MaPan : Jurnal Matematika dan Pembelajaran
p-ISSN: 2354-6883 ; e-ISSN: 2581-172X
Volume 13, No 2, Dec 2025 (448-470)
DOI: https://doi.org/10.24252/mapan.2025v13n2a11

Development of Nugle (Numerical Guide for Learning) Mobile Learning Media to Improve Students' Number Sense in State Islamic Junior High Schools

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Received July 7, 2025; Revised December 25, 2025; Accepted December 26, 2025
Available Online December 31, 2025

Abstract:
Mathematics is a fundamental discipline that supports problem-solving in daily life, particularly through number sense, which enables students to understand and reason flexibly with numerical concepts. However, research indicates that Indonesian students' number sense ability remains relatively low. To address this issue, this study developed a mobile learning–based instructional medium, namely the Numerical Guide for Learning (Nugle), to enhance students' number sense abilities. The development followed the ADDIE model, which includes Analysis, Design, Development, Implementation, and Evaluation. Nugle was implemented with 32 seventh-grade students at MTsN 4 Surabaya. Data were collected through field notes, expert validation sheets, teacher and student practicality questionnaires, as well as pre-test and post-test assessments. They were analyzed using descriptive and inferential statistics. The results indicate that Nugle is categorized as highly valid, with an average score of 4.7 from content experts and 4.6 from media experts. The media was also considered very practical by students (86.30%) and practical by teachers (77.5%). Furthermore, Nugle proved to be effective in improving students' number sense abilities, as indicated by 59.4% of students achieving moderate to high N-gain improvement. These findings suggest that Nugle is suitable for use as a learning medium to support the enhancement of students' number sense and is worthy of further investigation in broader classroom contexts.

Abstrak:
Matematika adalah disiplin ilmu dasar yang mendukung pemecahan masalah sehari-hari, terutama melalui pemahaman angka (number sense), yang memungkinkan siswa untuk memahami dan berargumen secara fleksibel dengan konsep numerik. Namun, penelitian menunjukkan bahwa kemampuan pemahaman angka siswa Indonesia masih relatif rendah. Untuk mengatasi masalah ini, penelitian ini mengembangkan media pembelajaran berbasis mobile learning, yaitu Numerical Guide for Learning (Nugle), untuk meningkatkan kemampuan pemahaman angka siswa. Pengembangan mengikuti model ADDIE, yang meliputi Analisis, Desain, Pengembangan, Implementasi, dan Evaluasi. Nugle diimplementasikan pada 32 siswa kelas VII di MTsN 4 Surabaya. Data dikumpulkan melalui catatan lapangan, lembar validasi ahli, kuesioner kepraktisan guru dan siswa, serta tes pra dan pasca, kemudian dianalisis

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menggunakan statistik deskriptif dan inferensial. Hasil penelitian menunjukkan bahwa Nugle tergolong sangat valid dengan skor rata-rata 4,7 dari ahli materi dan 4,6 dari ahli media. Media ini juga dinilai sangat praktis oleh siswa (86,30%) dan praktis oleh guru (77,5%). Selain itu, Nugle terbukti efektif dalam meningkatkan kemampuan *number sense* siswa, yang ditunjukkan oleh 59,4% siswa yang mencapai peningkatan N-gain pada kategori sedang hingga tinggi. Temuan ini menunjukkan bahwa Nugle layak digunakan sebagai media pembelajaran untuk mendukung peningkatan kemampuan *number sense* siswa dan layak untuk diteliti lebih lanjut dalam konteks kelas yang lebih luas.

Keywords:
Mobile Learning, Learning Media, Number Sense, Mathematics Education

How to Cite: Arum, W. F., Sutini, & Zhara, T. A. (2025). Development of Nugle (Numerical Guide for Learning) Mobile Learning Media to Improve Students' Number Sense in State Islamic Junior High Schools. *MaPan: Jurnal Matematika dan Pembelajaran*, 13(2), 448-470. https://doi.org/10.24252/mapan.2025v13n2a11.

INTRODUCTION

Mathematics plays a central role in developing students' cognitive abilities and supporting their success across academic disciplines. As the foundation of scientific thinking, mathematics fosters logical reasoning, critical analysis, creativity, and problem-solving skills that are essential for navigating real-world challenges (Arjudin, Sutiarso, & Mahmudah, 2024; Aminah, Lestari, & Yuliani, 2022). Among many domains of mathematics, the concept of numbers is fundamental because it supports students' readiness to engage with advanced topics such as algebra, geometry, and statistics. The National Council of Teachers of Mathematics (NCTM) emphasizes that the conceptual understanding of numbers developed in the early years strongly predicts long term mathematical achievement (Midgett & Eddins, 2001).

An important aspect of numerical understanding is the sense of numbers, which refers to an intuitive, flexible, and meaningful understanding of numbers and numerical relationships. The sense of numbers is reflected through several main indicators, including the ability to compare quantities and numerical values, make estimates, perform simple mental calculations, assess the fairness of results, and choose efficient solution strategies according to the context of the problem. Students with a strong sense of numbers can make estimates, perform mental calculations, assess the fairness of answers, and choose efficient

strategies in various contexts (Wulandari, 2023; Mohamed & Johnny, 2010). International assessments such as PISA and TIMSS consistently report that Indonesian students experience persistent challenges in numerical reasoning, estimation, and non-algorithmic thinking—core components of the sense of numbers (Jordan, Glutting, & Ramineni, 2010; Nurdiana, 2018). Recent national studies echo this pattern, showing that many Indonesian students show limited fluency in comparing numbers, understanding quantities, and interpreting numerical representations (Hermita, Alim, Putra, , Gusti, Wijaya, , & Pereira, 2021; Nurdiana, 2018).

