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Development of Smart Mathematics Education (SMEd): A mobile learning application to support mathematical literacy

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ABSTRACT

This study aims to develop Smart Mathematics Education (SMEd), a mobile learning application designed to support junior high school students' mathematical literacy through real-life problem-solving activities. The study adopted the ADDIE model, comprising five stages: Analysis, Design, Development, Implementation, and Evaluation. The participants included two media experts and two mathematics education practitioners who evaluated the application; eight students who participated in a small-group trial; 24 students and three teachers who participated in a field trial; and 15 students involved in the implementation stage. Data were analysed using descriptive and inferential statistics. The findings indicated that the SMEd application met the established validity criteria. In the small-group trial, the application obtained a mean attractiveness score of 3.59, which was classified as "very interesting." The field-trial results indicated that the application met the established practicality criteria. Furthermore, students' mathematical literacy test scores were higher after the implementation of SMEd than before its implementation. These findings suggest that SMEd is a valid and practical mobile learning resource with the potential to support mathematical literacy among junior high school students. However, the effectiveness findings should be interpreted cautiously in light of the one-group pretest–posttest design and the small sample involved in the implementation stage.

KEYWORDS

Mathematical literacy; mobile learning; SMEd; mathematics

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INTRODUCTION

Technology plays an increasingly important role in modern society and has become integral to many aspects of everyday life. The Big Indonesian Dictionary defines technology as "a scientific method for achieving practical goals." More broadly, technology enables people to perform tasks more efficiently and achieve better outcomes. It also provides access to information and supports the development of knowledge and skills (Sumantika et al., 2023).

Mobile learning can help address several challenges in mathematics education and the development of mathematical literacy by making learning more flexible, interactive, contextualised, and learner-centred. It may be particularly useful in supporting students' understanding of abstract mathematical concepts. When mathematical concepts are presented solely through verbal explanations and symbols, students may find them difficult to understand. Mobile learning can incorporate animations, simulations, visualisations, graphs,

and opportunities for interactive manipulation, thereby presenting mathematical ideas in more accessible ways. Mobile learning (m-learning) combines mobile technologies with electronic learning resources that can be accessed anytime and from different locations, supporting learning activities and performance-based assessment (Kulbi, 2021). Devices commonly used for m-learning include smartphones, personal digital assistants (PDAs), laptops, and tablet computers (Cahya et al., 2022).

In mathematics education, the National Council of Teachers of Mathematics (NCTM, 2000) emphasises the importance of technology because it influences how mathematics is taught and can support students' learning. Accordingly, m-learning has the potential to influence mathematics teaching practices and facilitate students' learning (Peças et al. 2022). The use of technology to develop mathematical literacy is particularly relevant when technological features are aligned with the literacy competencies that learning activities are intended to foster. Instructional technology should therefore serve not merely as a means of delivering content but also as a resource that helps learners understand information, formulate problems, apply mathematical concepts, reason mathematically, and interpret and evaluate problem-solving outcomes. Mobile learning is relevant in this regard because it can provide a flexible, interactive, and contextualised learning environment. Research cited by Sukendar (2023) suggests that mathematics applications can support the development of number and arithmetic skills, mathematical representation, the construction of mathematical objects, problem-solving, and mathematical programming. Such applications may also increase students' motivation and make learning more engaging and interactive. Furthermore, the use of information and communication technology (ICT) in mathematics education has been associated with positive outcomes in students' literacy development. Thus, m-learning may provide opportunities to support the development of mathematical literacy (Rhodes, 2022).

Mathematical literacy is an important competency that students need to develop. Students are expected not only to understand the mathematical concepts taught at school but also to apply them in everyday situations (Irdalisa et al., 2022). Mathematical literacy involves the ability to formulate, employ, and interpret mathematics in a range of contexts (Jogo et al., 2022). It is therefore an essential component of students' broader literacy development (Abidin, 2017). Developing this competency requires students to go beyond memorising formulas and performing calculations. They must also be able to recognise mathematical problems in real-life situations, select appropriate mathematical concepts and procedures, and interpret the results in relation to the original context.

