HUMAN, TECHNOLOGIES AND QUALITY OF EDUCATION, 2025
https://doi.org/10.22364/htqe.2025.24

EVALUATING THE IMPACT OF A MOBILE' MENTAL ARITHMETIC' APP ON PRIMARY SCHOOL STUDENTS' MOTIVATION TOWARD MENTAL ARITHMETIC

Elīna Juska-Mirbaha [1]

[1]University of Latvia, Latvia

ABSTRACT

As technology in education becomes a way of everyday life, it is crucial to transform the mindsets of both students and teachers. This transformation is needed to break down prevailing stereotypes that see technology as a source of entertainment or a burden on teachers' work and to raise awareness of the potential of technology as an enabler of engagement and motivation in the learning process, thus potentially contributing to better educational outcomes in the long term.

To contribute to this field, this study analysed the impact of mobile learning on the development of mental arithmetic skills and students' attitudes towards this process by developing a dedicated maths app designed to improve primary school students' mental arithmetic skills. The needs of teachers and students identified in the valid literature were integrated into the app's development, ensuring that the solution meets the needs of both stakeholders and respects key pedagogical principles to maximize students' development.

The study compared pre-test and post-test results to assess the impact of the newly developed mobile app on students' motivational changes while learning numeracy skills. It measured changes in students' attitudes and motivation levels when comparing traditional mental arithmetic methods with the newly developed app.

The results of the surveys and focus group interviews showed that the developed mobile learning app contributes to increased student engagement and motivation while serving as an effective tool for self-directed learning experiences. The expert interview showed that the app's design and content are in line with both the general pedagogical principles and the age range of primary school learners. In particular, the importance of immediate and structured feedback, the possibilities for progress analytics, and the different mental arithmetic strategies were highlighted as contributing to the development of targeted and sustainable skills.

Keywords: *educational mobile app, mental arithmetic, mobile learning, motivation, primary school students*

Introduction

Mental arithmetic is a core component of early mathematics education and serves as a fundamental prerequisite for mathematical reasoning and problem-solving (Anderson et al., 2022; Hickendorff et al., 2019). Longitudinal evidence shows that students who automatise basic number facts facilitates the acquisition of more advanced mathematical concepts and is positively associated with wider academic attainment, including reading comprehension and overall curriculum achievement (Hickendorff et al., 2019; Ten Braak et al., 2022; Sunde et al., 2023). Nevertheless, many students struggle with motivation and confidence when working on mental arithmetic. Traditional classroom routines that rely heavily on repetition, speed-based drills and written assessments can cause discomfort; for some students these methods may foster mathematics anxiety and other negative emotions (Kupferman, 2015; Lloyd, 2016; Bureau et al., 2022; Poçan et al., 2023). Strengthening students' motivation is therefore critical for supporting their progress in mental arithmetic and for realising the wider academic benefits that arise from fluent calculation.

In addition to motivational factors, research emphasises the importance of developing number sense and fostering flexibility in strategy use. Students should be encouraged to understand the internal structure of numbers and to solve the same problem in different ways, choosing the most effective approach for the context (Jay et al., 2019; Proulx, 2019; Sunde et al., 2023). Widely used mental strategies such as splitting numbers into known components, rounding and adjusting, or using doubles support accuracy, fluency, and conceptual understanding (Hickendorff et al., 2019; Sunde et al., 2023). Importantly, digital tools, especially mobile apps that integrate gamified elements and provide immediate feedback, have proven effective in helping students – particularly those with lower initial proficiency – automate facts and apply strategies in an engaging and adaptive environment (Gonçalves et al., 2020; Outhwaite et al., 2019; Kim et al., 2021). However, these tools must be carefully designed: overemphasis on speed or rewards without conceptual depth may foster superficial learning and reduce long-term retention (Baker & Cuevas, 2018; Kim et al., 2021). To build sustainable mental arithmetic competence, learning tools and classroom practices must combine strategic variety, meaningful feedback, and opportunities for metacognitive reflection.

Promoting Motivation in Learning Mental Arithmetic

Motivation is a key psychological driver of learning and achievement, yet it is not a single construct – it comprises a set of interrelated factors that initiate, direct, and sustain goal-oriented behaviour (Schunk et al., 2014). In educational contexts, motivation can be classified as intrinsic, when students are driven by curiosity or personal interest, or extrinsic, when behaviour is influenced by external rewards or demands (Ryan & Deci, 2000). According to self-determination theory (Ryan & Deci, 2000), intrinsic motivation is more likely to emerge when learners experience autonomy, competence, and relatedness. Research has shown that when these basic psychological needs are met, students demonstrate greater engagement, higher academic performance, and more sustained learning behaviours (Bureau et al., 2022; Howard et al., 2021; Schukajlow et al., 2023).

A central component of motivation is self-efficacy – students' belief in their capacity to successfully complete specific learning tasks (Bandura, 1977; Schunk & Pajares, 2009). Self-efficacy influences how much effort students invest, how they cope with setbacks, and how they emotionally respond to challenges. Learners with higher self-efficacy tend to persist longer, adopt more effective strategies, and display greater confidence – especially in mentally demanding areas such as mental arithmetic (Gonçalves et al., 2020; Bureau et al., 2022; Poçan et al., 2023). Bandura (1977) identified four sources that shape self-efficacy beliefs: mastery experiences, vicarious learning through observing peers, verbal encouragement, and the interpretation of emotional or physiological states. When students experience success and feel supported, they are more likely to develop a belief in their ability to improve and succeed.

In this study, the primary focus is on enhancing students' motivation to practise mental arithmetic. Motivation can be fostered through learning conditions that promote autonomy, competence, and a sense of achievement – such as success experiences, informative feedback, and opportunities for choice (Bureau et al., 2022; Howard et al., 2021). These are precisely the conditions embedded in the mobile learning approach used in this research. The mobile app integrates adjustable task difficulty, real-time feedback, and gamified elements that aim to support self-efficacy and engagement. These features are particularly effective for low-achieving students, providing a safe, structured environment in which learners can progress at their own pace (Kim et al., 2021; Herwin et al., 2022). However, existing literature consistently shows that such tools are most effective when integrated into a teacher supported and purposefully designed learning process (Al-Said, 2023).