Responding to the challenge of low number sense, mobile learning is seen as a strategic solution because its characteristics are aligned with the need for intuitive and gradual numerical skill development. The sense of numbers does not develop through mere exposure to procedures, but rather through repeated training, active exploration, and direct interaction with numerical representations in a variety of contexts. Mobile learning allows students to engage in these activities flexibly, both in terms of time, place, and learning pace, thus providing a wider opportunity to build personal and sustainable numerical understanding (Bano, Zowghi, Kearney, & Sherratt, 2018; Tang, Chen, & Zhao, 2023).

In addition to flexibility, the accessibility of mobile devices makes it a naturally integrated medium in students' daily lives. In the Indonesian context, the use of smartphones has spread across various socio-economic backgrounds, so mobile learning has the potential to have a more equitable reach than special device-based media. The integration of learning into devices that students are already familiar with allows numerical activities to be carried out spontaneously and contextually, conditions that support the reinforcement of the sense of numbers through repetitive and meaningful learning experiences.

Furthermore, mobile learning allows for the multimodal and interactive presentation of math content, which is important for facilitating the understanding of abstract numerical concepts. Visual representations, direct manipulation, and immediate feedback help students test estimates, assess the fairness of results, and reflect on the strategies used. Previous studies have shown that mobile math apps designed with the right scaffolding are able to increase engagement and support students' conceptual understanding (Martinez-Gomez & Nicolalde, 2025; Meylani, 2025). However, while the number of mobile based math apps continues to increase, many of them still focus on procedural exercises, rely on a stable internet connection, or have not

yet provided learning trajectories that take into account students' diverse learning readiness. This condition shows that there is a gap between the pedagogical potential of mobile learning and its actual implementation, especially in the context of the development of the sense of numbers that requires a structured, adaptive, and oriented approach to numerical thinking processes (Lubis, 2023; Mboneni, Chigona, & Mhlongo, 2024).

To address this gap, the study developed a Numerical Guide for Learning (Nugle) mobile learning app built on the Thunkable platform, with cross-device compatibility for Android and iOS. Nugle integrates visual representations, audio guides, interactive examples, and game-like quizzes to support intuitive numerical reasoning. It also incorporates differentiation features that categorize learners into Adventurer, Explorer, and Conqueror levels based on readiness, providing a scaffolding path that aligns with different instructional principles (Hall, Strangman, & Meyer, 2003; Tomlinson, 2014). Unlike many existing tools, Nugle is designed for offline use and embeds all instructional components, including materials, examples, and assessments, in a single app, reducing reliance on external links or internet access.

Based on the theoretical and empirical gaps outlined above, this study aims to examine the development, validity, practicality, and effectiveness of Nugle in improving students' sense of number abilities. The novelty of this research lies not only in the cross platform and offline functionality of Nugle, but also in its explicit foundation on the principles of learning different senses of numbers and instructions. By integrating evidence-based pedagogical strategies in a flexible and mobile environment, this research seeks to advance digital mathematics education and provide accessible and scalable solutions to strengthen the sense of numbers among secondary school students.

METHODS

The study used a research and development (R&D) approach to create and evaluate a mobile-based instructional media tool, Numerical Guide to Learning (Nugle), designed to improve students' number sense skills. The development process follows the ADDIE model: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was chosen because of its systematic and iterative structure, allowing developers to align instructional products with learner characteristics, curricular demands, and targeted competencies. Unlike other development models such as 4D, ASSURE, or Kemp, which emphasize product refinement or instructional delivery,

ADDIE offers a more comprehensive framework that integrates needs analysis, prototype design, formative evaluation, and implementation feedback. This makes it particularly suitable for addressing the deficit of the sense of numbers, as it allows the media development process to incorporate the diagnostic insights of the Analysis stage and repeated pedagogical adjustments during the Design and Development stage, ensuring that the resulting tools are technically functional and pedagogically aligned with the numerical sense-oriented learning strategies. These reinforced reasons support the methodological suitability of the use of ADDIE in the development of Nugle.

At the analysis stage, the researcher conducts needs analysis, curriculum studies, and assessments of student learning characteristics. This stage aims to identify the main problems related to the development of the sense of numbers and ensure the suitability of media content with the demands of the applicable curriculum. The design stage is focused on the preparation of a media design that includes interface layouts, learning flows, and user experience structures that support gradual and interactive numerical learning. The development stage includes the creation of Nugle learning media using the Thunkable platform. The developed products are further validated by subject matter experts and media experts to assess content suitability, clarity of display, and usability. Input from experts is used as a basis for revisions before the media is implemented in learning. The implementation stage is carried out through a limited trial in the classroom, where students use Nugle media as part of the mathematics learning process in accordance with the learning principles in the Independent Curriculum. After the use of media, students were asked to fill out a questionnaire to respond to the practicality and ease of use of media. The data obtained from this questionnaire were used as an initial evaluation material on the quality of the media. The evaluation stage is focused on assessing the quality of the media based on the results of expert validation and student responses. The final revision was carried out to improve Nugle's learning media so that it can be used as a supporting medium for numerical learning.