Mathematical literacy is a central focus of the Programme for International Student Assessment (PISA), an international assessment that evaluates students' achievement in mathematics, reading, and science across participating countries. Indonesia has participated in PISA since 2000, and students' mathematics performance has remained a concern (Rakoczy et al., 2019). According to the PISA 2022 results reported in this manuscript, Indonesia ranked 70th, with a mathematics score of 396, among 78 participating countries. However, the ranking and number of participating countries should be verified against the original PISA 2022 report before publication. Other studies have also identified challenges in students' mathematical literacy. Students with moderate and high abilities have demonstrated different levels of mathematical literacy, while Suningsih and Istiani (2021) found that students in their study had not reached Levels 5 or 6. These findings suggest that the challenges extend beyond students' calculation skills to include their ability to apply mathematics to understand, formulate, reason about, and solve problems in real-life contexts (Kight, 2021). Learning materials should therefore go beyond procedural exercises and provide opportunities for students to develop the competencies involved in mathematical literacy.

In response to challenges in mathematics education, including students' difficulties in understanding and applying mathematical concepts, limitations in instructional strategies, and the availability of appropriate learning media, the Indonesian government has introduced several initiatives to improve mathematical literacy. These include the National Literacy Movement and the replacement of the National Examination with the Minimum Competency Assessment (Pinger et al., 2018). Among other objectives, these initiatives seek to familiarise students with assessment tasks that require mathematical literacy (Suraji et al., 2018).

Students need regular opportunities to practise mathematical literacy. Providing exercises and problems that can be approached in different ways may help develop their mathematical thinking (Tripolca, 2023). Opportunities to generate and compare alternative solution strategies can also encourage creativity and support students in solving problems (Ramanisa et al., 2020). Therefore, learning activities should provide students with opportunities to engage with meaningful problems, explore different approaches, and explain their mathematical reasoning.

Teachers also play an important role in providing mathematical literacy tasks that familiarise students with this type of problem. Abidin (2017) argues that teachers should use appropriate learning materials to help students understand the information presented during instruction. Previous studies have developed mathematical literacy assessment instruments

and explored the use of digital learning platforms in mathematics education. For example, Mahdiansyah, and Rahmawati (2014) developed a mathematical literacy test based on Bugis-Makassar local wisdom for junior high school students. Dwiyani, at el., (2021) also reported improvements in students' mathematical literacy following the use of Google Classroom. Taken together, these studies indicate that research has addressed the development of assessment instruments and the use of digital learning platforms. Building on this research, the present study focuses on developing a mobile application that incorporates mathematical literacy activities into learning materials.

Educators and researchers therefore have an important role in supporting the development of students' mathematical literacy through appropriate instructional approaches and learning resources. One possible approach is to develop interactive learning materials that incorporate mathematical literacy activities and can be accessed offline. Such resources may provide students with opportunities to engage with mathematical problems in flexible and contextualised learning environments, including settings with limited internet connectivity. Accordingly, this study aimed to develop Smart Mathematics Education (SMEd), a mobile learning application designed to support mathematical literacy among junior high school students.

METHODS

This development study aimed to produce a mobile learning application called Smart Mathematics Education (SMEd). The application was designed to provide mathematical literacy learning materials for junior high school students in Langsa. The study adopted the ADDIE development model, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation (Septina et al., 2018).

During the Analysis stage, the researchers identified the competencies that students needed to develop through the SMEd application to support their mathematical literacy. In development research, this stage involves identifying learning needs and problems, learner characteristics, curriculum requirements, and technological considerations before designing the product. Accordingly, the development of SMEd involved analysing the needs associated with mobile learning materials for mathematical literacy among junior high school students. The researchers also considered possible responses to the identified needs, including the development of a mobile learning application containing mathematical literacy materials (Rohmah et al., 2020).