Conceptualizing Mobile Learning and Creating Pedagogically Aligned Apps

In recent years, mobile technology has been increasingly used in education to address challenges related to student motivation. Mobile learning (m-learning) environments provide flexible access to tasks, engaging visual elements, and timely feedback, which can promote students' autonomy and involvement in the learning process (Çukurbaşi Çalişir et al., 2022; Tang et al., 2023). These features are particularly effective in supporting the emotional side of learning by reducing fear of failure and reinforcing a sense of progress (Poçan et al., 2023; Mohamad Said et al., 2024). Additionally, m-learning encourages self-regulated learning by allowing students to choose when and how to practise. This autonomy not only increases engagement but also supports the development of self-efficacy – a key psychological condition for sustained motivation (Bureau et al., 2022; Gonçalves et al., 2020).

In scientific literature, however, m-learning is interpreted in varied ways – from a mere extension of e-learning offering content access anytime and anywhere (Hernawati & Jailani, 2019; Korucu & Alkan, 2011; Orhani, 2023) to a conceptually distinct pedagogical approach integrated within traditional classroom environments (Marcus-Quinn & Hourigan, 2021; Quan & Zhang, 2024). While older interpretations consider m-learning a subcategory of e-learning, more recent studies argue that it has developed along different technological, social, and conceptual lines and deserves a precise and independent definition (Yan, 2015; Quan & Zhang, 2024). In this study, m-learning is defined as the implementation of technology-enhanced learning in traditional classroom settings using smartphones, tablets, or other mobile devices. It functions as a complement to face-to-face instruction, enriching classroom activities through meaningful technological integration. Importantly, this definition excludes laptops unless they replicate mobile-like interaction patterns, such as touchscreen-based interfaces (e.g., Chromebook devices).

To ensure successful m-learning implementation, educators must consider both its potential benefits and its inherent risks. Among the most frequently cited advantages are increased accessibility to learning materials, the promotion of personalised learning paths, real-time feedback, and significant improvements in student engagement, academic achievement, and motivation (Pedro et al., 2018; Poçan et al., 2023; Tang et al., 2023; T.–H. Wang et al., 2021). For instance, m-learning helps to overcome time and place limitations, supports self-directed learning, and enhances learning opportunities for students in remote areas (Yosiana et al., 2021; Hernawati & Jailani, 2019). Moreover, digital tools provide access to varied resources, including video-based instructions and practice apps, that reinforce student understanding both inside and outside the classroom (Chang & Lin, 2024; Dehbi et al., 2023). The ability of mobile tools to deliver instant and adaptive feedback has also been identified as a central factor in strengthening both self-efficacy and motivation (Poçan et al., 2023; Gonçalves et al., 2020).

Nonetheless, various risks must also be acknowledged. These include cognitive overload, distraction due to entertainment apps and social media, unequal access to devices, varying levels of digital competence among students, technical barriers such as poor internet connection or incompatible devices, and excessive reliance on technology (Çukurbaşi Çalişir et al., 2022; Dehbi et al., 2023; Fombona et al., 2020; Tang et al., 2023). Mobile devices can overwhelm students when used without clear instructional design or when information is presented too densely (Poçan et al., 2023). Similarly, attention may be diverted from academic tasks due to the presence of unrelated apps and notifications (Yan, 2015; Zhang, 2015). The novelty effect has also been observed as high initial engagement that fades if content becomes repetitive (Kim et al., 2021; Schukajlow et al., 2023).

To address these challenges and ensure that mobile apps truly support learning, it is essential to approach their development systematically. Based on a comprehensive review of academic studies, the author has formulated a set of key criteria that must be observed when designing educational apps. These criteria are structured around three interrelated dimensions: content, pedagogy, and technology, in alignment with the TPCK (Technological Pedagogical Content Knowledge) model (Mishra & Koehler, 2006).

From the content perspective, the app must have clearly defined and measurable learning objectives that specify the exact knowledge and skills to be developed. The content should be focused and specific rather than overly broad or general, allowing learners to engage with well-scoped material (Al-Amri et al., 2023; Hernawati & Jailani, 2019; Katayeva, 2023; Outhwaite et al., 2019; Tang et al., 2023; T.–H. Wang et al., 2021). It is also essential that the subject matter is academically accurate and precise, especially in the context of mathematics, where proper terminology, symbolic notation, and theoretical soundness are critical for conceptual understanding (Al-Amri et al., 2023). Furthermore, the content must be logically structured and sequential, with tasks organized by increasing complexity to support gradual learning progression and facilitate self-directed learning (Al-Amri et al., 2023; Gonçalves et al., 2020; Outhwaite et al., 2019).

From the pedagogical perspective, the design must consider the learners' developmental stage, cognitive abilities, and prior experience. Learning strategies should be age-appropriate and tailored to student needs to promote engagement and meaningful participation (Mishra & Koehler, 2006). The app must maintain a balanced cognitive load by aligning the complexity of content, methods, and visual elements with students' working memory capacity. Overloading learners with information or interaction demands can reduce motivation and hinder comprehension (Burke et al., 2022; J. Wang et al., 2023). The provision of immediate and personalized feedback is also essential. This feedback should be delivered in a format appropriate to the learner's level, whether visual, textual, or auditory, and should help them identify errors and recognize their progress (Al-Amri et al., 2023; Yu et al., 2021). In addition, effective motivational strategies should be integrated, such as those based on Keller's ARCS model (Keller, 1987), which emphasizes attention, relevance, confidence, and satisfaction as key drivers of sustained motivation (Al-Amri et al., 2023).

