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iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 19 No. 7 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijim.v19i07.48377

PAPER

Smart Mobile Technologies in Math Education: Improving Elementary Students' Mathematical Communication Skills

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ABSTRACT

Despite mathematics being a mandatory subject in elementary schools worldwide, it is often taught using traditional methods that emphasise rote memorisation, frequent homework assignments, and retention. These approaches can feel monotonous and tiresome for 21st-century students. This study investigates the use of interactive technology in selected elementary school math classrooms to explore its potential for enhancing students' mathematical communication skills. The integration of technology in teaching methods has the potential to improve academic performance and foster excellent mathematical communication proficiency. Data were collected through a questionnaire administered to 30 fourth-grade students from two public elementary schools. The findings indicate that teachers recognise the significant role of interactive technologies in enhancing elementary students' mathematical communication skills. Furthermore, participants demonstrated improved abstract communication and comprehension following the implementation of interactive learning sessions. The results highlight a clear positive impact of technology on students' mathematics learning, particularly when applied in hands-on learning environments. Overall, the study concludes that incorporating interactive technologies in math education is more effective than traditional teaching methods, leading to higher academic performance, a deeper understanding of mathematical concepts, and improved student communication skills.

KEYWORDS

interactive learning, mobile technology, math education, mathematical communication skills

1 INTRODUCTION

Education must address the 4C competencies (collaboration, communication, creativity, and critical thinking) prevalent in the 21st century. For instance, teachers and students strive to acquire proficiency in this learning skill in an educational setting such as school. One of the four competencies is specifically communication. The term

Pasani, C.F., Amelia, R. (2025). Smart Mobile Technologies in Math Education: Improving Elementary Students' Mathematical Communication Skills. *International Journal of Interactive Mobile Technologies (iJIM)*, 19(7), pp. 159–177. https://doi.org/10.3991/ijim.v19i07.48377

Article submitted 2024-02-05. Revision uploaded 2024-11-23. Final acceptance 2024-11-23.

"mathematical communication" is commonly associated with mathematics. The National Council of Teachers Mathematics (NCTM) identifies five key competencies in mathematics learning: mathematical problem solving, mathematical communication, mathematical reasoning, mathematical connections, and mathematical representation [1]. In today's fast-paced world, possessing reasoning skills is essential for coping with the demands of life. As a result, mathematical literacy goes beyond crucial reading, writing, and arithmetic [2].

National Council of Teachers Mathematics defines mathematical communication abilities as conveying mathematical concepts using written language, verbal expression, or visual representations such as images and graphs [3]. When students articulate their thoughts verbally or in written form, it enhances their understanding and clarity of those concepts. Additionally, it allows other students to receive and absorb the knowledge [2], [4], [5]. The current cohort of students in the discipline exhibits a somewhat poor level of mathematical communication abilities on average. Students know the outcome and can provide the correct answer when presented with a mathematical issue. However, they have challenges when it comes to articulating the sequential processes or procedures involved [6]. That is due to a lack of instruction and practice in mathematical communication skills among teachers and students during the learning process. This incidence is further corroborated by the research conducted by Yuniarti, which indicates that students' proficiency in articulating their ideas is still deficient because of challenges in expressing their thoughts [7]. The accomplishments of Indonesian pupils are currently unsatisfactory and necessitate enhancement in the educational procedure.

Deviating from conventional methods of instructing and acquiring mathematical knowledge is a crucial part of the elementary school syllabus of the contemporary dynamic society. Teachers must empower their pupils to be responsible users of technology in all parts of life due to the rapid advancement of technology [8], [9]. The present era necessitates the upcoming generation to abandon traditional methods of learning knowledge, such as repetitive classroom exercises, continuous practice, and memorising [10], [11], [12]. To effectively teach in the twenty-first century, it is essential to provide students and teachers with suitable classroom materials, including but not limited to the Internet, video, print, media, and television.

The use of interactive technologies in mathematics education holds the potential to significantly enhance students' communication skills, beginning in elementary school and continuing through higher levels of education. Research indicates that technology can foster logical thinking and communication skills if it is integrated effectively by teachers and students to reinforce the understanding and acquisition of new mathematical concepts and skills [13]. However, this potential can only be fully realised when technology is not seen as the goal of instruction but rather as a tool to support and enrich the learning process [14], [15], [16], [17].

