



Development of Interactive Mobile Learning Media to Enhance Motivation and Learning Outcomes in Elementary School Students' Mathematics on Social Arithmetic

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Abstract

This study was motivated by the low motivation and learning outcomes of elementary school students in mathematics, particularly in social arithmetic, as well as the limited integration of digital technology in classroom instruction. The research aimed to develop interactive mobile learning (ML) media that is engaging, user-friendly, and aligned with the curriculum to enhance students' motivation and achievement. The study employed a research and development (R&D) method using the ADDIE model through the stages of analysis, design, development, implementation, and evaluation. Validation by media and content experts ensured technical quality and content accuracy. A quasi-experimental design with a pretest–posttest control group was implemented. The results revealed a significant improvement in the experimental group, with the mean posttest score rising from 40.97 to 72.47, while the control group increased by only 4.99 points. Paired t-test and ANCOVA confirmed these differences, and the motivation questionnaire demonstrated high reliability (Cronbach's Alpha >0.88). Observations and interviews supported the quantitative findings, showing increased engagement, independence, and teacher–student interaction. The interactive ML media proved effective, feasible, and ready for broader implementation as a digital learning innovation supporting 21st-century educational transformation

Introduction

Enhancing the quality of mathematics learning in elementary schools requires more than merely delivering content; teachers must orchestrate learning experiences that spark curiosity, foster independence, and remain relevant to students' real-life contexts. Consistent evidence highlights motivation as a primary driver of learning outcomes, yet in practice, instruction often remains teacher-centered and underutilizes engaging and accessible digital media for children. In this regard, mobile learning (ML), with its portable, personal, and interactive characteristics, emerges as a promising pedagogical strategy to address low motivation and achievement in mathematics from the elementary level.

Conceptually, ML supports two core needs of primary education: autonomous learning and strengthening conceptual understanding. Studies on ML development in mathematics have been shown to improve both learner independence and learning outcomes (Suprianto et al., 2019), while digital teaching materials designed around procedural–conceptual knowledge have enhanced elementary students' understanding of fractions (Andriah & Amir, 2021). These findings align with modern instructional design principles that emphasize coherence among goals, strategies, and assessment within a systematic development cycle (Branch, 2009). In

other words, ML is not merely about “transferring” content onto devices but about designing structured, adaptive, and student-centered learning experiences.

At the implementation level, the ecosystem of interactive media for elementary mathematics has grown rapidly, ranging from interactive multimedia (Gartika et al., 2019; Ratnasari et al., 2021), e-comics (Fahreza et al., 2022; Guntur et al., 2023), and 2D/3D animated videos (A. Fitri & Amelia, 2021; Gusteti et al., 2021) to ready-to-use Android applications (Batubara, 2018; Latifa et al., 2020) and authoring tools (Handayuni et al., 2023; Julia & Bentri, 2023). At the same time, game-based innovations and gamification such as snakes-and-ladders, fraction dominoes, or kobatar have demonstrated positive effects on engagement, problem-solving strategies, and concept retention (Ariyanto et al., 2020; Aziz, 2018; Farikhattuzaeniti & Purwanti, 2023; Gabriela & Anugraheni, 2022; Shidqi et al., 2023). Further evidence indicates that student worksheets (LKPD) oriented toward problem-based learning promote reasoning and concept transfer (Andeswari et al., 2022), while flash/QR-code-based media and interactive web platforms expand access and facilitate feedback (Arliani & Khabibah, 2022; Suana, 2019; Vawanda & Zainil, 2023).

From the perspective of learning theory, recent research supports the principle that knowledge is actively constructed through experience, multiple representations, and social interaction (Scott & Hargreaves, 2015). ML enables the orchestration of these principles through combinations of text, animation, simulations, adaptive quizzes, and immediate feedback that reduce extraneous cognitive load while enriching conceptual elaboration. The digital game-based learning approach (DGBL-ID) even demonstrates a systematic design for linking learning objectives, game mechanics, and formative assessment (Dhaniawaty et al., 2023). On the other hand, realistic and culturally contextualized approaches, such as ethnomathematics videos, ground abstract concepts in students’ lived experiences and strengthen learning meaning (Halimah & Kurniawati, 2022; Yandani & Agustika, 2022). Altogether, this body of evidence underscores that well-designed digital media not only enhance visual appeal but also facilitate deeper meaning-making in learning.