From the technological perspective, the structure of the app must match its pedagogical goals. This may involve either a linear structure, where content is presented in a fixed sequence for cumulative learning, or a modular structure that allows flexible navigation and promotes learner autonomy (Al-Amri et al., 2023; Burke et al., 2022; Farooqi et al., 2024; Joshi & Deole, 2025). The user interface must be visually clear and functionally supportive. This includes the use of readable fonts, high-contrast colour schemes, and intuitive icons, designed according to minimalist principles to avoid visual overload, particularly for younger learners (Ali et al., 2023; Joshi & Deole, 2025; Kaur et al., 2021; Ryan & Deci, 2000). Visual transitions and animations should only be used when they serve a pedagogical purpose, such as indicating progress or highlighting feedback, rather than as decorative distractions (Al-Amri et al., 2023; Ali et al., 2023; Outhwaite et al., 2019). The app should incorporate gamification elements, such as points, badges, avatars, or challenges, to enhance learner engagement and intrinsic motivation (Farooqi et al., 2024; Lee et al., 2023; Outhwaite et al., 2019; Yu et al., 2021). Moreover, learners should be able to monitor their progress through visible indicators, achievement levels, or personalized feedback, which supports self-regulation and goal setting (Al-Amri et al., 2023; Ali et al., 2023; Farooqi et al., 2024). Navigation must be consistent, intuitive, and cognitively accessible, especially for younger users, to reduce confusion and allow seamless movement between content areas (Kaur et al., 2019; Supandi et al., 2018; Tang et al., 2023). Finally, the app must offer adaptive functionality that responds dynamically to the learner's performance by adjusting the difficulty level and structuring content in ways that support individualized learning (Al-Amri et al., 2023; Ali et al., 2023).

Methodology

This study applied a quasi-experimental design to develop and evaluate a m-learning app aimed at improving primary school students' mental arithmetic skills and motivation. The research consisted of two distinct phases: app development and classroom implementation.

The first phase involved identifying pedagogical, technological, and content-related requirements for designing a mobile app tailored to students' needs. A web-based app was created using HTML, CSS, and JavaScript, with backend functionality implemented through Node.js and MySQL. The Railway platform was used for hosting, and version control was maintained with Git and GitHub. Visual and gamified elements, including avatars and background illustrations, were designed using Canva to enhance engagement.

To assess motivation and self-efficacy, a 27-item questionnaire was developed based on the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991). The questionnaire was adapted to suit primary school students and was administered as a pre-test before the classroom implementation using the Quizizz platform. A pilot version was tested with a small group of students to ensure clarity and relevance. Several items were rephrased to avoid ambiguity and better reflect students' cognitive engagement, and all items were presented on a four-point Likert scale with visual emoji support.

In the second phase, the app was tested in two primary school classrooms over seven consecutive school days. The same mathematics teacher was present but did not participate in leading the activities. The researcher independently introduced the mobile app and managed all sessions. Before using the app, students engaged in mental arithmetic tasks using traditional methods, such as verbal responses to mental computation tasks, number columns, and written answers without calculators or support tools. These tasks followed a structured and time-limited format with feedback provided only after all tasks were completed, reflecting the approach described by Mencis (2012). The mobile app was then introduced during the main part of each math lesson. Each day students completed one 5-minute session individually using the app, practicing mental arithmetic in a focused and engaging format. Sessions were conducted at the same time each day to ensure consistency. The app recorded response accuracy and provided immediate feedback, allowing students to monitor their progress and continue independently. The researcher observed students' behaviour and provided technical assistance when needed. To deepen the interpretation of the findings, video observations were conducted during the lessons. These focused on students' emotional responses, engagement, and interaction with the app. Verbal reactions and behaviour patterns were recorded and thematically analysed. Ethical protocols were strictly followed: informed consent was obtained from all participants and their guardians, and all recordings were deleted after analysis.

After the seven-day intervention, the same motivation questionnaire was administered again as a post-test to assess changes in students' motivation. Quantitative data were analysed using Jamovi software. Descriptive statistics, factor analysis, internal consistency (Cronbach's α), and paired sample t-tests were performed to evaluate the impact of the app on motivation levels.

In total, 83 students from Grades 4 and 5 participated in the study. Participants were selected using a convenience sampling method, consisting of students accessible to the researcher in a school where the research took place. After the post-test, a focus group interview was organized to gain a deeper understanding of students' experiences during the use of the app. To ensure that students with different achievement levels were represented, all 83 participants were initially ranked based on their self-reported grades in mathematics from the previous term. For this study, it was assumed that students' self-reported grades accurately reflected their actual performance. Based on this data, students were divided into three performance groups. The "Low" group (grades 1–3) and the "Sufficient" group (grades 4–6) were merged, as only one student had indicated a failing grade. The remaining students were classified as "Optimal" (grades 7–8) and "High" (grades 9–10). From each group, four students were randomly selected, resulting in a planned sample of twelve interview participants. On the day of the interview, one student who had not been originally selected expressed a wish to participate in the focus group interview. As this student belonged to the "Optimal" performance group and demonstrated a strong willingness to share feedback, they were included in the session. For data analysis, students were coded using the abbreviation SK followed by a sequential number, which was also used later in the results section. As a result, the "Optimal" group was represented by five students, and the total number of participants in the focus group was thirteen.

During the interview, students provided in-depth comments on their emotional experiences, perceptions of the app's use, positive and negative aspects, and suggestions for improving its functionality and usability. Thematic analysis of the transcripts was conducted to identify patterns in student responses and triangulate the quantitative results. This mixed-methods approach enabled a comprehensive evaluation of the mobile app's impact on primary school students' motivation and engagement in mental arithmetic.

Results

To evaluate the quality of the developed app and its alignment with the previously established pedagogical, instructional, and technological prerequisites, specific evaluation criteria were designed and categorized into three broad groups: content-related, pedagogical, and technological. Each criterion was assessed using a three-tier scale (from one to three stars), indicating the extent to which the respective aspect was implemented in the app.

The content-related criteria addressed the alignment of the app's content with educational goals, academic accuracy, and logical structuring of tasks. All criteria in this category received the highest possible rating (★★★). The app was developed with a clear objective – to improve students' mental arithmetic skills – while ensuring accurate terminology and a well-structured sequence of tasks. The level of difficulty gradually increases, starting with single-digit problems and progressing to multi-digit calculations.

The pedagogical criteria focused on the app's suitability for the target age group, the alignment of learning strategies with cognitive development, and the quality of feedback. Most pedagogical aspects were rated with three stars: the tasks are formulated and easy to understand, students have the freedom to choose between task types and difficulty levels, and gamification elements enhance engagement. However, the feedback system was rated with two stars due to its limited nature – it only indicates whether an answer is correct or incorrect without analysing the reasons behind mistakes or offering personalized suggestions.