Despite these promising insights, the challenge remains: many mathematics classrooms, especially at the elementary level, still rely on traditional instructional methods that may not adequately engage students or promote the development of critical communication skills. As the 21st century calls for adaptive and collaborative problem-solving abilities, there is a pressing need to bridge the gap between technology's potential and its actual usage in the classroom. Previous studies support this shift, highlighting that technology-facilitated learning experiences can improve students' problem-solving abilities, reasoning, and understanding of mathematical concepts [13], [17], [18]. These improvements lead to a deeper comprehension of the subject matter, yet the practical implementation of interactive technologies remains inconsistent.

The growing body of research on technology integration in mathematics education underscores the importance of using engaging, interactive technological tools to explain complex topics effectively. For instance, Murdiyanto illustrates in Edutopia how students can actively engage with technology to deepen their understanding of mathematics [19]. As other studies show, technology-supported collaborative learning can boost students' problem-solving skills, flexible thinking, and communication abilities [20], [21].

In addition, Hillmayr's exploration of specific math technology tools underscore the diverse ways technology can support mathematics communication [22]. Examples include Sumdog, an interactive tool with mathematical activities; Google Classroom, which promotes collaboration and classroom management; Haiku Deck, which empowers students to create personalised presentations; Plickers, a formative assessment tool for classrooms where students may lack individual devices; and Popplet, a resource for capturing and organising ideas [22]. These examples illustrate that interactive technologies provide numerous pathways to enhance students' mathematical communication skills from elementary levels onwards.

This study seeks to build on these findings by exploring the impact of interactive technology on elementary students' mathematical communication abilities. It focuses on how technology can be harnessed to support communication in mathematics classrooms, promoting a better understanding of mathematical concepts and an enhanced capacity to communicate and collaborate on complex ideas. Through this research, we aim to elucidate the essential role of interactive technology in improving math communication skills among elementary school students, ultimately contributing to more engaging and effective mathematics education.

The study poses the following research questions:

1. How do male and female students use digital mathematics and mobile communication technology?
2. What is the significance of digital cell phone communication in acquiring mathematical knowledge?
3. What is the use and frequency of cell phones for male and female students?
4. What are the advantages of using cell phone communications in teaching mathematics?

2 LITERATURE REVIEW

2.1 Mathematical communication skills

Mathematical communication involves expressing, interpreting, and debating mathematical ideas using appropriate language, symbols, diagrams, and reasoning. It is a critical component of mathematical literacy and an essential skill for problem-solving and collaboration. The NCTM highlights its importance in fostering deep understanding, as students must articulate their thought processes, justify solutions, and critique the reasoning of others [23]. Recent research has shown that interactive technology can enhance mathematical communication [24], [25]. For instance, digital whiteboards and collaborative apps like Google Jamboard enable students to present their work visually and share ideas with peers, facilitating dialogue and feedback. Tools like dynamic geometry software and simulation apps also support exploratory learning, encouraging students to construct and communicate their understanding of mathematical concepts. Researchers note that these tools improve communication and foster creativity and critical thinking [26].

A literature review reveals the multifaceted nature of mathematical communication and the evolving role of interactive technology in mathematics education. Mathematical communication encompasses various methods for expressing and understanding mathematical concepts, including oral, written, visual, and symbolic forms. These methods facilitate the comprehension of mathematical concepts and the development of logical reasoning and problem-solving abilities [27], [28]. By engaging in mathematical communication, students deepen their understanding and learn to construct rational arguments, express mathematical ideas, and utilise symbols effectively, which is essential for mathematics education from elementary school through higher levels [29], [30], [31].

A key component of mathematical communication involves oral expression, which enables students to articulate mathematical ideas clearly, and visual communication, often through graphs and diagrams, supports conceptual understanding [29]. Additionally, written communication helps students document the steps in solving problems, while symbolic communication involves mathematical notation, facilitating efficient problem-solving. According to the NCTM, students' mathematical communication skills should include expressing mathematical ideas verbally, in writing, and visually. Proficiency in using mathematical language, symbols, and structures to describe relationships and analyse mathematical concepts is critical for effective learning outcomes [29], [32].