Despite this, there remains a significant gap in the domain of social arithmetic an area closely related to students’ daily lives (buying and selling, discounts, taxes, profit and loss) yet it is often perceived as difficult and uninteresting. Many digital innovations have focused on geometry and fractions (Andriani et al., 2021; N. A. Fitri & Karlimah, 2018; Mutia & Mulyawati, 2021; Sintawati et al., 2020), while targeted empirical evidence examining the influence of ML on motivation and learning outcomes in elementary social arithmetic within the Indonesian context remains relatively scarce. Field observations indicate that practices are still dominated by lecture-exercise approaches, static presentations, and limited student engagement, despite adequate digital infrastructure and a high rate of device ownership among students. The disparity between available resources and their actual utilization signals the need for solutions that are not merely technical but also pedagogical.

Building on this foundation, the urgency of this study becomes clear: to design and evaluate an ML-based interactive learning medium specifically aimed at enhancing motivation and learning outcomes in social arithmetic. The design integrates the ADDIE instructional design framework (Branch, 2009) with contemporary good design practices multimodality, interactivity, immediate feedback, and progress tracking while linking these with problem-based learning (PBL) and educational games relevant to the local context (Andeswari et al., 2022; Nurfatanah et al., 2021). This strategy is expected not only to spark interest and engagement but also to facilitate the transition from procedural to conceptual mastery of key competencies essential for transfer to real-life situations (Andriah & Amir, 2021).

The contributions offered are twofold. First, the theoretical contribution: a design model of ML that synthesizes evidence from interactive multimedia, DGBL, and PBL for the elementary social arithmetic domain a research gap rarely addressed, as most prior studies have focused on geometry/fractions or single-media tools such as videos or comics (A. Fitri & Amelia, 2021; Guntur et al., 2023). Second, the practical contribution: an ML prototype that is feasible for teachers to use, compatible with students' existing devices, and equipped with formative assessment features and progress tracking that can be directly integrated into classroom routines. A microsite-based or no-code authoring approach enables rapid adoption by teachers and replication across schools (Julia & Bentri, 2023).

Finally, the evaluation framework will measure the impact on motivation (interest, persistence, and learning autonomy) and learning outcomes (conceptual understanding and application in buying–selling, discounts, taxes, profit–loss cases) through a rigorous development design and staged field testing aligned with the ADDIE model (Widodo, 2018). Grounded in extensive research evidence and real classroom needs, this study bridges the gap between the potential of ML and the practice of social arithmetic learning in elementary schools, while offering a realistic, measurable, and scalable implementation roadmap.

Methods

This study employed a Research and Development (R&D) approach using the ADDIE framework Analysis, Design, Development, Implementation, and Evaluation as recommended by Branch (2009), to produce an interactive mobile learning (ML) medium that is empirically tested for its effectiveness in improving elementary school students' motivation and mathematics learning outcomes.