The research was conducted at MTsN 4 Surabaya City during the second semester of the 2024/2025 academic year. The participants consisted of 32 seventh-grade students from class VII-D. Classes are selected through purposive sampling based on recommendations from math teachers. To minimize subjectivity, the selection criteria were operationalized as follows: (1) the class showed stable classroom management conditions, demonstrated by consistent learning engagement and low levels of disruptive behavior; and (2)

classrooms had adequate supporting facilities, including access to school-provided smartphones and internet when needed, ensuring all students could use the Nugle app effectively. Although this sampling approach is not random and may limit the generalization of findings, it is considered appropriate for R&D studies, which prioritize feasibility, controlled implementation, and suitability of the test environment. Nugle itself was developed using the Thunkable platform and is designed to operate on both Android and iOS devices, providing structured materials, problem examples, and integrated quizzes in a single mobile app.

Research data was collected through field notes, expert validation forms, questionnaires, and written tests. Field notes were used to document the media development process as well as learning activities during the trial, focusing on student engagement when using Nugle media and the role of teachers in facilitating their use in the classroom. Expert validation forms are used to assess the suitability of content and media design quality, while questionnaires are used to gather students' and teachers' perceptions regarding the practicality and ease of use of media. In addition, pre-test and post-tests are used to measure students' number sense skills before and after using Nugle.

Data were analyzed using descriptive and inferential statistical methods. The validity of Nugle media is assessed through expert validation using a five-point Likert scale. The Average Validity Rating (AVR) is calculated for each component. This scoring system ensures that Nugle is evaluated not only on its appearance but also on the quality of the content, user interface, and pedagogical coherence. The results are classified into five categories, as shown in table 1.

Table 1. Validity Criteria for Nugle Media

Interval Score	Categories
$4 \leq AVR \leq 5$	Highly Valid
$3 \leq AVR < 4$	Applicable
$2 \leq AVR < 3$	Quite Valid
$1 \leq AVR < 2$	Less Valid
$0 \leq AVR < 1$	Not Valid

Similarly, the practicality of the media was evaluated based on questionnaire responses from students and teachers after they used the media. The questionnaire contains statements about ease of use, clarity of instruction, learning engagement, and relevance of content. This assessment also provides

diagnostic insights into specific aspects of the media, such as smooth navigation, screen design, and learner motivation. Responses were analyzed using the Percentage Response Score (PRS). A higher PRS indicates that the media is considered more practical and user-friendly in supporting classroom learning activities (Akker, Van den, McKenney, & Nieveen, 2013; Nieveen, 1999). In addition, the PRS results provide empirical evidence for determining whether the media can be implemented effectively without significant technical or instructional barriers (Tessmer, 1993). Total PRS is used to determine practicality based on the following categories, as shown in table 2.

Table 2. Practicality Criteria Based on Questionnaire Scores

Percentage Interval	Categories
80% ≤ PRS < 100%	Very Practical
60% ≤ PRS < 80%	Practical
40% ≤ PRS < 60%	Quite Practical
20% ≤ PRS < 40%	Less Practical
0% ≤ PRS< 20%	Impractical

Effectiveness is evaluated based on student learning outcomes, which are measured through pre-test and post-test results. This test is designed to assess various components of the sense of numbers, including estimation, numerical comparison, and mental calculations. The results were analyzed using the Normalized Gain Score (N-gain) to measure the level of learning improvement. A categorization of the level of effectiveness is provided in table 3.

Table 3. Effectiveness Criteria Based on N-gain Score

N-gain score	Categories
g ≥ 0.7	Height (3)
0.3 ≤ g < 0.7	Medium (2)
g < 0.3	Low (1)

Media Nugle is considered effective if more than 50% of students achieve a moderate or high gain score. Furthermore, statistical tests are used to determine the significance of improvements. The Shapiro-Wilk test is used to assess normality, followed by a paired sample t-test if the data is distributed normally, or the Wilcoxon signed-rank test otherwise. All statistical analysis was performed using SPSS version 25.

Through this comprehensive methodological framework, Nugle's development and evaluation are carried out in a rigorous and structured manner. The use of validated instruments, clear assessment criteria, and a combination of descriptive and inferential analysis ensures that media products are not only pedagogically sound but also practical and effective for implementation in mathematics teaching.

RESULTS AND DISCUSSION

Based on this research and development, the description of the results at each stage is as follows:

1. Analysis Phase

The analysis phase aims to identify educational gaps and inform the development of Nugle's mobile learning media. The researcher began by conducting a curriculum analysis that aligned the Nugle material with the Merdeka curriculum adopted at MTsN 4 Surabaya City. The curriculum emphasizes differentiated learning, a student-centered approach, and technology integration. The researcher examines the core competencies and specific learning objectives related to the sense of numbers to ensure that Nugle content meets instructional requirements.