Standards set by NCTM outline that from elementary school through grade 12, students should develop mathematical communication skills that enable them to (1) organise and integrate mathematical thoughts through clear and effective communication, (2) analyse and evaluate mathematical reasoning, and (3) use precise mathematical language to articulate concepts accurately [28]. However, traditional mathematics instruction often falls short of these standards by relying heavily on rote memorisation and procedural learning, which can limit students' opportunities for meaningful engagement and communication.

In recent years, interactive technology has been recognised as a transformative tool for enhancing mathematical communication and engagement in the classroom. Sarifah's research highlights the potential of technology, particularly mobile devices, to support interactive and collaborative learning experiences in mathematics classrooms [33]. Mobile communication tools, as accessible and convenient technologies, provide opportunities for students to engage more deeply in learning, enhance communication with peers, and collaborate efficiently with minimal expense. These devices, which are portable and widely available, enable rapid communication and immediate feedback, making them well-suited for classroom use, especially in settings where resources may be limited [34], [35].

While the literature underscores the positive impact of technology on mathematical communication, several challenges remain. First, the successful integration of technology in mathematics education requires that both teachers and students have the skills and knowledge to use these tools effectively. Additionally, technology should be viewed as a support and enhancement to learning rather than an end in itself [29], [30], [31]. When thoughtfully implemented, technology can facilitate interactive learning experiences that encourage students to express their mathematical ideas more freely, engage in collaborative problem-solving, and develop a firmer grasp of mathematical concepts.

In summary, interactive technology has the potential to address the limitations of traditional mathematics instruction by fostering a more dynamic and communicative learning environment. Nevertheless, this potential can only be realised when technology is integrated purposefully and used to complement other forms of mathematical communication, ensuring that students not only learn to solve problems but also communicate and reason effectively within the field of mathematics.

2.2 Digital mobile communication technologies

This literature review comprehensively examines the benefits, complexities, and potential challenges of integrating mobile and interactive technology in educational contexts, specifically in mathematics learning. Interactive technology refers to digital tools and platforms that enable active engagement, collaboration, and personalised learning experiences. Its role in education has been widely studied, particularly for its ability to transform traditional teaching methods into dynamic, student-centred approaches. Researchers like Vroom and Walkington found that interactive technologies, such as mobile apps, virtual simulations, and gamified platforms, enhance learning outcomes by providing immediate feedback, fostering engagement, and catering to diverse learning styles [36], [37]. These tools are particularly effective in mathematics education, allowing learners to visualise abstract concepts, manipulate variables, and explore real-world applications. For example, programs like GeoGebra enable students to interact dynamically with geometric figures, while collaborative platforms like Padlet support group problem-solving tasks [38].

The global trend toward open access to information has pushed telecommunications and mobile industries to prioritise accessible, cost-effective communication, transforming mobile devices into essential tools for personal and academic communication worldwide [39], [40]. Indonesia, like many other nations, has witnessed a significant shift from landlines to mobile phones, with mobile devices becoming increasingly accessible and multifunctional, providing platforms for voice and multimedia communication, social media, and academic collaboration tools such as WhatsApp, Google Duo, and Facebook [10], [41].

In the educational context, mobile devices offer numerous benefits. They provide students and educators with flexible communication options, enabling interaction inside and outside the classroom. This extended accessibility fosters an active and collaborative learning environment, as teachers can engage with students beyond scheduled lessons, and students can collaborate on learning activities at their convenience. Studies suggest this dynamic can improve students' comprehension, retention, and communication of mathematical concepts [42]. However, some researchers question the broader social implications of this trend, raising concerns about the impact of technology on face-to-face interactions and social cohesion [10], [41].

On the positive side, research by Neves [43] and Kim et al. [44] indicates that social networks, as interactive technology, foster social relationships by enabling meaningful interactions within communities. These networks encourage collaboration, support, and knowledge sharing, which can be advantageous in educational settings, particularly in mathematics learning, where communication of concepts is critical. Social networks facilitate the exchange of information, thereby enhancing collective problem-solving and concept comprehension among students.