During the Design stage, the researchers planned the SMEd mobile learning

application and identified the components required for its development. They also designed the research instruments, consulted relevant literature to inform the preparation of the learning materials (Fajriah et al., 2020and prepared the materials to be used during the trial and implementation stages. In addition, they estimated the costs associated with developing the application (Kumar, 2019).

The Development stage involved producing Draft I of the SMEd application and its supporting research instruments. The application and instruments were reviewed by two media experts and two mathematics teachers who served as practitioner reviewers. The product was revised based on their assessments and recommendations until it was considered suitable for further testing. Formative evaluation was then conducted through a small-group trial involving eight students from School A, resulting in Draft II. This version was subsequently evaluated in a field trial involving 24 students from School B and three mathematics teachers, resulting in Draft III. Following further revisions, Draft IV was produced as the final version for the implementation stage (Beijaard, 2019).

During the Implementation stage, the researchers coordinated with the teacher and selected a Grade VII class at School A. The SMEd application was then implemented in Class VII-1 according to the planned schedule.

The Evaluation stage aimed to assess the quality of the SMEd mobile learning application. The researchers established evaluation criteria, selected appropriate instruments, and assessed the developed product. In addition to the expert validation conducted during the Development stage, the evaluation process involved subject-matter experts in mathematical literacy and experts in media or learning technology. Their assessments provided a final review of the product. Evaluation was conducted throughout the development process to examine the application's feasibility, practicality, and effectiveness in supporting mathematical literacy. Subject-matter validation focused on the alignment of the content with the intended learning outcomes, the accuracy of mathematical concepts, the relevance of problem contexts, and the relationship between learning activities and mathematical literacy indicators. Media validation focused on interface design, navigation, readability, interactivity, ease of use, presentation quality, and the alignment of technological features with the learning objectives. Following this review, the SMEd application was designated as the final version. The ADDIE development process is illustrated in Figure 1.

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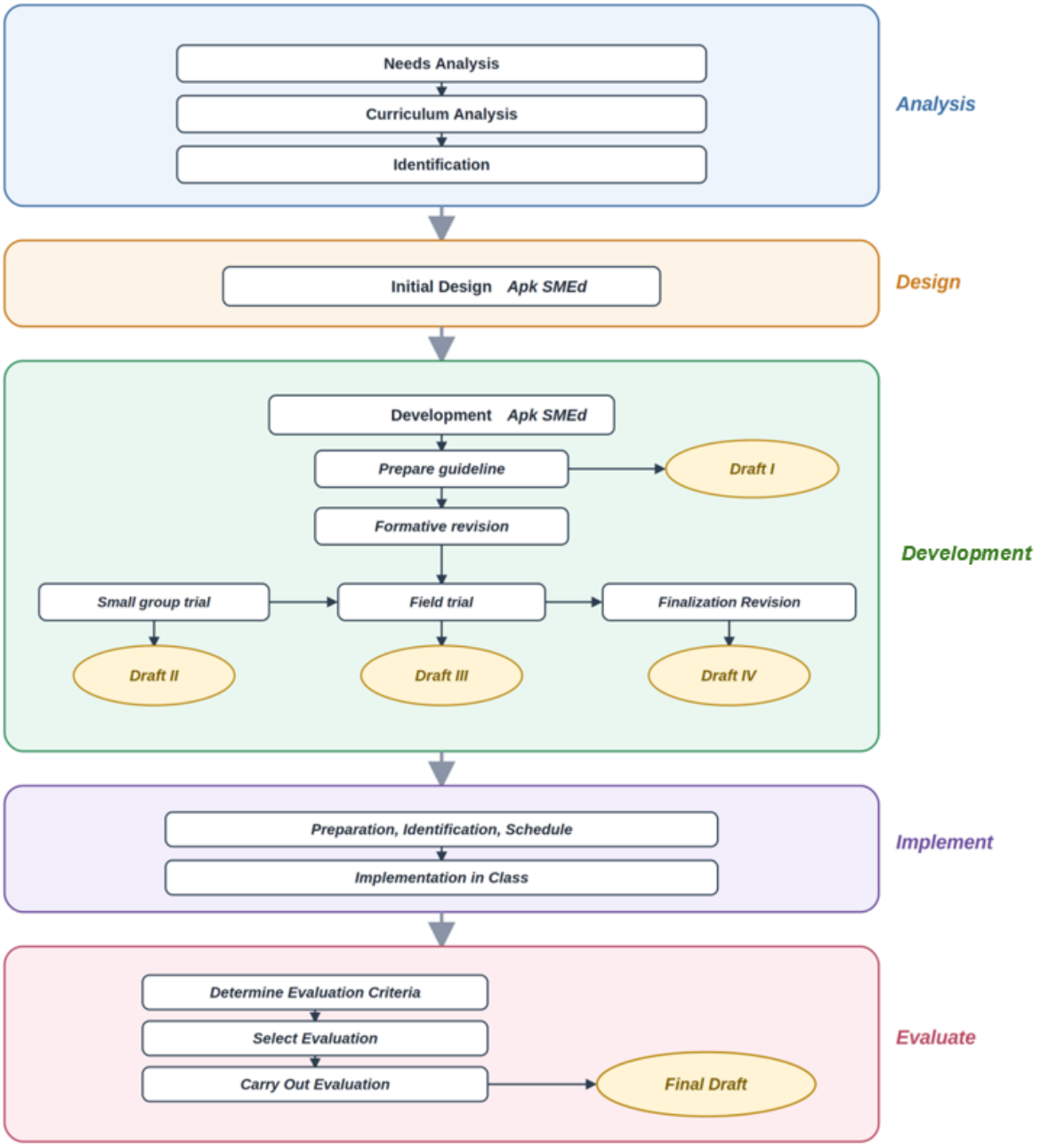