The technological criteria were used to assess the app's design, functionality, usability, and adaptivity. Most of these aspects also received the highest score. The app features intuitive navigation, a modular structure providing personalized learning paths, and a visual design tailored to young learners with contrasting colours, readable fonts, and a minimalistic layout. Nevertheless, some elements were rated with two stars: animations are used mainly for gamification, while the absence of sound effects limits sensory feedback. Additionally, the app lacks detailed progress tracking – it does not provide performance insights based on specific operations or number sets, nor does it allow learners to resume tasks from where they left off.

In total, out of 14 evaluated criteria, 11 received three stars, indicating full compliance, while three criteria were marked for improvement. These include personalized feedback, more detailed progress monitoring, and enhanced sensory engagement through sound. These areas represent key directions for further development to maximize the app's educational potential and support student motivation.

In addition to the evaluation of the development prerequisites, which enabled the analysis of the app's quality from pedagogical, content-related, and technological perspectives, quantitative data analysis was conducted using a structured observation protocol. Descriptive statistics provided an overview of students' usage intensity, such as how many students attended, actively participated, and completed at least one level, as well as emotional engagement, including enthusiasm, anxiety, distraction, perceived difficulty (e.g., challenging tasks, need for assistance), strategy use, and technical issues encountered. These indicators helped identify key trends in the app usage process, including both strengths and areas for improvement. The results were further interpreted in connection with qualitative data gathered through student's focus group interviews to offer a multidimensional insight into the app's effectiveness, user needs, and suggestions for improvement.

Quantitative data indicated high student engagement with the app throughout the implementation period. On average, 77 students participated in each session, and 76 completed at least one task level, representing a 98.7% active engagement rate (see Table 1). This high figure demonstrates that the app not only captures attention but also sustains it. These findings are reinforced by interview responses for example, student

SK5 noted, “Maybe I wouldn’t want to play it all day and night, but I liked using it at the beginning of the lesson and sometimes at home.” Similarly, several students expressed that they enjoyed using the app outside of class time during breaks or at home. SK7 remarked, “I played again in the evening because it was fun to build my island.” This aligns with the usage data, showing that an average of 36 students per day voluntarily accessed the app beyond the scheduled sessions, highlighting its potential as a sustainable and motivating tool for independent learning.

Student engagement was evident not only through activity but also through emotional involvement – on average, 68 students per session expressed joy, and excitement, or made comments about what was happening, especially when rewards were earned, new island parts were unlocked, or avatars were changed. This emotional involvement indicates the effectiveness of the visual and content-based design elements. For instance, SK7 emphasized, “I couldn’t stop solving tasks and earning coins because I wanted to build my island and buy the next piece!” Such statements reflect how the app was able to maintain attention and inspire continued participation. Other interviewees similarly cited island-building and avatar customization as key reasons they returned to the app. The app’s modular structure, allowing students to choose task types and difficulty levels, as well as engage in creative elements like island construction and avatar design, created an environment where learners felt in control and motivated to engage. Thus, the design and gamification elements contributed significantly to students’ willingness to solve more tasks.

Despite the generally high engagement and positive trends, the personalized feedback within the app did not fully meet students’ needs for deeper understanding. While all tasks provided instant feedback on whether answers were correct or incorrect, there was not enough time during sessions for students to reflect on their mistakes or explore the strategy mode, which could have supported understanding of problem-solving steps. Several students in interviews expressed a desire for explanations for example, understanding why an answer was wrong or what to do differently next time. These responses indicate that the personalized feedback criterion was only partially met: the feedback was quick and functional but not analytical. Enhancing this feature in the future could significantly support deeper understanding and learning progression.

Some minor technical issues were also observed during implementation – 3.9% of students encountered technical difficulties (see Table 1). Reported issues included unsaved progress (requiring task repetition) and problematic button placement that hindered navigation. These problems were documented and resolved promptly during the first days of the trial: the button layout was improved, the data-saving function was enhanced, and the home screen was optimized to improve usability. No reports were registered of app slowdown, error codes, or authentication issues. The only significant error occurred on the first day when a faulty line of code caused incorrect division tasks with remainders to be generated for 16 users, this was corrected immediately. The feedback received from students directly informed immediate improvements to the app, making it more suited to their needs. Therefore, the learning environment provided by the app is considered stable and reliable, allowing students to focus on the learning tasks rather than technological problems.

Table 1 Summary of students' engagement and experience with the app

Number of students who	Mean	Median	SD	Min	Max
attended	75.429	77	4.276	67	80
actively used the app	74.857	76	5.242	64	80
completed at least one level	75.429	77	4.276	67	80
showed enthusiasm	67.571	69	8.121	53	78
disengaged	2.857	2	2.410	1	8
needed teacher assistance	6.857	4	8.295	0	24
expressed dissatisfaction	0.000	0	0.000	0	0
showed anxiety	0.714	0	1.496	0	4
reported tasks as too difficult	3.000	0	5.508	0	15
putted in minimal effort	1.000	1	1.000	0	2
used the app voluntarily outside scheduled time	36.000	43	17.944	0	52
asked about additional app features	7.714	7	4.821	2	16
learned strategies	0.286	0	0.756	0	2
had login technical issues	0.000	0	0.000	0	0
were unable to complete	2.286	0	6.047	0	16
tasks due to technical issues needed to switch devices due to technical limitations	0.429	0	1.134	0	3

Following the evaluation of the pedagogical, content-related, and technological alignment of the developed mobile app, this subsection analyses its potential impact on students' motivation to improve their mental arithmetic skills. The analysis is based on data collected from two testing sessions, before and after the app's implementation, using custom-designed questionnaires aimed at identifying statistically significant changes in motivation levels and their possible links to the app usage experience.