Further studies highlight the potential of interactive technologies to support cooperation and communication on a broad scale, which is valuable for academic purposes [45]. Lengacher [46] and Licoppe [47] found that phone-mediated communication can have effects comparable to direct, in-person interactions. For instance, students benefit from deeper engagement through digital communication channels that allow them to interact with classmates, teachers, and even family members, thereby building supportive learning networks that improve mathematical communication skills.

Despite these promising outcomes, several studies critique the effectiveness of these technologies by questioning their implications for social relationships and traditional methods of interpersonal communication [48]. While mobile and digital communication can provide additional support for collaboration and concept learning, the literature often lacks a comprehensive exploration of their specific impact on mathematics instruction. Most studies focus on general communication dynamics rather than examining how mobile communication specifically affects learning and comprehension in mathematics [49].

The current study aims to address this gap by investigating the role of mobile phone communication in enhancing mathematical communication abilities [50]. It underscores the potential for mobile technologies to provide elementary students with engaging, collaborative experiences that strengthen their understanding of mathematical concepts [51]. This research also encourages teachers who are hesitant to integrate mobile technologies to view them as tools for enhancing students' engagement with mathematics, particularly in communication-heavy areas such as mathematical reasoning and problem-solving.

The study further draws on theories of social attachment and collaboration, emphasising the importance of interconnections among students and between students and teachers [52]. According to this theory, solid relationships foster trust and academic success, suggesting that students who feel connected and supported within their school community may exhibit higher motivation and performance [53], [54], [55]. This theoretical perspective highlights a key benefit of mobile communication: it supports the development of attachment and trust, which can positively influence academic achievement.

In conclusion, while interactive technology provides significant opportunities for enhancing mathematical communication and collaboration, its successful integration in educational settings remains contingent upon addressing potential challenges related to social cohesion and ensuring that technology use enhances rather than detracts from personal interactions. This study contributes valuable insights to the existing literature on technology in education, serving as a reference for further exploration into how mobile communication can be optimised to support mathematics learning specifically.

3 METHODS

3.1 Research design

This research was conducted using quantitative descriptive methods with a survey approach. The current investigation involved administering a questionnaire survey to gather the data. The participants were students and staff members from two government schools in Banjarmasin. All thirty surveys were delivered and then collected for data analysis. The data was analysed using SPSS Windows Version 17 to perform descriptive and inferential statistics. The survey was conducted with a sample size of 30 participants. The eligibility criteria for participants are limited to students with a mobile phone. Moreover, the study employs a purposive random sampling technique further supported by careful consideration. Purposive sampling is a method where decisions are made based on criteria that are believed to be appropriate for the target population's characteristics [56], [57].

The survey's demographic profile is classified based on gender, age group, nationality, school year, physical distance of the school, and duration of mobile phone use for studying. The male respondents constituted 50% of the total, as did the female respondents (50%). The age group of nine years old had the highest percentage, accounting for 53.3%, followed by the age group of 11 years and above, which accounted for 40%, and the age group of 12–13 years, which accounted for 6.7%. Most of the sample consisted of students who had studied for nine years, comprising 40%. That was followed by students who had studied for over 10 years, accounting for 33.3%. Collaborative learners constituted 60%, and individuals utilising interactive technologies comprised 40%.

3.2 Data collection

The data collection used a 30-item questionnaire containing indicators of mobile communication instruction, as shown in Table 1. Respondents were required to identify their degree of agreement with the statements using Likert's 4-point scale, which contains the following options: 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = highly agree.

Table 1. Sub-variable indicators of instrument

No	Indicator	Question Number
1	The student's capacity to endure without mobile devices.	1, 2, 3
2	The capacity to acquire mathematical knowledge efficiently without a mobile device.	4, 5, 6, 7
3	Frequency of communication with peers regarding mathematics instruction.	8, 9, 10, 11
4	Frequency of telephone communication among students of different genders regarding mathematical education.	12, 13, 14
5	Frequency of receiving calls from peers of the same gender regarding mathematics education.	15, 16, 17, 18
6	They commonly share the content and characteristics of the messages with students or friends while working together on mathematics learning.	19, 20, 21, 23
7	The frequency at which students initiated their initial cell phone communications.	24, 25, 26
8	Advantages of incorporating cell phones in mathematics education.	27, 28, 29, 30

This table clearly guides you through the aspects measured in the study, including the frequency and nature of students' mobile communications and the impact of these interactions on mathematics learning.