In the needs analysis, it was found that many students showed weak abilities in interpreting numbers, making estimates, and assessing the fairness of the calculation results. These findings were confirmed through interviews with math teachers as well as direct observations in the classroom. For example, when students are asked to compare two simple fractions or estimate the result of an integer operation without algorithmically calculating, most students immediately resort to formal procedures and come up with unnatural answers, such as stating that the approximate result of 48 + 52 is close to 80 or that 3/4 is smaller than 2/3 without magnitude reasoning. In contextual problem-solving, students also tend to have difficulty determining whether the results of their calculations make sense in a given situation.

The results of the observation showed that students were actively engaged when using Nugle. They navigate the app independently after a brief initial tutorial, interact with visual and audio materials, and discuss answers with peers. Students in lower levels of differentiation review examples as learning supports, demonstrating the use of appropriate strategies. Teachers are facilitated by providing instruction, monitoring student progress, and

providing feedback during sessions. Classroom conditions remained conducive, and no significant technical issues occurred. This observation confirms that Nugle supports an interactive, manageable, and motivating learning experience.

Meanwhile, digital readiness analysis shows that most students already have and are used to using smartphones in their daily lives. Student characteristics indicate the need for visual, simple, and interactive learning media in order to support intuitive understanding of concepts. Based on these findings, Nugle is conceptualized as a mobile learning medium that can be accessed independently, facilitates numerical activities based on the sense of numbers, and is relevant to the student's learning context.

2. Design Phase

In the design phase, the structure of the media is outlined. The Nugle app features a main menu with four sections: Home, Materials, Examples, and Quizzes. Each topic integrates key indicators of number understanding: quantity recognition, flexible computing, estimation, and assessment of the fairness of results. Flowcharts and storyboards are created to visualize the navigation and delivery of content.

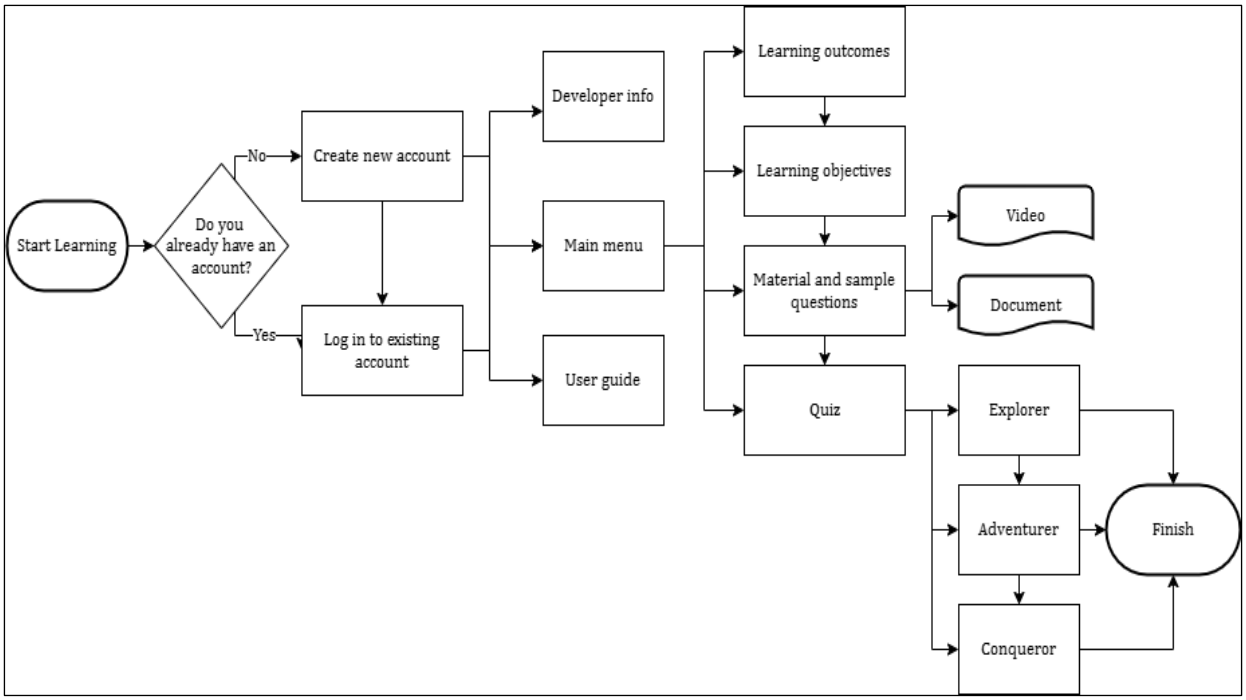


Figure 1. Product Flow Chart

Visual and interactive components are created in Canva, while Thunkable is used to implement functional design on Android. The medium adopts large icons, minimal text, and clear audio instructions to accommodate different levels of students' digital literacy. The questions in the quiz are upgraded to three levels of increased complexity, with automatic feedback after each attempt.

Data collection instruments were also prepared during this phase, including expert validation rubrics, teacher and student questionnaires, and pre- and post-tests that focused on numerical sense indicators.

3. Development Phase

The development phase involves converting the design into a working application using the Thunkable platform. Three experts then validated the Nugle prototype.