The results show that after using the app, both the arithmetic mean and the median values increased across most statements, while the standard deviation (*SD*) often decreased. This indicates not only a general improvement in students' interest in mental calculation but also a more consistent and less dispersed set of responses. The most notable change was in the statement "Mental arithmetic is an enjoyable activity I like doing" where the mean score increased from 2.26 ($SD = 0.92$) to 3.46 ($SD = 0.67$), suggesting a clear shift in attitudes (see Table 2). According to Bandura's Self-Efficacy Theory, a sense of competence influences motivation. The app's gradual difficulty progression, error-tolerant structure, and gamified feedback allowed students to experience success, which is one of the strongest sources of self-efficacy. Quantitative observations supported these findings. On average, 68 students per day showed visible enthusiasm (smiling, cheering, or sharing success), while expressions of anxiety were rare – only about one student per day. The only exception occurred on day three when four out of 80 students experienced difficulty with the speed test due to overly rapid task progression, which was corrected the following day. No dissatisfaction was reported at any point.

Table 2 Comparison of survey responses before and after using the app

Statement	Mean	Median	SD
(Pre) I like doing mental arithmetic	2.82	3.00	0.817
(Post) like doing mental arithmetic	3.41	4.00	0.771
(Pre) Mental arithmetic is an enjoyable activity I like doing	2.26	2.00	0.922
(Post) Mental arithmetic is an enjoyable activity I like doing	3.46	4.00	0.674
(Pre) I would be interested in learning mental arithmetic with a special app	3.53	4.00	0.831
(Post) I would be interested in learning mental arithmetic with a special app	3.77	4.00	0.516
(Pre) I would like to learn mental arithmetic using a phone or tablet	3.16	3.00	0.922
(Post) I would like to learn mental arithmetic using a phone or tablet	3.59	4.00	0.807
(Pre) The more I practice, the better I can perform mental arithmetic	3.64	4.00	0.821
(Post) The more I practice, the better I can perform mental arithmetic	3.80	4.00	0.528

The scale items related to technology use already showed high values in the pre-test, but post-test results were more consistent. For example, the percentage of students who strongly disagreed with learning via a special app dropped from 8.2% to 0%, while strong agreement rose from 67.6% to 81.4%. Similarly, the average score for the statement about learning via phone or tablet increased from 3.16 to 3.59. Interview participants also expressed a clear preference for practising mental arithmetic in digital form. For instance, student SK7 noted: "In the app, you can choose what you want to calculate, but in class, you just do what the teacher assigns to you. And sometimes there's not enough time to think." During the use of app, students remained focused on tasks; on average, only two students per day momentarily disengaged, such as by looking away or briefly talking to classmates.

Two separate motivation scales were constructed, one before and one after using the app, each consisting of six statements reflecting students' motivation to perform mental arithmetic. Statements included: "I like doing mental arithmetic", "Mental arithmetic is an enjoyable activity", "I like doing challenging mental tasks", "I prefer difficult examples over easy ones", "Mental arithmetic is important", and "I do mental arithmetic even when not required". To ensure the reliability and structure of the scale, statistical tests were conducted. Shapiro–Wilk tests showed that none of the 12 items (six before and six after) followed a normal distribution ($p < .001$). Skewness for the pre-test ranged from −0.98 to 0.80; post-test data showed more negative skewness, particularly for the statement "Mental arithmetic is an enjoyable activity" with skewness = −1.45 and kurtosis = 3.13. Therefore, non-parametric methods were used. Spearman's correlation confirmed statistically significant relationships between most items (e.g., $r = 0.63$

Table 3 Motivation changes before and after using the app

	W	*p*	Mean	Median	*SD*
Motivation (before)	210	< 0.001	2.59	2.50	0.668
Motivation (after)			3.10	3.17	0.568

and $r = 0.78$, $p < 0.001$). Exploratory factor analysis supported a single-factor structure, and Cronbach's α confirmed internal consistency: 0.76 (before) and 0.75 (after). Based on these results, each respondent's motivation score was calculated as the average of the six items. To compare the motivation levels before and after using the app, a Wilcoxon signed-rank test was conducted. The results showed a statistically significant increase in motivation: $W = 210$, $p < 0.001$. The mean score rose from 2.59 to 3.10, and the median increased from 2.50 to 3.17. The standard deviation also decreased (from 0.668 to 0.568), indicating more consistent and unified attitudes among students (see Table 3).

Although no statistically significant correlation was found between students' midsemester grades and motivation changes ($r = -0.131$, p = 0.290), a tendency was observed: students with lower academic performance showed slightly higher motivation gains. ANOVA results (p = 0.177) and Games–Howell post hoc tests confirmed that differences between groups were not statistically significant, but descriptive data supported the trend. Students' confidence was also assessed. For the statement "When I do mental arithmetic, I feel confident in my abilities" the average rating increased from 2.70 ($SD = 0.96$) to 3.26 ($SD = 0.74$). Strong agreement doubled from 20.3% to 41.4%, while strong disagreement dropped from 14.9% to 1.4%. A separate self-efficacy scale was also created using six statements (five positive, one reversed). After recoding the negative item, Cronbach's α values were $\alpha = 0.74$ (before) and $\alpha = 0.75$ (after), with no significant reliability loss when excluding any item. Factor analysis confirmed a single-factor structure. A Wilcoxon test showed a significant increase in self-efficacy: $W = 372$, $p < 0.001$, with the average score rising from 2.92 to 3.26.

In conclusion, the use of a pedagogically grounded mobile app significantly enhanced students' motivation and self-efficacy in mental arithmetic. While no statistically significant differences between performance groups were observed, the trend indicates that such tools are particularly beneficial for students with initially lower confidence. These findings highlight the potential of m-learning apps to support both engagement and independent learning.

Discussion

The aim of this study was to design and pilot a mobile app for improving mental arithmetic skills and to determine whether and how its use contributes to increased motivation among primary school students. To ensure the app's alignment with educational goals and learners' needs, the design process was guided by the TPCK framework, which emphasizes that effective digital tools in education must integrate pedagogical goals, content-specific requirements, and technological possibilities (Mishra & Koehler, 2006).

This framework led to the formulation of 14 preconditions, which were later adapted as evaluation criteria.

The developed app included multiple functional sections to foster both mental arithmetic skills and student engagement. Learners could choose between natural or whole number sets and practice four arithmetic operations in varied combinations, enabling individualized task sets suitable for grades 1–6. This supports personalized learning principles, which Boynge et al. (2024) argue enhance self-regulation, motivation, and academic outcomes. Similarly, Gonçalves et al. (2020) highlight that flexibility in task selection allows students to focus on areas requiring more practice, fostering deeper learning and sustained engagement.