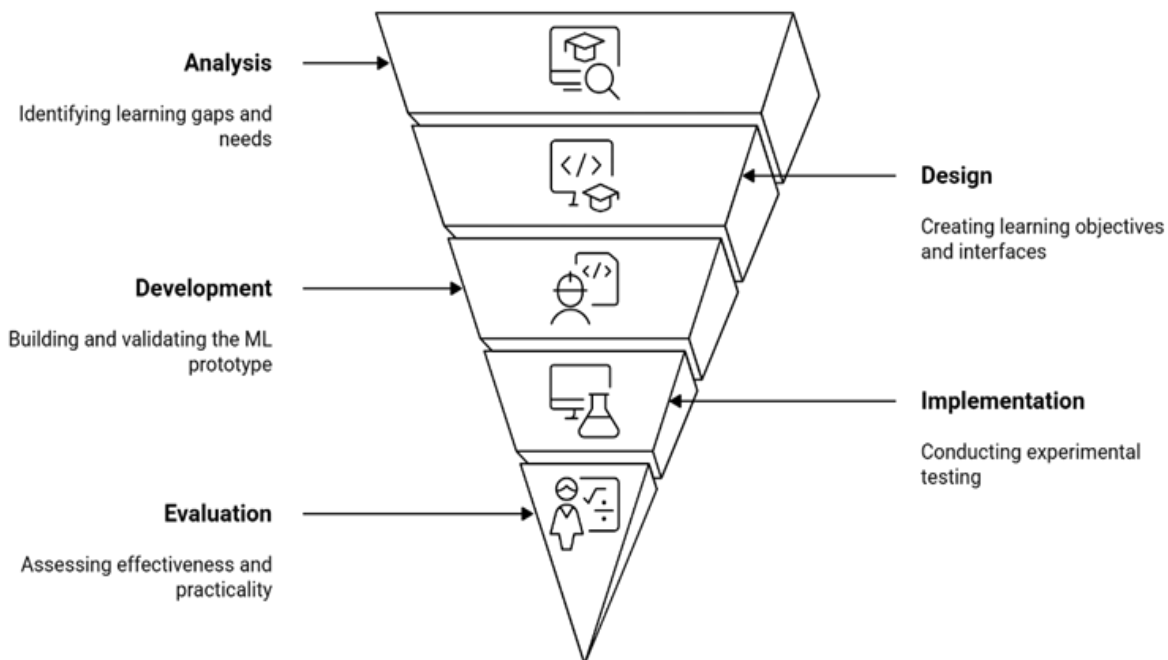


Figure 1. Research and Development Procedure

The development procedure began with the analysis stage, conducted through classroom observations, needs assessment questionnaires, and in-depth interviews to map gaps in motivation and achievement in social arithmetic, in line with findings on students' low engagement reported by Suprianto et al (2019) and Fitri & Amelia (2021). The design stage involved formulating learning objectives, storyboards, and media interfaces based on interactive multimedia principles (Gartika et al., 2019) and game-based learning strategies (Dhaniawaty et al., 2023). During the development stage, the prototype was validated by media and content experts and revised according to feedback, following the practices of (Batubara, 2018). The implementation stage was carried out through a quasi-experimental pretest–posttest design with control and experimental groups, as applied by (Andriah & Amir, 2021). The evaluation stage assessed the practicality and effectiveness of the product through formative and summative evaluations, consistent with (Kumala, 2024).

The research subjects were fifth-grade students of SD Negeri 14 Batu Nanta and their mathematics teacher, selected purposively due to the school's strong digital infrastructure support (Latifa et al., 2020). Data were collected using a Likert-scale motivation questionnaire (Widodo, 2018), learning achievement tests (Andriani et al., 2021), observation sheets, and interviews. Quantitative data were analyzed using paired t-tests and ANCOVA (Fahreza et al., 2022), while the reliability of motivational data was tested using Cronbach's Alpha. Qualitative data were analyzed through reduction, presentation, and conclusion drawing following the Miles and Huberman model.

Table 1. Observation and Interview Guideline Framework

Aspect	Main Observation	Core Interview Question	Source
Engagement	Participation in discussions, activeness in quizzes/animations	Interest and experiences in interactive learning	Students & Teacher
Motivation	Enthusiasm, persistence, positive attitude	Interest, independence, self-confidence	Students
Conceptual Understanding	Explanation of concepts, accuracy in exercises	Understanding of concepts before–after ML	Teacher
Teacher Interaction	Feedback and use of ML features	Ease of classroom management and progress monitoring	Teacher
Technology Utilization	Independence in operating the application	Experiences and technical challenges in device use	Students & Teacher

The data analysis techniques combined quantitative and qualitative approaches. Learning outcomes were analyzed using paired t-tests and ANCOVA to measure significant improvements between pretest and posttest, aligning with statistical practices in multimedia development research (Guntur et al., 2023). Motivational data were analyzed descriptively and inferentially with Cronbach's Alpha for reliability testing, while observational and interview data were analyzed through reduction, presentation, and conclusion drawing according to the Miles and Huberman model.

Results and Discussion

The initial stage of the study focused on mapping problems and needs through classroom observations, student questionnaires, and teacher interviews. These activities highlighted the main challenges in teaching social arithmetic at SD Negeri 14 Batu Nanta: low student motivation and engagement. At the same time, they provided an overview of digital

infrastructure readiness and students' habits in using mobile devices. These findings confirmed previous studies that emphasized the importance of utilizing interactive learning technology and mobile learning to enhance motivation and mathematics achievement (Andriah & Amir, 2021; Suprianto et al., 2019).

Table 2. Main Findings at the Analysis Stage

Analyzed Aspect	Key Findings
Content Difficulties	67% of students experienced difficulties in understanding social arithmetic concepts (buying–selling, discounts, profit, tax).
Learning Motivation	57% of students showed low motivation: easily bored, passive during lessons, and lacking interest in doing exercises.
School Digital Infrastructure Readiness	The school had 32 Chromebook units, stable internet access, and 100% activation of teacher learning accounts.
Device Ownership & Usage Habits	92% of students owned personal smartphones and were accustomed to using them for daily digital activities.
Teaching Methods	Lessons were still dominated by lectures, PowerPoint, and written exercises; interactive media use remained low.

Observation data indicated that mathematics learning remained teacher-centered with minimal interaction, consistent with (A. Fitri & Amelia, 2021) findings on low student engagement when digital media were not optimized. The questionnaires revealed students' strong interest in media featuring animations, quizzes, and gamification, supporting the recommendations of (Suprianto et al., 2019) that mobile learning effectively fosters independence and motivation. Teacher interviews emphasized the need for user-friendly, curriculum-aligned technology-based media, consistent with evidence that interactive multimedia and Android applications can improve mathematics conceptual understanding (Batubara, 2018).