Experts assess content, media design, and technical functionality using Likert scale instruments. The following table summarizes the results of their validation:

Table 4. Nugle Expert Validation Results

Aspects	Validator Assessment 1	Validator Assessment 2	Validator Assessment 3	Average	RTV
Materials Expert Validation					
Content Relevance	4.8	5.0	4.0	4.6	4.6
Sense of Numbers	4.75	5.0	4.0	4.58	
Readability	4.5	4.75	4.0	4.42	
Media Validation					
Media Design	5.0	5.0	4.0	4.67	4.53
Language	4.5	4.75	4.0	4.42	
Software Engineering	4.6	5.0	4.0	4.53	
Audio	4.5	5.0	4.0	4.5	
Visualization	4.6	5.0	4.0	4.53	

RTV (Rubric Total Validity) values of 4.6 and 4.53 fall into the 4.0–5.0 range, which are classified as "very valid". These results confirm that the product has strong alignment with the curriculum, appropriate interface design, and functional learning features. However, some minor revisions are recommended by validators to improve usability and instructional clarity.

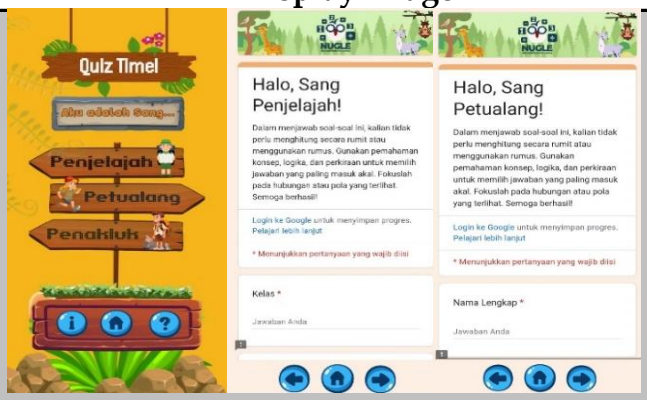
First, the login or account registration feature is removed. This decision was based on validator input and field feedback that showed that most seventh-graders did not have an active email address or enough digital literacy to manage accounts. Eliminating this step simplifies access and reduces potential barriers to use. Second, the format of the presentation of learning materials is revised. Initially, instructional content was displayed directly from Thunkable in a horizontal scrolling format, resulting in visual inconsistencies and navigation difficulties. To overcome this, the material is converted into PDF format and integrated into Thunkable. These changes allow for a cleaner, vertically scrollable layout that is more structured and user-friendly. Third, examples of early problems include conventional algorithmic solutions and numerical sense-based solutions. However, this is considered inconsistent with the product's learning objectives and has the potential to confuse students. The revised version now focuses exclusively on the numerical sense strategy, emphasizing flexible thinking and estimation without relying on standard algorithmic measures.

These revisions are implemented based on expert feedback and classroom observations to improve pedagogical clarity, accessibility, and consistency. Some of the revised product display pages are presented in table 5.

Table 5. Product Page Display

No	Display Image	Description
1.		Start and main menu screens.

No	Display Image	Description
2.	 	User guide and developer info
3.		Learning outcomes and objectives
4.		Learning materials and sample questions

No	Display Image	Description
5.		Rating screen
6.		Completion screen

The development of students' sense of numbers in the Nugle application is supported through the materials and quizzes provided, which combine key indicators of number sense, namely understanding numerical quantities, mental calculations, computational estimation, and evaluating the fairness of results. These indicators are embedded in instructional content and assessment features to promote meaningful mathematical thinking. The materials and quizzes in Nugle are carefully designed to present numerical problems that actively engage students in meaningful mathematical thinking. These problems encourage learners to compare quantities, make reasonable estimations before performing calculations, and critically evaluate whether the results obtained are logical and appropriate within the given context. By emphasizing estimation and reflection, Nugle helps students develop number sense and problem-solving skills rather than relying solely on procedural computation. Figure 2 illustrates how these instructional elements are integrated and implemented within the media to support students' learning processes.