Two learning modes were available in the app: a training mode and a speed mode. The training mode allowed students to solve tasks at their own pace without time pressure – crucial for those who may experience anxiety or attention difficulties under timed conditions. Prior studies have shown that time limits can negatively impact younger students' emotional wellbeing and performance, often increasing stress and anxiety (Gonçalves et al., 2020; Hussain et al., 2021; Outhwaite et al., 2019). Therefore, offering a stress-free mode contributed to a more positive learning experience. In contrast, the speed mode was included based on research showing that dynamic and game-based challenges can boost student motivation and engagement (Anderson et al., 2022; Boynge et al., 2024). Pilot results confirmed that high-achieving students more often used the speed mode, underscoring the value of offering both formats.

A dedicated strategy section provided textual and audiovisual explanations of various mental arithmetic techniques. This multimodal approach addressed diverse learning styles and supported engagement and comprehension (Gonçalves et al., 2020; Kim et al., 2021). It was also designed to support self-directed learning by allowing students to explore and experiment with different strategies independently (Poçan et al., 2023; Ryan & Deci, 2000). However, during the pilot, this section was underused. Observations showed that students focused primarily on task-solving and game elements due to time constraints. Even during breaks, strategy exploration was rare. This suggests the feature's potential was not fully realized and may be more effective in-home learning or teacher-guided settings. Further research is needed to evaluate its actual impact, though literature suggests that strategy explanations can serve as valuable resources when learners have adequate time and a supportive environment (Howard et al., 2021; Kim et al., 2021).

Gamification elements such as point systems, virtual currency, levels, avatars, and progress tracking were included to increase motivation and engagement. Students earned points for correct answers and used them to unlock island features in a virtual world. Although the island layout was the same for everyone, the avatar customization feature offered a sense of personalization. This reward system supported intrinsic motivation by providing immediate feedback and a sense of accomplishment. Gamification is known to enhance engagement by fostering autonomy, competence, and a sense of belonging, particularly when paired with clear rewards and achievable goals (Bureau et al., 2022).

A simplified progress tracking feature helped students monitor their improvement, promoting self-efficacy by highlighting both strengths and areas for improvement (Hussain et al., 2021).

To evaluate the impact of these features on motivation, changes were analysed before and after app usage using both quantitative and qualitative data. Results showed a statistically significant increase in motivation ($p < .001$). The median score rose from 2.50 to 3.17, suggesting notable motivational gains within a short pilot period. This increase can be attributed to several app features designed to support motivation: personalized content, immediate feedback, and gamification that aligns with students' developmental levels (Howard et al., 2021; Bureau et al., 2022). These findings are consistent with self-efficacy theory, which states that belief in one's capabilities enhances persistence, focus, and achievement (Schunk & Pajares, 2009).

Interview data further supported this: students reported that visible progress and improvements motivated them to continue. Some noted that the speed mode pushed them to outperform themselves, while the training mode helped them strengthen specific skills. These observations show that students actively used the app to guide their learning based on individual needs. Such adaptive use aligns with studies highlighting that motivation increases when learners can set goals, control the pace, and see tangible progress (Bureau et al., 2022; Howard et al., 2021). The app's progress tracking and structured game environment contributed to building self-efficacy, which in turn supported goal-directed behaviour and motivation (Hussain et al., 2021).

Conclusions

Based on the analysis of the scientific literature, the app development process, the app validation and the results obtained, the author has drawn several important conclusions:

1. The well-thought-out implementation of m-learning in the learning process contributes to students' learning motivation, digital skills development and targeted engagement if it is planned strategically, i.e. considering students' needs, age and subject specifics. Its effectiveness is based on the choice of appropriate apps, clear rules for use and structured lesson planning that allows technology to be used meaningfully rather than formally or for entertainment.
2. Developing numeracy skills in primary school is an essential prerequisite for improving students' mathematical reasoning and cognitive abilities, and its targeted development relies on promoting number sense, flexibility of strategies, automation of numerical facts and integration of modern teaching techniques, including digital technologies, into the learning process.
3. The quality of the development of an app is essentially determined by its compliance with clearly defined pedagogical, content and technological criteria that ensure its suitability for learning purposes.
4. The use of a mobile app that is pedagogically, content-wise and technologically sound can significantly increase students' motivation to do mental arithmetic.

5. The adaptive environment of the app, which allows students to choose the tasks and the pace, not only promotes positive emotional engagement and low anxiety, but also contributes significantly to self-efficacy, giving students confidence in their ability to complete learning tasks, contributing to increased motivation.
6. Personalisation, adaptive logic and gamification elements, combined with the possibility to choose the type of tasks and review one's own progress, contribute to students' engagement, learning motivation and the development of self-directed learning skills.

Summarizing the above mentioned findings, the author concludes that the aim of the thesis is fulfilled and the research hypothesis "developing and validating a mobile app for developing mental arithmetic can contribute to increasing the motivation level of primary school students' is confirmed.

A possible way forward includes the implementation of a longitudinal study to assess the impact of regular use of the app on students learning performance and long-term motivational change, comparing the results with a control group without the app. At the same time, the app can be improved in several aspects. Firstly, it could be enhanced with new head counting strategies. Secondly, the feedback system should be improved to make it more accurate and informative. Thirdly, the gamification elements of the app could be extended by introducing new visual themes and interactive features that would encourage more sustained user engagement. Finally, it would be useful to improve the system for measuring progress by developing a detailed statistical report in which the user could see their mistakes, the strategies used, the distribution of task types and the dynamics of progress over time.