Figure 1. Research Flow Based on a Modified ADDIE Model

During the Development and Evaluation stages, expert ratings were analysed against the established criteria and supplemented by written comments and recommendations. The findings informed revisions to the content, design, features, and learning activities of SMEd. Once the application had met the feasibility criteria, it was tested with a small group of students to examine its practicality and comprehensibility. Data were collected through observations of application use, student and teacher response questionnaires, and interviews or open-ended questions addressing ease of use, clarity of instructions, attractiveness, technical issues, and the usefulness of the application's features.

Three types of research instruments were used to evaluate the SMEd application. First, the validation instruments assessed language, content selection and organisation, content presentation, sample questions and problems, formative exercises and tests, and the application's display and layout. Second, the practicality questionnaire examined the implementation of SMEd in mathematics lessons. Third, an effectiveness instrument in the form of a mathematical literacy test was used to assess students' mathematical literacy performance before and after using the application.

The experts' validation ratings, based on a Likert scale, were analysed using descriptive statistics and converted into percentages before being presented graphically. The experts also provided written comments and recommendations regarding the application's content and feasibility to inform product revisions. Responses to the practicality questionnaire were analysed by calculating mean scores and interpreting them according to the established assessment criteria (Sari & Usmeldi, 2019).

Data on the effectiveness of the SMEd application were analysed using inferential statistics and hypothesis testing. The data were obtained from students' mathematical literacy test performance before and after learning with the application. The study employed a one-group pretest–posttest design involving one class of students. A paired-samples t-test was conducted using SPSS version 21 to examine whether the difference between students' pretest and posttest scores was statistically significant. The school and class involved in this analysis should be identified consistently throughout the manuscript.

RESULT AND DISCUSSION

The study resulted in a mobile learning application designed to support students' mathematical literacy. The application was validated by media experts and mathematics education practitioners and subsequently evaluated through a small-group trial and a field trial. The learning materials for junior high school students were packaged into a 91-page mobile application. Its components included instructions for use, core competencies, basic competencies, learning indicators, concept maps, learning materials, sample questions, project assignments, exercises on statistics and probability, and profiles of the research team. Mathematical literacy activities were integrated into the learning materials to support the development of students' mathematical literacy (Voller 2019).