These preliminary findings formed the basis for developing an interactive mobile learning medium using the ADDIE model. The design phase emphasized formulating curriculum-based learning objectives, preparing a storyboard, and designing a child-friendly, engaging interface. The instructional strategy integrated problem-based learning, cooperative activities, and features such as animations and quizzes, in line with (Andeswari et al., 2022), as well as evidence that animation- and gamification-based interactive media can increase motivation and learning outcomes (Gartika et al., 2019).

Table 3. Results of the Design Phase

Design Component	Key Results
Learning Objectives	Formulated with the SMART principle, emphasizing conceptual understanding of social arithmetic and contextual applications.
Storyboard	Included screen flow, layout sketches, text placement, animations, and interactive quizzes as development guidelines.
User Interface (UI)	Designed with bright colors, intuitive icons, and simple navigation to be child-friendly.
Learning Strategy	Combined problem-based learning, cooperative group work, and quiz-based independent activities.
Interactive Features	Animations, contextual illustrations, and adaptive quizzes to enhance engagement and conceptual understanding.

The formulation of specific, measurable, and curriculum-based learning objectives ensured alignment with national competencies while addressing student needs, as recommended by in the ADDIE (Branch, 2009) model. The storyboard was developed as a detailed guide for screen flow and interaction, supporting multimedia design effectiveness (Julia & Bentri, 2023). The child-friendly and easy-to-navigate interface promoted independent learning, reinforcing findings from (Andriah & Amir, 2021) on the importance of accessibility in mobile learning. The integration of animations and adaptive quizzes enhanced visual appeal and stimulated active engagement and conceptual understanding, consistent with (Dhaniawaty et al., 2023) on digital game-based learning. This design provided a solid foundation for developing the interactive mobile learning prototype.

At the development stage, the design was implemented into a mobile learning application prototype for teaching social arithmetic. The prototype integrated curriculum objectives, the storyboard, and a child-friendly interface, then underwent validation by media and subject matter experts to ensure content accuracy, visual consistency, interactivity, and navigational ease. This approach followed digital media development practices emphasizing expert review prior to field trials (Batubara, 2018; Julia & Bentri, 2023).

Table 4. Results at the Development Stage

Development Component	Key Findings
Prototype Development	The ML application was developed as an interactive microsite featuring animations, adaptive quizzes, and simple navigation.
Media Expert Validation	Assessed aesthetics, text readability, animation quality, access speed, and interface responsiveness.
Content Expert Validation	Examined curriculum alignment, accuracy of social arithmetic concepts, and relevance to learning objectives.
Product Revision	Improvements in color schemes, navigation icons, and restructuring of some quiz items based on expert feedback to enhance usability.

The development process emphasized the importance of iterative revisions to ensure the final product's feasibility and effectiveness. Media expert validation confirmed that the application's visual design and interactivity supported student engagement, consistent with recommendations from interactive multimedia research (Latifa et al., 2020). Content expert validation ensured the accuracy of mathematical concepts, reinforcing findings from (Padmawati & Agustika, 2021) and (Nanda et al., 2022) that content accuracy is crucial for mobile learning success.

Feedback from both experts resulted in significant improvements in visual quality and content presentation, making the prototype ready for classroom testing. This validation phase was an essential part of formative evaluation within the ADDIE model, which emphasizes iterative expert reviews to refine products and ensure they meet technical, visual, and academic standards before large-scale implementation (Anjarsari et al., 2020; Arliani & Khabibah, 2022).

Table 5. Results of Media and Content Expert Evaluations

Validation Type	Focus of Assessment	Key Findings
Media Expert	Design aesthetics, text readability, animation quality,	The interface was considered attractive and child-friendly; text was easy to read;

	access speed, and interface responsiveness.	animations were smooth; loading time was fast; navigation was responsive.
Content Expert	Curriculum alignment, accuracy of social arithmetic concepts, and consistency with learning objectives.	The content fully aligned with the elementary school curriculum; social arithmetic concepts were accurate; learning objectives were clearly achieved.

The media expert validation assessed visual and technical aspects, including design aesthetics, text clarity, and the performance of animations and interface responsiveness. The results indicated that the application was visually appealing, suited to elementary school learners, with clear text, smooth animations, and stable access supporting (Batubara, 2018) findings on the importance of visual design and responsive interfaces in educational multimedia. The content expert validation ensured the accuracy of curriculum-based mathematics content, social arithmetic concepts, and alignment with learning objectives. All materials were rated as appropriate and supportive of competency achievement, consistent with (Suprianto et al., 2019), who emphasized content alignment as a determinant of digital media success.

The implementation stage then tested the effectiveness of mobile learning media through a quasi-experimental pretest–posttest design, dividing fifth-grade students at SD Negeri 14 Batu Nanta into an experimental group using the ML application and a control group taught through conventional methods. This design enabled comparative assessment of the media’s impact on motivation and mathematics learning outcomes, following recommendations in development research emphasizing empirical testing with controlled variables (Dewi & Ramadan, 2021; Rustam et al., 2022).