REFERENCES

Al-Amri, S., Hamid, S., Noor, N. F. M., & Gani, A. (2023). A framework for designing interactive mobile training course content using augmented reality. *Multimedia Tools and Apps, 82*(20), 30491–30541. https://doi.org/10.1007/s11042-023-14561-4

Ali, W., Permatasakti, D., Bening, L. M., & Sarwono, D. (2023). Enhancing Children's Learning Experience as a Sustainable Approach through Gamified App Design. *E3S Web of Conferences, 426,* 02115. https://doi.org/10.1051/e3sconf/202342602115

Al-Said, K. (2023). Influence of teacher on student motivation: Opportunities to increase motivational factors during mobile learning. *Education and Information Technologies, 28*(10), 13439–13457. https://doi.org/10.1007/s10639-023-11720-w

Anderson, S., Schurig, M., Sommerhoff, D., & Gebhardt, M. (2022). Students' learning growth in mental addition and subtraction: Results from a learning progress monitoring approach. *Frontiers in Psychology, 13,* 944702. https://doi.org/10.3389/fpsyg.2022.944702

Baker, A. T., & Cuevas, J. (2018). The Importance of Automaticity Development in Mathematics. *Georgia Educational Researcher, 14*(2). https://doi.org/10.20429/ger.2018.140202

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Boynge, A. T., Arman, S. A., & Gumelar, R. T. (2024). Mobile-Based Mathematics Quiz App (Case Study of International Mental Arithmetic Course). *Journal of Computer Science Advancements, 1*(5), 291–305. https://doi.org/10.70177/jsca.v1i5.533

Bureau, J. S., Howard, J. L., Chong, J. X. Y., & Guay, F. (2022). Pathways to Student Motivation: A Meta-Analysis of Antecedents of Autonomous and Controlled Motivations. *Review of Educational Research, 92*(1), 46–72. https://doi.org/10.3102/00346543211042426

Burke, P. F., Kearney, M., Schuck, S., & Aubusson, P. (2022). Improving mobile learning in secondary mathematics and science: Listening to students. *Journal of Computer Assisted Learning, 38*(1), 137–151. https://doi.org/10.1111/jcal.12596

Chang, P.–C., & Lin, R.–H. (2024). A Visual Prompt-Based Mobile Learning System for Improved Algebraic Understanding in Students with Learning Disabilities. *IEEE Access, 12,* 3540–3553. https://doi.org/10.1109/access.2023.3348787

Çukurbaşi Çalişir, E., Sabuncu, F. H., & Kişla, T. (2022). Mobile learning in grades K–12: A literature review. *Journal of Educational Technology and Online Learning, 5*(4), 1000–1029. https://doi.org/10.31681/jetol.1145967

Dehbi, A., Dehbi, R., Bakhouyi, A., & Talea, M. (2023). Survey Analysis of Students and Teachers' Perceptions of E-Learning and M-Learning in Morocco. *International Journal of Interactive Mobile Technologies (iJIM), 17*(03), 102–122. https://doi.org/10.3991/ijim.v17i03.36325

Farooqi, M. T. K., Siddique, Z., & Awan, S. M. (2024). The effectiveness of educational software and apps for primary students' learning outcomes: A systematic review. *Journal of Excellence in Social Sciences, 3*(4). https://doi.org/10.69565/jess.v3i4.347

Fombona, J., Pascual, M. A., & Pérez Ferra, M. (2020). Analysis of the Educational Impact of M-Learning and Related Scientific Research. *Journal of New Approaches in Educational Research, 9*(2), 167–180. https://doi.org/10.7821/naer.2020.7.470

Gonçalves, S., Rocha, A., & Paz, J. (2020). Using Apps to Develop Mental Calculation in Primary Education. *EDEN Conference Proceedings, 1,* 296–304. https://doi.org/10.38069/edenconf-2020-rw-0032

Hernawati, K., & Jailani. (2019). Mathematics mobile learning with TPACK framework. *Journal of Physics: Conference Series, 1321*(2), 022126. https://doi.org/10.1088/17426596/1321/2/022126

Herwin, H., Nurhayati, R., & Dahalan, S. C. (2022). Mobile Assessment to Improve Learning Motivation of Elementary School Students in Online Learning. *International Journal of Information and Education Technology, 12*(5), 436–442. https://doi.org/10.18178/ijiet.2022.12.5.1638

Hickendorff, M., Torbeyns, J., & Verschaffel, L. (2019). Multi-digit Addition, Subtraction, Multiplication, and Division Strategies. In A. Fritz, V. G. Haase, & P. Räsänen (Eds.), *International Handbook of Mathematical Learning Difficulties* (pp. 543–560). Springer International Publishing. https://doi.org/10.1007/978-3-319-97148-3_32

Howard, J. L., Bureau, J., Guay, F., Chong, J. X. Y., & Ryan, R. M. (2021). Student Motivation and Associated Outcomes: A Meta-Analysis from Self-Determination Theory. *Perspectives on Psychological Science, 16*(6), 1300–1323. https://doi.org/10.1177/1745691620966789

Hussain, A., Mkpojiogu, E. O. C., & Ezekwudo, C. C. (2021). Improving the Academic Self-Efficacy of Students Using Mobile Educational Apps in Virtual Learning: A Review. *International Journal of Interactive Mobile Technologies (iJIM), 15*(06), 149. https://doi.org/10.3991/ijim.v15i06.20627

Jay, T., Habgood, J., Mees, M., & Howard-Jones, P. (2019). Game-Based Training to Promote Arithmetic Fluency. *Frontiers in Education, 4,* 118. https://doi.org/10.3389/feduc.2019.00118

Joshi, M., & Deole, P. (2025). Enhancing UI/UX Design for Children's Educational Gaming Platforms: An Integrated Multicriteria Decision Making Framework. *Journal of Scientific & Industrial Research, 84*(2). https://doi.org/10.56042/jsir.v84i02.9675

Katayeva, M. (2023). Analysis and recommendations on mobile learning in the educational process. *Scientific Journal of the Fergana State University, 29*(3). https://doi.org/10.56292/SJFSU/vol29_iss3/a40

Kaur, K., Kalid, K. S., & Sugathan, S. (2021). Exploring children user experience in designing educational mobile app. *2021 International Conference on Computer & Information Sciences (ICCOINS),* 163–168. https://doi.org/10.1109/ICCOINS49721.2021.9497234

Kaur, K., Kalid, K. S., & Sugathan, S. K. (2019). UX guideline for children educational mobile app: Pilot case study. *International Journal of Engineering and Advanced Technology, 8*(5c), 39–46. https://doi.org/10.35940/ijeat.E1005.0585C19

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development, 10*(3), 2–10. https://doi.org/10.1007/BF02905780