In addition to doing research, we assessed the significance of mobile phone communication in teaching mathematics by utilising three specific questions. Is mobile phone communication crucial to your learning? The participants were required to indicate the degree of significance, ranging from 'very significant' to 'not important at all'. The second inquiry pertained to the significance of equipping every student with a mobile device for intercommunication.

The researchers surveyed respondents and asked them to identify how often they send messages or call their classmates daily to investigate the patterns of phone communication among learners and their peers. The researcher also requested that the subjects indicate the frequency at which their peers contacted them and sent them messages. In addition, participants were required to specify the nature of the messages they typically exchange with their collaborating students or friends. Within the same section, the questionnaire asked participants to indicate the frequency with which they started their first mobile phone communication, either by themselves or with their collaborating friend. A final open-ended question was included in the questionnaire to get the respondents' input on the reasons for using mobile phones in math education. The respondents were free to provide their reasons for using mobile phones. The participants had to enumerate five prevalent motives for communicating with fellow students using mobile devices.

The context of data collection, such as whether students felt observed while completing the questionnaire, could affect their responses. Additionally, differences in students' familiarity with mobile technology might lead to varied responses, introducing bias based on prior exposure. Providing clear instructions and creating a neutral, non-intimidating data collection environment can reduce response bias. Collecting additional background information, such as participants' familiarity with technology or educational history, would allow researchers to control for these external factors during analysis.

3.3 Data analysis technique

The data collected in this study were processed and analysed using descriptive statistical methods. Descriptive analysis was used to present general patterns within the data, such as frequency distribution, mean, and minimum and maximum values of the analysed variables. This step allowed the researchers to provide a clear overview of the data's fundamental characteristics before diving into more detailed analyses to examine the relationships between variables [56].

The validity of the questionnaire items was assessed using the Pearson product-moment correlation method and Cronbach's alpha reliability test. Pearson's product-moment correlation was applied to evaluate the validity of the questions—determining how consistently the items in the questionnaire measured the intended concept. Meanwhile, Cronbach's alpha was used to measure the internal consistency of the questionnaire, ensuring that the study's findings were reliable and interpretable.

The data were analysed using SPSS Windows Version 17, which facilitates descriptive and inferential statistical analysis. The software enabled researchers to process the data accurately and efficiently. Inferential statistical analysis was used to test the research hypotheses and determine whether significant differences existed between groups within the data.

Using SPSS Windows Version 17 ensures accuracy in data processing, but errors in data entry or parameter settings could introduce technical bias. Double-checking data entry and involving multiple researchers in the analysis process can reduce errors and enhance objectivity. Cross-verifying results with other software or manual calculations can also increase confidence in the findings.

The researchers employed an independent two-sample Mann-Whitney U test, a non-parametric statistical method, to evaluate the collected data. This test was selected because the data did not meet the normality assumptions, making non-parametric statistical tests a more suitable choice. The Mann-Whitney U test allowed the researchers to compare two independent groups to determine if there was a significant difference between them. The analysis revealed significant differences among students in how mobile phone communication impacted their understanding of mathematical topics. These findings suggest that the use of mobile phones had a noteworthy influence, either supporting or hindering students' comprehension of certain mathematical materials.

4 RESULTS AND DISCUSSION

4.1 Mobile communication technology that has been digitised

Precondition tests are performed prior to conducting inferential statistical tests. A validity test was conducted using the Pearson product-moment correlation method. Initially, 30 items were included, out of which three were found to be invalid. As a result, only 27 statements were considered for scoring. The dependability calculation using the Cronbach's alpha approach yields a value of 0.890, indicating a classification in the very high range.

The researcher used the two independent samples Mann-Whitney U (non-parametric) test to assess the data and discovered significant disparities among the students regarding how mobile phone communication aids their understanding of mathematical concepts. The girl had a higher average rank of 19.83, whereas the man had an average rank of 11.17. The p-value of 0.007 was deemed statistically significant. The calculated value of the Z-test was 2.708, which can be seen in Table 2.