Table 6. Key Findings at the Implementation Stage

Implementation Component	Key Findings
Trial Design	Quasi-experiment with a pretest–posttest scheme using experimental and control groups.
Experimental Group	36 students used the interactive ML application over four sessions; animation and quiz features were fully activated.
Control Group	36 students followed conventional mathematics learning using lecture and practice methods.
Measurement Instruments	Social arithmetic achievement test, Likert-scale motivation questionnaire, and student activity observation sheets.
Initial Observation Results	Students in the experimental group demonstrated higher engagement and positive responses toward digital media.

The initial implementation results indicated that students in the experimental group were more active in discussions, asked more questions, and completed quizzes more frequently compared to the control group. These findings highlight the potential of mobile learning (ML) to enhance student engagement and independent learning, consistent with (Suprianto et al., 2019) on the effectiveness of ML in elementary schools. Preliminary analysis also showed an increase in motivation and learning outcomes in the experimental group, supporting the findings of (Dhaniawaty et al., 2023) regarding the role of game-based and animation-supported media in fostering interest and conceptual understanding in mathematics.

Data collection during the implementation phase focused on changes in motivation and learning achievement following the use of interactive ML media. Data were gathered through pretest–posttest assessments, direct classroom observations, and structured interviews with both students and teachers. This mixed-method approach ensured the validity of findings and provided a comprehensive picture of the media’s effects, in line with instructional development principles emphasizing layered effectiveness testing (Branch, 2009; Subhan et al., 2023; Vebimawarti, 2018).

Table 7. Mean Pretest–Posttest Results of Control and Experimental Groups

Group	Total Pretest Score	Mean Pretest	Total Posttest Score	Mean Posttest	Mean Gain
Control	1,529	42.47	1,709	47.47	+4.99
Experimental	1,475	40.97	2,609	72.47	+31.50

The pretest results showed that both groups had relatively comparable initial abilities (42.47 for control and 40.97 for experimental). However, after the learning intervention, the experimental group using interactive ML media achieved an average gain of 31.5 points substantially higher than the control group’s gain of 4.99 points. These findings provide strong evidence that the integration of animations, quizzes, and interactive features significantly improves the understanding of social arithmetic concepts while enhancing learning motivation, consistent with (Andriah & Amir, 2021) on the positive impact of mobile learning on academic achievement.

Table 8. Statistical Test Results

Analysis	Group	Mean Pretest	Mean Posttest	t-value (paired)	p-value
Paired t-test	Control	42.47	47.47	4.21	0.0003
Paired t-test	Experimental	40.97	72.47	18.85	0.0000
ANCOVA	Experimental vs. Control			F (1,69) = 145.6	0.0000

The statistical findings of this study help create a clear picture of the way in which learning develops according to various pedagogical conditions. The control group showed a slight improvement in the mean score between 42.47 and 47.47 with t-value of 4.21 and the p-value of 0.0003. Though statistically significant, this small increment indicates the limited movement in pedagogy i.e. that learning in traditional settings is usually predictable and superficial. It seems that students develop by being exposed to material and repetition, but this may not necessarily enhance conceptual knowledge and independent thinking. The figures consequently point to the fact that the progress in this area is based on exposure and not on significant transformation, where learning takes place within the precincts of known standards of teaching.

The performance of the experimental group shows a greater change. The mean score dramatically increased with the rise of 40.97 to 72.47 with the help of a t-value of 18.85 and p-value of less than 0.0001. This drastic growth cannot be just attributed to repetition but it represents a shift in the way students approached knowledge. The intervention seems to have created room so that learners are now able to think critically, interpret, and take actions on ideas more freely. They stopped being passive receivers of information and made themselves active contributors of meaning-making, building up understanding on the basis of reflection,

discussion, and facilitated autonomy. The statistics indicate that learning turned into experience and not a mechanical reaction, which is reminiscent of active and transformative learning, in which learners gain possession of their intellectual experience.

The additional evidence is the findings of ANCOVA, which demonstrate that there was a significant differentiation between groups even after initial differences were taken into account ($F(1,69) = 145.6, p < .0001$). This result is consistent, and it proves the fact that the improvement which was observed in the experimental group was not an accident but it was supported by the very structure of the instruction. The well-organized and, at the same time, mobile world provided chances to communicate, work in cooperation, and explore things, which tend to make people more curious and can maintain their motivation. Learning can become internalized, when the students have the room to experiment and reflect, not only the progress will be measured by quantitative measures, but also the relationship to what is being learned.