Kim, J., Gilbert, J., Yu, Q., & Gale, C. (2021). Measures matter: A meta-analysis of the effects of educational apps on preschool to grade 3 children's literacy and math skills. *AERA Open, 7,* 23328584211004183. https://doi.org/10.1177/23328584211004183

Korucu, A. T., & Alkan, A. (2011). Differences between m-learning (mobile learning) and e-learning, basic terminology and usage of m-learning in education. *Procedia – Social and Behavioral Sciences, 15,* 1925–1930. https://doi.org/10.1016/j.sbspro.2011.04.029

Kupferman, R. (2015). *Elementary school mathematics for parents and teachers: Volume 1.* World Scientific. https://doi.org/10.1142/9696

Lee, J., Su, Z., & Chen, Y. (2023). Mobile apps for children's health and wellbeing: Design features and future opportunities. *AMIA. Annual Symposium Proceedings. AMIA Symposium, 2023,* 1027–1036.

Lloyd, B. (2016). Computational fluency: The key to multiplicative success [Assumption University]. https://digitalcommons.assumption.edu/honorstheses/8

Marcus-Quinn, A., & Hourigan, T. (Eds.). (2021). *Handbook for online learning contexts: Digital, mobile and open: Policy and practice.* Springer. https://doi.org/10.1007/978-3-030-67349-9

Mencis, J. (2012). *Skaitļu slejas. 1. daļa: Racionālie skaitļi.* Zvaigzne ABC.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record,* 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mohamad Said, M. N. H., Abdul Hanid, M. F. B., Ali, M. F. B., & Punyanathan, K. (2024). The effect of mobile app to promote learning English for primary school students. *Advances in Mobile Learning Educational Research, 4*(1), 940–950. https://doi.org/10.25082/AMLER.2024.01.006

Orhani, S., (2023). Philosophy of e-learning vs m-learning. *Futurity Philosophy,* 4–23. https://doi.org/10.57125/FP.2023.12.30.01

Outhwaite, L. A., Faulder, M., Gulliford, A., & Pitchford, N. J. (2019). Raising early achievement in math with interactive apps: A randomized control trial. *Journal of Educational Psychology, 111*(2), 284–298. https://doi.org/10.1037/edu0000286

Pedro, L. F. M. G., Barbosa, C. M. M. D. O., & Santos, C. M. D. N. (2018). A critical review of mobile learning integration in formal educational contexts. *International Journal of Educational Technology in Higher Education, 15*(1), 10. https://doi.org/10.1186/s41239-018-0091-4

Pintrich, P. R., Smith, D. A. F., Duncan, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ).* University of Michigan.

Poçan, S., Altay, B., & Yaşaroğlu, C. (2023). The effects of mobile technology on learning performance and motivation in mathematics education. *Education and Information Technologies, 28*(1), 683–712. https://doi.org/10.1007/s10639-022-11166-6

Proulx, J. (2019). Mental mathematics under the lens: Strategies, oral mathematics, enactments of meanings. *The Journal of Mathematical Behavior, 56,* 100725. https://doi.org/10.1016/j.jmathb.2019.100725

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2023). Emotions and motivation in mathematics education: Where we are today and where we need to go. *ZDM – Mathematics Education, 55*(2), 249–267. https://doi.org/10.1007/s11858-022-01463-2

Schunk, D. H., Meece, J. L., & Pintrich, P. R. (2014). *Motivation in education: Theory, research, and apps* (4th ed., Pearson new international edition). Pearson.

Schunk, D. H., & Pajares, F. (2009). Self-efficacy theory. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (1st publ.). Routledge.

Sunde, P. B., De Smedt, B., Verschaffel, L., & Sunde, P. (2023). Grade one single-digit addition strategies as predictors of grade four achievement in mathematics. *European Journal of Psychology of Education*. https://doi.org/10.1007/s10212-023-00761-x

Supandi, S., Ariyanto, L., Kusumaningsih, W., & Aini, A. N. (2018). Mobile phone app for mathematics learning. *Journal of Physics: Conference Series, 983,* 012106. https://doi.org/10.1088/1742-6596/983/1/012106

Tang, D. M., Nguyen, C. T. N., Bui, H. N., Nguyen, H. T., Le, K. T., Truong, K. L. G., Tran, N. T., Vo, N. K., & Nguyen, T. T. (2023). Mobile learning in mathematics education: A systematic literature review of empirical research. *Eurasia Journal of Mathematics, Science and Technology Education, 19*(5), em2268. https://doi.org/10.29333/ejmste/13162

Ten Braak, D., Lenes, R., Purpura, D. J., Schmitt, S. A., & Størksen, I. (2022). Why do early mathematics skills predict later mathematics and reading achievement? The role of executive function. *Journal of Experimental Child Psychology, 214,* 105306. https://doi.org/10.1016/j.jecp.2021.105306

Wang, J., Tigelaar, D., Zhou, T., & Admiraal, W. (2023). The effects of mobile technology usage on cognitive, affective, and behavioural learning outcomes in primary and secondary education: A systematic review with meta-analysis. *Journal of Computer Assisted Learning, 39*(2), 301–328. https://doi.org/10.1111/jcal.12759

Wang, T.–H., Kao, C.–H., & Wang, T.–J. (2021). Implementation of mobile learning in mathematics instruction for elementary second graders. *Mathematics, 9*(14), 1603. https://doi.org/10.3390/math9141603

Yan, Z. (Ed.). (2015). *Encyclopedia of mobile phone behavior.* IGI Global. https://doi.org/10.4018/978-1-4666-8239-9

Yosiana, Y., Djuandi, D., & Hasanah, A. (2021). Mobile learning and its effectiveness in mathematics. *Journal of Physics: Conference Series, 1806*(1), 012081. https://doi.org/10.1088/1742-6596/1806/1/012081

Yu, Z., Gao, M., & Wang, L. (2021). The effect of educational games on learning outcomes, student motivation, engagement and satisfaction. *Journal of Educational Computing Research, 59*(3), 522–546. https://doi.org/10.1177/0735633120969214

Zhang, Y. (Aimee). (2015). *Handbook of mobile teaching and learning.* Springer Berlin Heidelberg.