Table 2. The results of the two independent samples of Mann-Whitney U analysis

No.	Student's Gender	Average Rank	P-Value	Z-Test
1	Girl	19.83	0.007	2.708
2	Boy	11.17		

Table 3. The results of the cross-tabulation analysis

No.	Statement	Student	
		Boy	Girl
1	I am unable to survive without a cell phone.	20%	46%
2	I am unable to operate effectively without a cell phone.	60%	46.7%

Table 3 shows cross-tabulation analysis. The researcher saw that girls exhibited higher agreement with the items assessing mathematics cell phone communication than boys, who expressed considerable disagreement with specific issues. Regarding the necessity of a cell phone, 46% of girls strongly agreed that they cannot live without one, compared to 20% of boys who strongly agreed. In contrast, 60% of boys decided they could not function without a cell phone, while 46.7% of ladies agreed.

Suppose mathematics is perceived as a static body of knowledge (mathematical knowledge). In that case, technology can be a proficient instrument to expedite the resolution of mathematical difficulties, such as calculation problems. If mathematics is regarded as an activity involving mathematical operations, technology can serve as an educational tool to assist students in exploring mathematical concepts and their interconnections [33], [58]. That, in turn, enhances students' comprehension of mathematical principles and their ability to communicate mathematically. In their study on integrating technology in mathematics learning, Tezer identified four different ways teachers and students perceive technology in relation to mathematics learning [59]. These conceptions include viewing technology as a master, servant, or an extension of oneself and co-workers.

If students and teachers perceive mathematics solely as understanding mathematical computations, they will regard technology as a superior authority. If individuals see that mathematics extends beyond traditional pen-and-paper activities, technology can be viewed as a tool rather than a replacement for such learning methods. If technology is an integral component of the mathematical activity itself, meaning that technology is included in the mathematical knowledge being studied, then in this scenario, technology will be perceived as an extension of oneself included in the learning material [32]. When teachers and students perceive mathematics as a form of knowledge that can be built upon, they will regard technology as a tool for learning. Technology can help them explore new angles on mathematical concepts, identify connections between different mathematical ideas, and apply these connections to solve a range of mathematical problems [33], [35], [60]. Teach and enhance pupils' comprehension of mathematical concepts. Technology serves as a collaborative tool for students and instructors in elementary schools. Incorporating technology into education should enable students to comprehend and excel in mathematical concepts and communication skills by utilising technology to explore and investigate feedback, patterns, changes, and relationships [59], [61].

4.2 Significance of digitised mobile phone communication in the acquisition of mathematical knowledge

The Mann-Whitney test revealed that the boy group had a significantly higher mean rank of 18.47, whereas the girl group had a mean rank of 12.53. Consequently, the boy strongly believed mobile phone contact was crucial for learning and enhancing collaboration. The p-value of 0.059 did not reach the significance level, indicating no statistically significant differences between male and female students regarding their communication in class. The Z-test value of 1.891 was also observed, as seen in Table 4.

Table 4. Significance of digitised mobile phone communication in the acquisition of mathematical knowledge

No.	Student's Gender	Average Rank	P-Value	Z-Test
1	Girl	12.53	0.059	1.891
2	Boy	18.47		

The perspectives of teachers and students toward mathematics will impact their utilisation of technology in the learning process. Their comprehension of the philosophy of mathematics, including the ontology, epistemology, and axiology components, is crucial in selecting the technology integration model they will utilise for mathematics education. Mathematics is a knowledge system that is constructed and comprehended by the human mind through a series of experiential processes rather than being a pre-existing concept [27], [30], [33], [35]. Therefore, when technology is integrated into learning, its role is most suitable as a collaborator, assistant, or learning aid. In this scenario, incorporating technology should not deteriorate students' comprehension of mathematical concepts or supplant the significance of students' intuition in mathematics. Contrarily, technology integration seeks to enhance students' understanding of concepts and aid in the advancement of mathematics communication abilities among students in elementary school [29], [32], [58], [62].