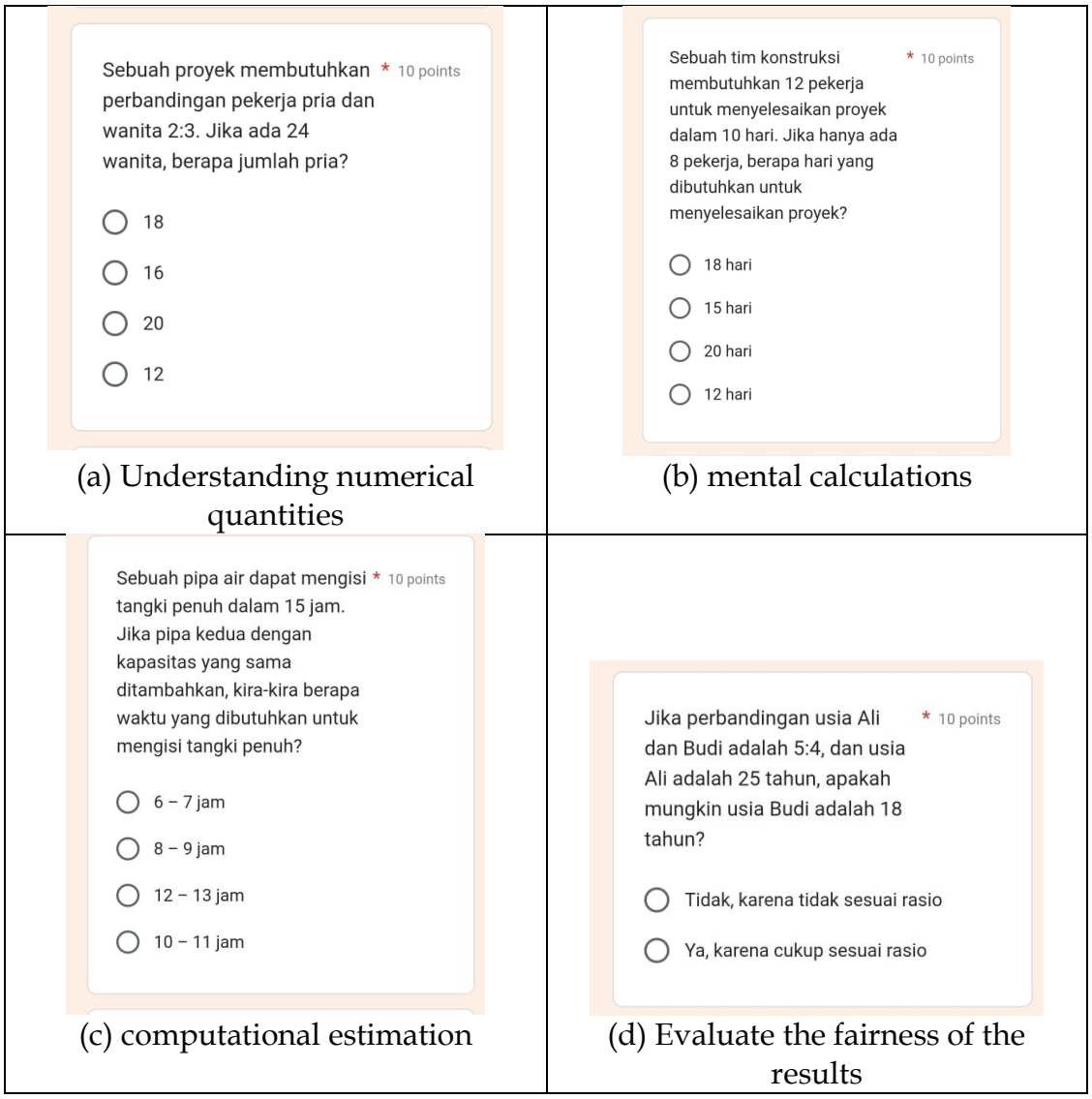


Figure 2. Examples of Numerical Sense Components in Nugle Media

4. Implementation Stage

After expert validation, Nugle was implemented in class VII-D at MTsN 4 Surabaya City, involving 32 students. The app is used over three sessions, including teacher-guided activities and self practice. The learning process integrates Nugle with different learning strategies, allowing students to access quizzes tailored to their proficiency level.

Specifically, Nugle features a three-level quiz structure labeled "Adventurer" (Explorer) for students with lower abilities, "Explorer" (Adventurer) for those with moderate abilities, and "Conqueror" (Conqueror) for students who demonstrate high-level thinking. Students are guided to try

out the quizzes starting from the appropriate level, and only after mastering the lower levels can they progress to the next level. This approach ensures that all students engage with material that matches their current abilities, fostering a sense of accomplishment and supporting the practice of scaffolding.

To assess the practicality of Nugle, both students and teachers fill out a practicality questionnaire after implementation. Practicality data is presented in table 5, which summarizes the average responses for each item.

Table 5. Practical Responses of Students and Teachers

Respondent	Average Score (%)	Categories
Students	81.79	Very Practical
Teacher	77.5	Practical

Student responses were particularly high for statements that showed motivation and clarity, such as "Nugle helped me understand the sense of numbers better" (91.07%) and "I feel more motivated using Nugle" (80.53%). Teachers report that Nugle is effective in differentiating instruction and managing diverse learning needs, while praising offline access and intuitive interface.

In addition to practicality, Nugle's effectiveness is measured using pre- and post-tests. This assessment focuses on the indicators of number understanding discussed in the application. Table 6 presents the average scores obtained from both tests.

Table 6. Pre-test and Post-test

Indicator	Means	Min	Max
Pre-test	45.78	20	90
Post-test	65.16	37	95
N-Gain	0.36	0.00	0.88

Table 7. N-gain Results

N-gain Category	Number of Students	Percentage
Pre-test	13	40.6%
Post-test	17	53.0%
N-gain	2	6.3%

As shown in table 6 and table 7, each student's pretest and post-test results are presented along with the calculated N-gain score and the corresponding categories. The table shows individual improvements, with some students making significant progress in their counting. For example, MH students achieve a pre-test score of 45 and increase to 90 on post-test, resulting in a high N-gain of 0.82 and a classification in category 3 (high). In contrast, some students, such as UI and MAP, show minimal gains, placing them in the low category. This variation illustrates the diversity of learning outcomes among students, potentially influenced by factors such as early ability, motivation, and learning strategies during Nugle use.