The results highlight a crucial reality related to the education process: what matters is not the amount of education but the kind of interaction it develops. The experimental group success proves that the ability of the students to grow is higher than it might be expected when they are treated as thinkers but not as recipients. Their progress is evidenced not just in their acquisition of new skills but also in a new confidence, mission and intellectual agency. The statistical findings, accurate in their own manner, eventually demonstrate a very human process, namely the shift of learning to compulsory repetition to the inquiry, from obedience to the actual discovery, and from the mere knowledge to the profound insight.

Table 9. Learning Motivation Analysis Results

Group	Mean Motivation Score	Improvement (%)	Cronbach's Alpha	Reliability Interpretation
Control	Pre: 3.05	Post: 3.30	+8%	0.88
Experimental	Pre: 3.10	Post: 4.03	+30%	0.90

Descriptive analysis showed that the experimental group using ML media experienced a 30% increase in motivation scores, far higher than the control group's 8%. This increase reflects greater enthusiasm, persistence, and interest in mathematics after engaging with animations, quizzes, and gamification features, in line with (Dhaniawaty et al., 2023) on the motivational role of digital games. Cronbach's Alpha reached 0.90 for the experimental group and 0.88 for the control group, both categorized as "highly reliable," indicating strong internal consistency of the questionnaire and meeting educational instrument development standards (Ratnasari et al., 2021). These results confirm the validity of motivation data in supporting the conclusion that interactive ML media significantly enhances student learning motivation.

Table 10. Observation and Interview Results

Aspect	Control Class	Experimental Class
Student Engagement	Low participation in discussions; most waited for teacher instructions.	Students actively asked questions, completed quizzes, and engaged with interactive animations throughout lessons.
Learning Motivation	Limited enthusiasm, easily bored; motivation increased only by ~8%.	High enthusiasm, consistently followed activities; motivation increased ~30%, consistent with survey results.

Concept Understanding	Mean posttest score 47.47; difficulties remained with buying selling and discount concepts.	Mean posttest score 72.47; most students could explain social arithmetic concepts and apply them in contextual problems.
Teacher–Student Interaction	Predominantly one-way communication; teacher as the main learning source.	Two-way interaction; teacher facilitated discussions and provided feedback through app features.
Technology Utilization	Limited to PowerPoint presentations; students rarely used digital tools independently.	Full utilization of ML media: students independently operated the app, using animations and quizzes as primary learning tools.

Observations highlighted sharp differences between the two classes. The control group remained lecture- and exercise-dominated; teachers reported partial concept mastery but noted minimal interaction and declining motivation, consistent with (Suprianto et al., 2019) on the limitations of conventional methods. Conversely, the experimental class displayed dynamic learning: students actively discussed, eagerly engaged in quizzes, and demonstrated deeper understanding of social arithmetic concepts. Teachers observed that mobile learning facilitated progress monitoring and encouraged two-way communication. Student interviews confirmed that animations and gamification made lessons “more enjoyable and easier to understand,” echoing (Dhaniawaty et al., 2023) on the effectiveness of digital games in enhancing motivation. These qualitative findings reinforce the quantitative pretest–posttest and statistical results, showing that ML-based interactive media enhances engagement, motivation, comprehension, and technology use, while fostering more effective teacher–student interactions.

Table 11. Findings at the Evaluation Stage

Type of Evaluation	Assessment Focus	Key Findings
Formative	Expert validation of media and content, limited trials, prototype revision.	Improvements in interface (color, navigation icons), refinement of quizzes and animations, and restructuring of some items for readability.
Summative	Media effectiveness on motivation and learning outcomes based on pretest–posttest, observation, and interviews.	Average score rose from 40.97 to 72.47 (+31.5 points); motivation increased by ~30%; high levels of student engagement and independence.

During formative evaluation, expert validations of media and content were conducted from design through development. Media experts refined visual design and navigation, while content experts ensured mathematical alignment with the elementary school curriculum. Iterative revisions followed best practices in multimedia development as recommended by (Julia & Bentri, 2023) regarding the importance of expert review prior to field trials. Following implementation, summative evaluation demonstrated the significant impact of mobile learning (ML) media on both learning outcomes and motivation. The experimental group’s posttest scores increased by an average of 31.5 points, far surpassing the control group’s gain of 4.99 points. Observations and interviews confirmed greater enthusiasm, active discussion, and improved confidence in explaining social arithmetic concepts, supporting (Putri et al., 2022)

on ML's academic benefits and (Dhaniawaty et al., 2023) on the effectiveness of digital gamification.

