li>It teaches maths in a great way.</li> </ul>
Hints and solution	4	<ul style="list-style-type: none"> <li>If you get a question wrong, it will show you the solution.</li> <li>I do not like how MangaHigh has hints and free answers.</li> </ul>

Note. F: Frequency

**Table 2.** Common themes of the survey analysis: numbers indicate how often themes were referred to and some responses for girls (n = 45)

Theme	F	Examples
Understanding	24	<ul style="list-style-type: none"> <li>It helps me understand and shows me a video for better understanding.</li> <li>MangaHigh was not helpful in geometry because it barely explains what to do even if you press hint, it tells you, but you would not understand.</li> </ul>
Learn with fun mathematics games	14	<ul style="list-style-type: none"> <li>I like how the games educate me in a fun way.</li> <li>You can play math games. Also shows how you can improve and my mistake.</li> </ul>
Motivation	5	<ul style="list-style-type: none"> <li>I like the timetable games because the more timetables you get right, the smarter I get.</li> <li>I loved that MangaHigh made a multiplication/division game where we could compete with others.</li> </ul>
School recommendation	6	<ul style="list-style-type: none"> <li>It is homework and I am required to do it each week.</li> </ul>
Revision	5	<ul style="list-style-type: none"> <li>I like that it strengthens your prior knowledge a lot.</li> </ul>
Confusing	14	<ul style="list-style-type: none"> <li>They don't teach us how to play the games.</li> <li>The questions aren't what I learnt.</li> </ul>
Time-consuming	7	<ul style="list-style-type: none"> <li>Sometimes I don't like MangaHigh because it glitches and confuses me about what tasks I completed.</li> </ul>
Easy online learning	14	<ul style="list-style-type: none"> <li>It is easier to do than homework on paper.</li> <li>It is very easy and convenient to learn math at home.</li> </ul>
Feedback	3	<ul style="list-style-type: none"> <li>Helps me understand what I did wrong.</li> </ul>
Boring	9	<ul style="list-style-type: none"> <li>It is very boring and complicated.</li> </ul>
No explanation	4	<ul style="list-style-type: none"> <li>It is not explaining the topic.</li> </ul>

Note. F: Frequency

**Table 2** summarizes girls' views on using MangaHigh for learning mathematics. Some girls said it helped them with addition, subtraction, multiplication, and division, and supported their understanding even without explanations. As the teacher noted, tasks start with basic ideas and gradually develop skills. Less than half of the girls (n = 14) enjoyed learning through games and found MangaHigh easy to use. However, some girls (n = 14) said it was confusing, boring, time-consuming and offered no explanations.

As shown in **Table 1** and **Table 2**, 53% of girls reported understanding, compared to 35% of boys. In contrast, 73% of boys believed that MangaHigh had an impact on learning mathematics, compared to 31% of girls. Most boys (n = 19) and some girls (n = 14) described MangaHigh as fun and interactive. These findings support Howard and Crotty (2017), who found a positive relationship between MangaHigh and student motivation, and with Loong and Herbert (2018), who reported a link between enjoyment and understanding in mathematics. However, 31% of boys noted that MangaHigh provided no explanations, compared to 9% of girls.

This study highlighted several benefits of GBL using technologies like MangaHigh. First, students remained engaged through gradually more difficult tasks, and the teacher observed that the challenge level motivated them to persist. Second, competitive features such as class rankings, certificates, and awards may motivate students to score higher and potentially lessen mathematics anxiety, with one boy saying, "It helps me compete with others to be first in class." Third, repeated practice promoted ongoing improvement, as one girl mentioned that MangaHigh offered "extra tasks for understanding the topics better." The platform also seemed to foster strategic thinking through interactive games. Lastly, progress tracking allowed the teacher to monitor student achievement and plan lessons more effectively using data on attempts and results, like gold, silver, or bronze medals. Overall, the findings contribute to primary mathematics education by highlighting how specific technologies may enhance student learning and influence pedagogical approaches.

### Limitations of the Study

The limitations of this study include a small sample size, participants from only one school, and data collected at a single point in time. Additionally, all year 6 classes are taught by the same teacher, who seemed very knowledgeable about how MangaHigh can assist students in understanding mathematics. There was also no opportunity to interview the students due to the limited data collection period. While the findings might be relevant to similar Australian primary school contexts due to the shared mathematics curriculum, they should be viewed with the limitations of this case study in mind. In particular, the gender comparisons reported should be interpreted cautiously, as they pertain to a single classroom and are not generalizable. Future research could examine the long-term impacts of specific GBL platforms on student outcomes and attitudes, compare the effectiveness of different GBL design principles across diverse school settings, and explore the factors affecting student engagement with GBL, including gender, prior achievement, learning preferences, and socio-cultural background. Further studies could also focus on how to best support teachers in developing the necessary TPACK for integrating GBL into a balanced mathematics curriculum and assess the potential of adaptive learning algorithms to personalize instruction and cater to individual student's needs.

### CONCLUSION

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The research results indicated the role of MangaHigh in students' understanding of mathematics, as it helps them grasp selected mathematical concepts such as addition and multiplication. The teacher successfully integrated content, pedagogy, and technology, aligning with the TPACK framework. Using GBL platforms such as MangaHigh, along with effective teaching strategies, made mathematical concepts more engaging and easier to understand.

The students in this study used MangaHigh to complete their homework, and the data showed that most students rated MangaHigh as very helpful or sometimes helpful in supporting their understanding of mathematics concepts in their classroom learning. However, this support varied across different mathematics topics and between students. Harrison and Lee (2018) stated that using GBL technology to learn mathematics helps students communicate their understanding with others.

There were common themes describing the role of GBL technologies, including MangaHigh, in understanding mathematics, such as building current skills and supporting engagement in learning. In this study, more boys than girls perceived MangaHigh as an effective technology for enhancing fun and confidence in mathematics learning. However, the quantitative analysis indicated no statistically significant gender differences in students' use of or attitudes toward MangaHigh, suggesting that the platform may support mathematics learning similarly for both boys and girls within this classroom context.

As participants mentioned, most MangaHigh questions lack explanations, so students sometimes prefer other resources that provide them. Overall, the results indicated that GBL technologies can influence mathematics teaching and learning by providing a motivating, game-based environment that engages students and supports practice with difficult topics.

This research investigated students' use of GBL technology in learning mathematics and teachers' reflections on its use in teaching mathematics, which may provide useful insights for teachers' professional development. The findings may also inform school administrations about ways to use GBL technology

effectively in the classroom. Further research is needed to evaluate the role of similar digital platforms in supporting mathematics teaching and learning in primary education.

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**Data availability:** Data generated or analyzed during this study are available from the authors on request.

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