4.3 Mobile phone usage and frequency

However, the cross-tabulation data indicated that male students had a communication frequency of 60% through messages, whereas female students had a lower frequency. The female students reported a usage rate of 53.3% for digital devices in their daily learning activities. Nevertheless, Table 5 indicated that the p-value of 0.409 did not reach statistical significance. Regarding message reception, the female participants stated a frequency of 46.7% within 3–4 times per day. The boy exhibited a frequency of 40% throughout 3 to 4 times per day.

Table 5. The results of the cross-tabulation analysis

No.	Student's Gender	Average Rank	P-Value
1	Girl	60%	0.409
2	Boy	53.3%	

Regarding the frequency of phone calls between students, boys comprised 73.3% of those who called each other 1–2 times a day, while girls accounted for 66.7% of those who called each other 12 times a day (refer to Table 6). Regarding the frequency of receiving calls from fellow students, ladies reported a rate of 66.7%, while boys reported a rate of 53.3% for 1–2 times per day.

Table 6. Mobile phone usage and frequency

No.	Statement	Student	
		Boy	Girl
1	Frequency of phone calls between students	73.3% (1–2 times a day)	66.7% (12 times a day)
2	Frequency of receiving calls from fellow students	53.3% (1–2 times a day)	66.7%

4.4 Advantages of utilising mobile phone communication in instruction

The respondents' motivations for utilising mobile phones to communicate with others can be summarised as follows: staying informed, expressing emotions, enhancing relationships, acquiring knowledge about new concepts and mathematical formulas, fostering closeness, and sharing personal challenges, such as academic difficulties. Additionally, mobile phone communication is valued for its convenience and ability to provide immediate feedback. This phenomenon can be attributed to the synchronous nature of mobile phones, wherein immediate input can be obtained through calling and messaging unless the recipient's phone is turned off.

Most participants indicated that they maintain proximity, stay informed, and receive information via mobile devices, particularly among students working together on the same task. The results above are partially consistent with the findings of [46], which indicate that mobile communication fosters a sense of intimacy between partners, resulting in desired outcomes such as mutual commitment and improved comprehension, enhancing communication abilities.

Some participants chose not to respond to the open-ended inquiry regarding the rationale behind mobile phone communication in mathematics education. Nevertheless, despite the researcher providing sufficient time for the participants to finish the questionnaire while reviewing the received responses, it was discovered that specific individuals who chose not to respond had not answered the final questionnaire. The many viewpoints on this matter could have assisted the researcher in uncovering the crucial factors behind why interactive technology, such as mobile phones, improves the communication abilities of learners [63], [64].

Another constraint is the diminutive sample size of 30 responders. Generalising the outcomes of this study based on such a limited sample size is challenging. An unequivocal result cannot be deduced; thus, future research can reproduce the identical study by employing a more representative group. Nevertheless, we must acknowledge the significance of this study in contributing to the existing body of work on the utilisation of interactive technology in mathematics education to enhance communication skills [65], [66], [67].

There is no debate about the efficacy of technology in facilitating learning. Multiple studies indicate that students can acquire a more comprehensive, profound, and significant understanding of mathematics when technology is employed suitably during learning [32], [33], [34], [35], [58]. Nevertheless, the problem for teachers and researchers is determining how to utilise technology to construct mathematical learning activities suitably. The effective utilisation of technology in mathematics education entails the application of technology integration concepts in the context of mathematics learning. Technology should not be employed as a substitute for fundamental knowledge and instincts. Instead, it can and should be utilised to cultivate and enhance the knowledge and instincts of students in elementary school education regarding mathematical communication. The fundamental idea of incorporating digital technology in mathematics education is to refrain from employing technology that hinders the development of conceptual understanding and undermines students' mathematical communication skills.

This research brings critical insights into mathematics education by directly addressing a significant gap in teaching methods in Indonesia. While mathematics is a core subject across elementary schools, traditional methods still dominate instruction, emphasising rote memorisation and frequent repetitive tasks. These outdated approaches often fail to engage students meaningfully, especially in a modern educational landscape that demands interactive and critical thinking skills. The study's focus on interactive technology in elementary mathematics classrooms in Banjarmasin, Indonesia, provides a fresh perspective on how contemporary tools can transform learning experiences, making math education more dynamic, accessible, and relevant to today's learners.