To summarize the distribution of these categories among students, table 8 presents the cumulative frequency, percentage, and percentage for each N-gain category.

Table 8. Distribution of Student's N-gain Categories

		Frequency	**Percentage**	**Applicable Percentages**	**Cumulative Percentages**
Applicable	Low	13	40.6	40.6	40.6
	Medium	18	56.3	56.3	96.9
	High	1	3.1	3.1	100.0
	Total	32	100.0	100.0	

The results of the frequency analysis showed that 13 students (40.6%) were in the low category, showing minimal improvement after using Nugle media. Meanwhile, 18 students (56.3%) were categorized as intermediate, showing that the majority experienced a significant increase. Only one student (3.1%) was in the high category, showing a significant improvement in score after using the media. Overall, the majority of students (59.4%) fall into the middle or high category, indicating that Nugle media is effective in improving students' sense of numbers.

5. Evaluation Phase

The evaluation stage aims to find out whether the product developed in this case Nugle's mobile learning media is valid, practical, and effective in improving students' sense of numbers. This stage includes formative and summative evaluation throughout the development and implementation phases.

Evaluation during the development phase is formative and serves as the basis for product revision. It involves expert validation by media experts, materials experts, and practitioners. Based on the assessment of the three validators, the product received an average material score of 4.6 and a media score of 4.53, resulting in a total average score of 4.565. This score is located in the interval of 4.1–5.0, which is categorized as "very valid". Suggestions provided during validation include increasing font size, simplifying instructions, and improving content clarity all of which are implemented before classroom testing.

Evaluations during the implementation phase were conducted to assess the practicality and effectiveness of Nugle on a larger scale this involved testing the product in grades VII-D with 32 students. Practicality is evaluated through questionnaires given to students and teachers. Based on these responses, students assessed practicality as 81.79%, while teachers gave a score of 77.5%. These results fall into the "very practical" and "practical" categories, respectively, indicating that Nugle media is well-received in terms of usability and classroom applications.

Effectiveness was evaluated using pre-test and post-test data to measure students' increase in number sense. The average pre-test score is 47.09, and the post-test average is 65.22. The results of the paired sample t-test showed an average difference of 18.13 ($p < 0.001$), indicating a statistically significant improvement. In addition, N-gain analysis is performed to assess each student's improvement. The N-gain results showed that 40.63% of students were in the low category ($g < 0.3$), 56.25% were in the medium category ($0.3 \leq g < 0.7$), and 3.12% were in the high category ($g \geq 0.7$). This means that 59.37% of students achieved moderate to high learning improvements, indicating that the media is effective in accordance with the N-gain criteria.

Positive student responses to the Nugle app support these results. Students value the ability to work at their own pace through different quiz structures adventurer (beginner level), explorer (intermediate level), and Conqueror (advanced level) which allows them to learn at their own pace. Based on all the data obtained during the evaluation phase, it can be concluded that the Nugle application developed using the ADDIE model is a valid, practical, and effective mobile learning medium to increase the sense of number among junior high school students.

The findings of this study show that the Nugle application is a valid, practical, and effective digital tool to support the development of the sense of

numbers in elementary school students. A high validity score reflects that media content, interface design, and learning flows are aligned with curriculum objectives and pedagogical principles. These results confirm Akker, Van den, McKenney, and Nieveen (2013) criteria for high quality learning media and are in line with Mayer's multimedia learning theory, which emphasizes the integration of visual and auditory elements to reduce cognitive load.

Further practicality assessments show that Nugle is easy to use and accessible across devices, with students (86.30%) and teachers (77.5%) rating it to be very practical. Cross device compatibility allows all students to engage with Nugle without significant technical constraints, supporting previous findings by Tang, Chen, and Zhao (2023) regarding the importance of accessibility in mobile math learning. In addition, the different levels, Adventurer, Explorer, and Conqueror, help tailor instruction to student readiness, which is consistent with Tomlinson (2014) differentiation framework and contributes to a positive user experience.

Another critical point that emerges from these findings is the role of classroom observation in explaining the practicality of the Nugle app. Observational data reveal that students can operate the app independently, navigate between levels smoothly, and engage in learning tasks with minimal teacher assistance. Teachers also reported that the learning flow ran efficiently, with few disruptions related to device handling or interface difficulties. These observations reinforce the results of the questionnaire, demonstrating high practicality, as they show that Nugle works effectively in real classroom conditions. This is in line with the argument of Akker, Van den, McKenney, and Nieveen (2013) that practicality is best evidenced by ease of use and smooth implementation. It's also important to emphasize that observations are used to support practicality not effectiveness interpretations, as effectiveness must be strictly measured through learning outcomes, such as pre-test and post-test scores. So, while observations help illuminate how students interact with media, significant improvements in number sense performance are determined solely from empirical test data, not from observational impressions.

The effectiveness results showed a significant improvement in students' number sense performance, with the average score increasing from 47.09 to 65.22 and the mean difference of 18.13 ($p < 0.001$). The majority of students (59.4%) achieved moderate to high N-gains, indicating meaningful conceptual growth. These results support findings by Della, Wijaya, and Sugiarso (2023), who emphasize that multimedia-based representations can improve conceptual

understanding through dual channel processing. Although some students achieve only low N-gain scores, these cases can be partly attributed to technical limitations such as device storage capacity and the lack of Nugle's built-in analytics, which limit opportunities for formative feedback, an issue highlighted in (Tulim & Helman, 2022).