The researchers designed the SMEd mobile learning application based on relevant theories and adapted its content to the selected Grade VII topics of statistics and probability. They also developed supporting research instruments in accordance with the research

questions. These instruments comprised validation instruments to assess the feasibility of the SMEd application, a mathematical literacy test to examine its effectiveness, and questionnaires to evaluate its practicality during the trials (Kalaw, 2019).

The researchers produced Draft I of the application and its supporting instruments. The learning materials and instruments were then submitted for expert validation. The subsequent stages involved formative evaluation through a small-group trial and a field trial. Feedback obtained from these stages informed revisions to the application, resulting in the version prepared for implementation.

Expert Validation Results

The media experts and mathematics education practitioners reviewed the mobile learning application and provided recommendations for addressing the issues identified during the validation process.

Validation by Media Experts

The media experts' validation results are summarised using descriptive statistics in Figure 2, which presents the ratings provided by the two experts. The results indicate that the application met the established feasibility criteria, subject to minor revisions. For content quality, the experts assigned similar ratings of 3.3 and 3.4. Their ratings for the application/device and presentation techniques were 3.3 and 3.7, respectively. The language aspect also received similar ratings of 3.5 and 3.6, while the implementation aspect received ratings of 3.7 and 3.6. Overall, these ratings suggest that the experts considered the application's technical features, interface, presentation, and language appropriate for its intended users. The ratings for the implementation aspect further suggest that the application was considered suitable for use in the intended learning environment. The experts' recommendations were subsequently used to make minor revisions before the application proceeded to the next stage of the development process.

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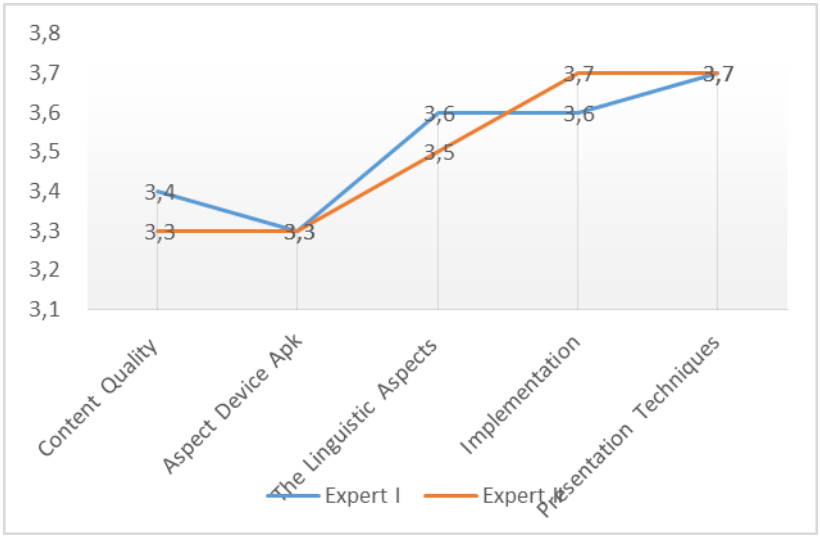


Figure 2. Descriptive Statistics for The Media Experts' Validation of The SMEd Application

Validation by Mathematics Education Practitioners

The results of the validation conducted by the mathematics education practitioners are summarised using descriptive statistics in Figure 3, which presents their ratings of the SMEd application. The ratings for the application/device, presentation techniques, and implementation aspects were 3.5, 3.5, and 3.6, respectively. The two practitioners assigned different ratings to content quality (3.2 and 3.5), whereas their ratings for language were similar (3.5 and 3.4). Overall, these results indicate that the practitioners considered the application's design and presentation suitable for use in mathematics lessons.