The findings hold considerable significance, as they reveal that integrating technology into math education can substantially enhance students' mathematical communication skills—a fundamental aspect of understanding and expressing complex concepts. By shifting the instructional focus from passive memorisation to interactive engagement, the study showcases that students can achieve higher academic performance and develop a deeper, more conceptual understanding of mathematics [1], [68]. Moreover, the data show that when interactive learning sessions are implemented, students demonstrate improved abilities in abstract communication and comprehension, which are essential for progress in mathematics and other analytical disciplines.

Integrating innovative mobile technologies in math education has the potential for transformative long-term impacts, ranging from enhanced mathematical communication skills to broader social and economic benefits. Enhanced mathematical communication skills fostered by mobile technologies can lead to better articulation and understanding of mathematical concepts [29], [69]. Over time, this can improve students' ability to explain and justify their reasoning, which is critical for higher education and STEM careers [70]. Strengthen collaboration and teamwork skills as students learn to collectively share ideas and solve problems. The engaging nature of intelligent mobile technologies help students associate mathematics with positive learning experiences. This sustained engagement can result in a lifelong interest in mathematics and related fields. Incorporating innovative mobile technologies into education could shift societal attitudes toward mathematics, making it more accessible and less intimidating for students [1], [71]. Additionally, these technologies might inspire more students to pursue math-related careers.

This study's contribution extends beyond immediate academic outcomes, offering valuable insights for educators and policymakers looking to modernise education systems in Indonesia and other regions with similar instructional challenges. The research underscores the potential of interactive technologies to act as catalysts for educational reform, bridging the gap between traditional and modern methods and equipping students with the skills necessary to thrive in a technology-driven world. Ultimately, this work enriches the existing body of literature on educational technology by providing evidence of its effectiveness in enhancing academic achievement and crucial communication and problem-solving skills, setting a benchmark for future studies aimed at integrating technology in early mathematics education.

5 CONCLUSIONS AND LIMITATIONS

The results demonstrate that students extensively depend on mobile phone communications, particularly in today's information culture, where they require the most current information from others, friends, and the general situation. The research findings also indicate a notable and favourable influence of technology on students' acquisition of mathematical knowledge, mainly when the chosen technology is employed in a real-world setting. Technology helps them explore new angles on mathematical concepts, identify connections between different mathematical ideas, and apply these connections to solve various mathematical problems. Research has conclusively demonstrated that interactive technology for mathematics education is far more effective than traditional teaching methods. Implementing this technique leads to enhanced academic achievement, heightened comprehension of mathematical principles, and enhanced student proficiency in communicating. This study implies that technology should not replace students' reliance on conceptual understanding and intuition in mathematics. Instead, it should be utilised to enhance their mastery of these concepts and foster the development of their mathematical communication skills during elementary school education.

The demonstrated positive impact of interactive technology offers a valuable framework for future research. One avenue for further study is to investigate which specific types of interactive tools (e.g., mobile applications, visual simulations, and collaborative platforms) are most effective in fostering mathematical communication skills. Researchers could also explore the long-term effects of interactive technology use on students' mathematical abilities as they progress through higher grades. Additionally, studies could examine how technology-based teaching strategies affect other critical learning outcomes, such as problem-solving skills, creativity, and collaboration.

Future research might also focus on broader educational settings, exploring how these findings apply in different regions or socio-economic contexts, thus providing insight into the scalability and adaptability of interactive technology in diverse classrooms. Lastly, as technology continues to evolve, there is ample opportunity to investigate the effects of emerging technologies, such as augmented reality and artificial intelligence, on students' engagement and understanding of mathematics. This study sets a foundation for such exploration, suggesting that interactive technologies enhance academic achievement and play a pivotal role in equipping students with the skills they need for future educational and professional success.

This research is limited in scope, as it only examines two variables: mobile communication technologies and math education. Various elements can impact the dedication to digital learning in mathematics education, including the learning environment, learning style, parental occupation, learning model, family economic conditions, and the emotional bond between teachers and pupils. If this can be implemented within the community, subsequent studies should consider these supplementary aspects.

6 ACKNOWLEDGEMENT

The authors thank the editors of the *International Journal of Interactive Mobile Technologies (iJIM)* for publishing this paper. The Faculty Research Support Fund funded this study.

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