Reframing Mathematics Learning through Interactive Mobile Pedagogy: Motivation, Cognition, and Contextual Engagement

The results of this research paper set in motion a covert but powerful discussion on the legitimate standards of making mathematics relevant to kids. The significant increase in the motivation and the performance of the students is not only a telling indication of a successful innovation, but a good indication that learning is an active process when allowed to take place in a human-relatable manner. Once technology is introduced in the classroom not as a spectacle but as a continuation of curiosity, then it changes the topography of affect in learning. Math which often seems so distant and so mechanical is turned into something to be discovered instead of being suffered. Although this change can be measured by numbers and tests, it ultimately comes to be felt in gestures, in tones, in the air of the room, the laughter of finding out, the silent attention which succeeds understanding, the shy pride which succeeds the solving of a problem on your own. In this respect, the effectiveness of mobile learning (ML) in this research is not vested on the complexity of its code, but due to its ability to re-establish an affinity between learning and affect.

Observation was beginning to speculate that what it was not their capacity which changed most among the students, but their character. The children met mathematics with a new hitherto sensitive responsiveness and with a willingness to fail, to experiment and to make a second attempt. This slight change of attitude is attributable to the thirty-percent increase in motivation scores; but the statistics are not the most effective means of measuring the vibrations that started to run through the classroom. Students bent forward and shared ideas with each other, discussed answers, and asked questions, which went beyond the screen. They did not engage in response to novelty but were responding to ownership. In the course of the interaction challenges they experienced, they started perceiving themselves not as receivers of knowledge but as co-builders of knowledge. Theory Suprianto et al. (2019) and Ratnasari et al. (2021) have demonstrated that the two motivation drivers of digital learning are autonomy and feedback because they are twin engines. The current research proves that view right and goes a step further: as soon as a child comes to the feeling that the effort he puts in has a immediate and noticeable effect, so that feedback has taken the shape of a discussion, children start to be interested once again in the process, rather than in the result.

This process of shift was also the process of transformation of the development of the understanding as this became active rather than passive. Students started to play with ideas as opposed to replicating patterns or memorizing steps. They were playing with figures, proving the hypothesis and comparing their responses as quickly as possible. This type of cognitive discourse was stimulated by the media itself. It was not just the information that was presented in the form of animation; it was something that caused thinking. Quizzes were not an evaluation but a reflection of understanding, every wrong answer was a silent invitation to go on a second try. With this interactive and reciprocal action and reflection, learning was developed into an ongoing process of developing refinement. This is consistent with the results of Andriah and Amir (2021), who indicated that the strength of mobile learning is found in the fact that it can be used to make abstract ideas concrete and experience the results. Interactivity allowed students in this research not only to memorize the formula of calculating the discounts or profits but also to start seeing the logic behind the formula that makes them significant. This type of learning was no longer enforced on them but acted out.

What gave such transformation a specific richness was the way in which the media put mathematics in a grounding in the mundane fabric of life. The issues and images were sourced out of markets, stores and day to day deals- the type of world children subconsciously know. This familiar ground gave the abstract numbers a base to establish themselves in the memory and imagination. In cases when the students were computing the price of goods, talking about the definition of profit, or approximating taxes, they were not only working with exercises but reciting bits of their social world. This is the entirety of ethnomathematics as expressed by Halimah and Kurniawati (2022) and Yandani and Agustika (2022): mathematical thinking is most genuine when it is formed as a result of what learners have experienced. The happiness that I saw on the faces of students in these sessions was not the happiness of amusement but the happiness of being understood and getting to know how mathematics was already present in their lives. In this contextual design learning reestablished its relevance, technology which had led to distance, was used to reconnect.

This pedagogical reawakening was manifested in the experiences that were described by the teachers. Instead, they were not sent home by technology, but their role as instructors was deepened. Teachers were free of the constant urge to explain, which enabled them to pay more attention to student cognition to observe the patterns of reasoning, their hesitation, and collaboration. They therefore shifted to being de facto knowledge reporters to being keen learners. This development is in line with the pedagogical changes reported by Rustam et al. (2022) and Andriah and Amir (2021), who outline how online spaces allow teachers to become facilitators, mentors, and co-learners. These roles also emerged naturally in the current study, without resistance. Teachers had classrooms that were more colorful, their students were more expressive and their professional practice was more meaningful. The machine-learning media became a common point of interest whereby the Teacher and the learner would meet in curiosity and not authority. This subtle shift of authority between human and digital, between teacher and student, implies that the most important role of technology might be not to deliver content but rather to redefine relationships.

Below these changes is a design philosophy that is based on empathy and not efficiency. The designing of the machine-learning media was influenced by the fact that children view the world in a different way, they need things in a clear but not sterile way, in a structured but not rigid manner. The choice of bright and harmonized colour schemes, smooth transitions, and the lack of complicated navigation were not only attractive decisions but invitations to cognition. Intuitive design reduces mental load and leaves the cognitive load to be created in the mind, which is necessary to reflect on (Latifa et al., 2020; Nanda et al., 2022). The mind is free of confusion and can then focus on meaning. Such design harmony could be observed in this research whereby the students were able to navigate through the application smoothly. They did not need to be instructed in the matter, it was discovered in the same manner as motor skills. The success of the media thus lay in its invisibility the ability to direct cognition but without attracting too much attention to itself. This balance between the uncomplicated and the interactive makes digital media a potential distracter, turned into a pedagogical tool.