In terms of numerical sense indicators, students show clear improvements in magnitude comparison, mental calculations, partial-overall reasoning, and estimation. Before using Nugle, students often relied on procedural strategies and showed weaknesses in estimation and flexible thinking. After using Nugle, students show greater fluency in comparing numbers, deciphering quantities, estimating values, and assessing the fairness of answers. These improvements are supported by Nugle multimedia scaffolding, interactive visualizations, and level based challenges, which align with Bruner's representational model and Dehaene's number sense framework.

In addition, the differentiation feature that categorizes learners into Adventurer, Explorer, and Conqueror levels has been instrumental in supporting the readiness of diverse learners. Students report that this level helps them choose assignments that align with their abilities, contributing to positive practicality rankings. This is in line with Hall, Strangman, and Meyer (2003); Tomlinson (2014), who emphasize that readiness-based scaffolding can increase learners' confidence and perseverance factors that may have influenced the stable development observed in post-test scores.

Despite these strengths, some limitations require careful consideration. First, Nugle's requirement for moderate device storage may have created inequities in the sample, as students with lower capacity smartphones sometimes experience delayed loading times. Although no participants were excluded due to device constraints, the technical glitch may slightly reduce the intensity of use for some students, potentially affecting their learning advantages. This is in line with the findings of Liusman and Arijianto (2022), who noted that device limitations can moderate the effectiveness of mobile learning interventions.

Second, the current version of Nugle lacks built in performance tracking, limiting teachers' ability to monitor progress in real time. While this does not directly affect students' post-test performance as assessments are administered externally, it limits opportunities for formative feedback during the learning process. As Tulim and Helman (2022) point out, the absence of direct progress

data can reduce the accuracy of teacher guidance, which may help explain why some students remain in the low N-gain category despite using the app.

In addressing these limitations, the proposed mitigation strategies should be interpreted with caution. Although the use of school owned laptops or peer-to-peer device sharing has been supported in other studies, this study did not empirically test this approach. As such, future research should examine whether the strategy significantly expands Nugle's accessibility or enhances its learning impact. Similarly, integrating external tools such as Google Forms for progress tracking presents a promising direction but remains a suggestion for further development rather than the improvements validated in this study.

Overall, the findings suggest that Nugle's pedagogically informed features, accessibility, multimedia scaffolding, and differentiated paths are likely the main contributors to the observed improvements in numerical sense. While there are technical limitations, they do not substantially impair the overall effectiveness of the tool. Future iterations of Nugle should prioritize storage optimization and integrated progress analytics to reinforce usability and instructional value.

CONCLUSION

The study concluded that Nugle, a mobile learning app developed to improve the number sense of seventh graders, successfully met the criteria for validity, practicality, and effectiveness. The application is designed using the ADDIE model, which includes a phased analysis, design, development, implementation, and evaluation. Nugle integrates different instructions, allowing students to access tiered quizzes based on their initial ability level, thus supporting a more personalized learning experience. Expert validation results show that Nugle is "very valid", with an average score of 4.6 for content and 4.53 for media. The practicality is reflected in the high response scores from students (86.30%) and teachers (77.5%), highlighting the app's usability, accessibility, and motivational design, which shows that Nugle is easy to use, well accessible, and has an attractive design. These findings are reinforced by observations during the trial, which show that students can follow the flow of media use smoothly and teachers can facilitate learning without significant technical barriers. In terms of effectiveness, the app significantly improved the students' sense of numbers, as shown by the paired sample t-test ($p < 0.001$) and N-gain analysis, with 59.4% of students achieving moderate to significant improvement.

Based on the overall results, it can be concluded that Nugle is a valid, practical, and effective tool for improving the sense of numbers. Nugle's practicality is not only supported by high ratings of students and teachers but also by classroom observations that show the app is easy to use, easy to access, and seamlessly integrated into the learning process. These observational findings confirm that Nugle meets the criteria for a practical learning medium, as students can engage with the application without significant technical or instructional difficulties. At the same time, the effectiveness of Nugle is evidenced by quantitative evidence from pre-test and post-test results, which show a significant improvement in students' number sense abilities. Observational data does not play a role in determining effectiveness; Instead, the advantages of learning are validated solely through statistical analysis. Together, these findings reinforce that Nugle is feasible to implement and capable of improving students' numerical comprehension, making it a promising tool for future mathematics instruction.

ACKNOWLEDGEMENT

The authors would like to express their deepest gratitude to all the individuals and institutions that made this research possible.

DECLARATIONS

Author Contribution	:	WFA: Conceptualization, Writing–Original Draft, Methodology, Supervision, Instrument development, Data collection, Data curation, Data analysis, Writing–Review & Editing. S: Formal analysis, Methodology refinement, and Writing–Review & Editing. TAZ: Data analysis support, Data curation, and Writing–Review & Editing.
Funding Statement	:	This research was not funded.
Conflict of Interest	:	The authors declare that there is no conflict of interest regarding the publication of this paper.
Additional Information	:	Additional information is available from the corresponding author upon reasonable request.

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