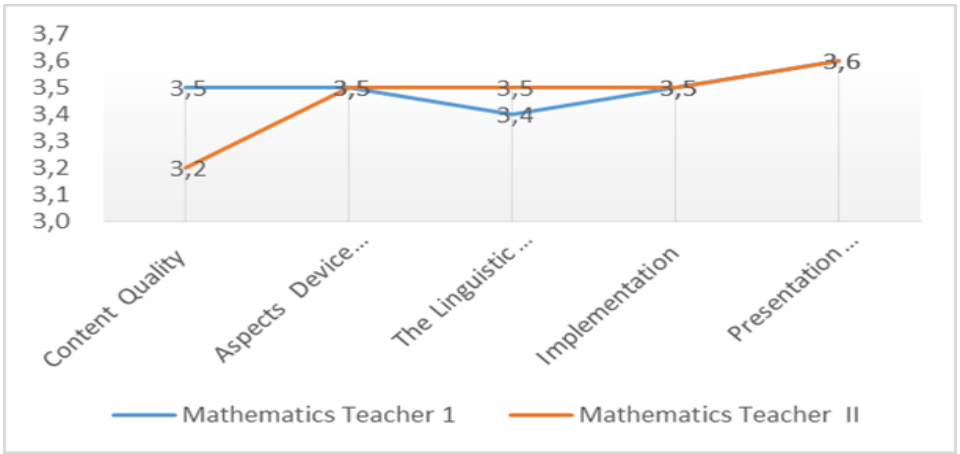


Figure 3. Descriptive Statistics for The Mathematics Education Practitioners' Validation of The SMEd Application

Although the practitioners' ratings for content quality differed, both scores fell within the feasibility category based on the criteria established in this study. This difference may reflect variations in their assessments of content depth, alignment with the learning objectives, or integration of mathematical literacy indicators. The similar ratings for language suggest

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that both practitioners considered the wording sufficiently clear and appropriate for the intended users.

Product Revision

The researchers revised the SMEd application in response to feedback from the media experts and mathematics education practitioners (mathematics teachers). Figure 4 presents the application interface before and after the revisions.