In the midst of these mental and aesthetic aspects, there occurred a deeper experience, feelings of agency. Students started to take independent choices in terms of ways of dealing with task, when to revisit a challenge and how to interpret feedback. The free cooperation that came in the forms of exchange of strategies and common findings transformed the classroom into a small learning community. Nothing that might seem to the surface as play is, in reality is, the embryonic form of self-regulated learning. Dhaniawaty et al. (2023) and Nurfatanah et al. (2021) also revealed similar developments and stated that game-based settings prompt students or individuals to self-track their progress using cyclic processes of trial, error, and insight. In

this case, these patterns occurred not as prescriptive game mechanisms but as an inherent attitude to knowledge. The learners developed perseverance, self-assessment and appreciation of the learning steps as part of the learning rhythm. These examples of spontaneous independence have the potential of going outside the mathematics classroom.

The questions of sustainability, which are often ignored in the studies that are technology-based, were brought up implicitly through the design accessibility. The machine-learning system was designed as a microsite, which can easily be modified to different devices, and equally simple enough to be operated independently by teachers. This was not a coincidental decision, it was a result of an ethical belief that innovation should not be limited to resource-rich institutions, but rather, it should be accessible to everyone. The reality of digital pedagogy as Vawanda and Zainil (2023) point out is the ability to access average classrooms without increasing the existing inequalities. These educators in this research cited the media to be friendly and flexible and they were confident of continuing using it without any external technical resources. This kind of accessibility will make sure that innovation is not a one-time event, but something that is integrated with the everyday pedagogical practice of an activity, as opposed to disrupting it.

The final distinction between this study is the quality of the atmosphere that this study stirs up instead of the numerical data that the study depicts. Although the increases in the achievement scores and motivation are somewhat encouraging, these can be seen as mere surface effects of the real process happening: the silent revival of joy in the learning. This classroom was turned into a dynamic and mobile environment of movement, conversation, and laughter, in which mathematics was no longer being imposed on students as a mandatory task but discovered as a place of exploration. Educators simultaneously renewed their practice by seeing this as a form of mentoring and not control. The digital tool did not replace human presence but made it light, so that there was space to be empathetic, attentive and work together to re-weave at the core of teaching. These changes have highlighted by the study that educational technology is not always about efficiency, but above all, it is about bringing back the life in the process of learning.

The results all come down to a very basic but very significant principle: innovation works when it listens. The machine-learning media was a success not due to the spectacular display but due to their consideration of the thinking process of children, the demands of the teachers, and the environmental factors that create understanding. Such attentiveness facilitates learning. So, technology is not the focus of the story of this study but the design that respects the lived experience of the learner. Empathy, curiosity, and digital technology that is designed to serve meaning all make mathematics human again. The nature of education, as a dialogue between understanding and wonder is being reasserted in this rediscovery.

Conclusion

This study concludes that interactive learning media based on mobile learning (ML) has proven to be effective and feasible for improving the quality of mathematics learning on social arithmetic topics in elementary schools. Employing the ADDIE R&D model, all stages of development were carried out systematically and evidence-based. Expert validation ensured both technical and pedagogical appropriateness, while formative and summative evaluations demonstrated a significant increase in motivation and learning achievement: the experimental group's average posttest score rose from 40.97 to 72.47, far surpassing the control group. Inferential analyses (paired t-test and ANCOVA) along with questionnaire reliability (Cronbach's Alpha > 0.88) confirmed the validity of the findings. Observations and interviews further emphasized that ML media foster enthusiasm, independence, and two-way interaction

between teachers and students. Overall, the product is not only visually engaging and technically responsive but also generates tangible impacts on motivation and learning outcomes, making it ready for wide implementation as a digital learning innovation that supports 21st-century educational transformation.

Based on the findings, it is recommended that elementary schools begin integrating interactive learning media based on mobile learning (ML) as a complement to conventional methods to enhance students' motivation, independence, and mathematics achievement. Teachers should also receive training in technology utilization, interactive instructional design, and gamification to optimize the use of ML media in alignment with learners' needs. Furthermore, developers and education policymakers are encouraged to expand the application of the ADDIE model in digital media development by adopting validation, formative, and summative evaluation processes as quality standards. Future research is suggested to broaden the implementation of ML media across other subjects, different educational levels, as well as in online and hybrid learning contexts, and to conduct longitudinal studies to evaluate the sustainability of its impact on students' motivation and achievement.

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