Before *After*

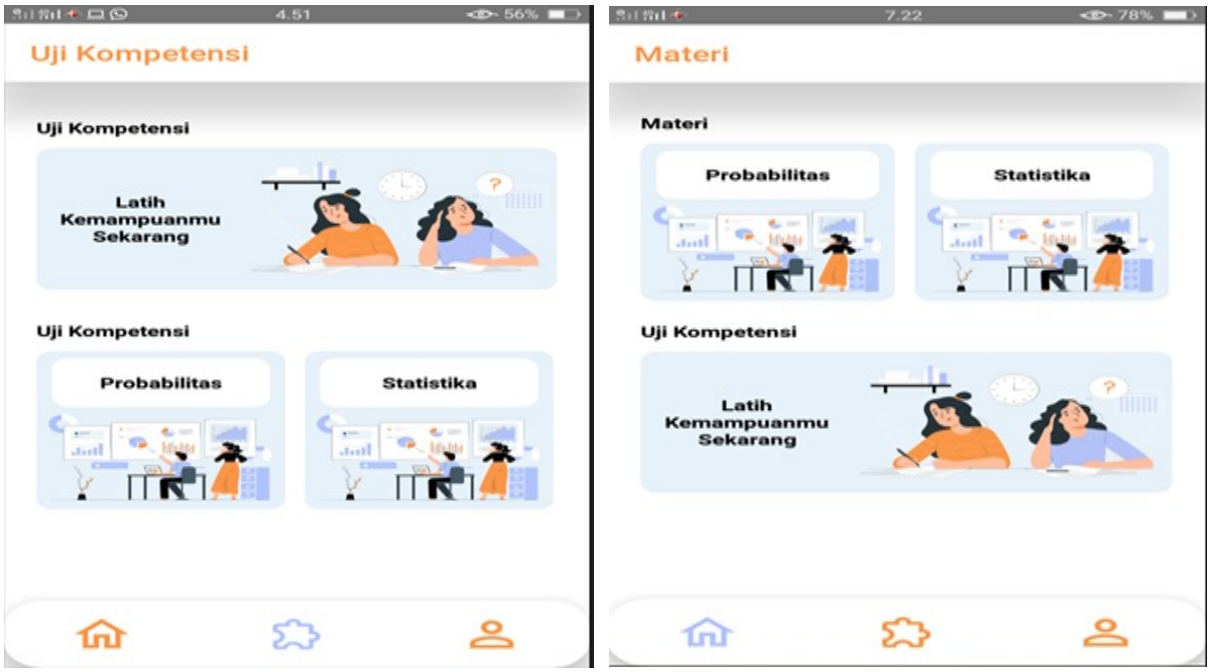


Figure 4. SMEd Application Menu Before and After Revision

Small-Group Trial

The small-group trial involved eight Grade VII students from Junior High School A in Langsa. This stage aimed to obtain preliminary information about students' perceptions of the attractiveness of the Smart Mathematics Education (SMEd) application. Data on students' responses were collected using an attractiveness questionnaire (Charrua-Santos et al., 2019), and analysed descriptively (see Table 1).

Table 1. Descriptive Statistics for The Small-Group Trial

N	Minimum	Maximum	Mean	Std. Deviation
8	3.4	4.0	3.588	.2748

As shown in Table 2, the students' attractiveness scores ranged from 3.4 to 4.0. The mean score was 3.588, with a standard deviation of 0.275. According to the assessment criteria established in this study, the mean score was classified as *very interesting*. These findings indicate that the eight students generally responded positively to the SMEd

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application.

Table 2. Student Responses in The Small-Group Trial

Students	Score Attractiveness		Criteria
	Total	Average	
1	24	3.4	Very Interesting
2	28	4.0	Very Interesting
3	26	3.7	Very Interesting
4	24	3.4	Very Interesting
5	28	4.0	Very Interesting
6	24	3.4	Very Interesting
7	24	3.4	Very Interesting
8	24	3.4	Very Interesting

The relatively small standard deviation also indicates that the students' ratings were fairly consistent. These findings provide preliminary evidence that the SMEd application was appealing to its intended users. However, the small-group trial focused solely on assessing attractiveness; therefore, its results should not be interpreted as evidence of the application's practicality or effectiveness. Instead, the findings provided an initial basis for proceeding to a larger field trial, in which the practicality of the application could be examined more comprehensively.

Field Trial

Following the small-group trial, a field trial was conducted with 24 Grade VII students from Class VII-2 at School B and three mathematics teachers. This stage aimed to evaluate the practicality of the SMEd application in a mathematics learning context. Practicality was assessed using questionnaires completed by the students and teachers. The questionnaires covered three aspects: ease of use, attractiveness of the application's presentation, and perceived benefits.

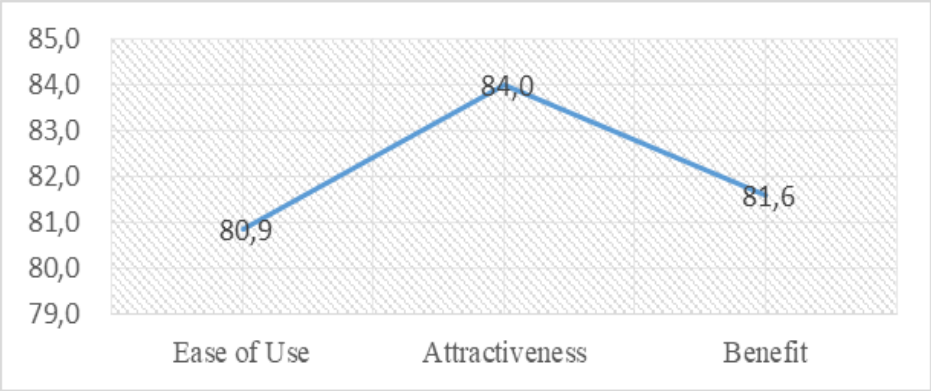


Figure 5. Student Ratings of The Practicality of The SMEd Application in The Field Trial

Figure 5 presents the students' assessments of the practicality of the SMEd application. The mean scores were 80.9 for ease of use, 84.0 for attractiveness of presentation,

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and 81.6 for perceived benefits. All three aspects were classified as *very practical* according to the assessment criteria used in this study. The overall practicality score was 82.16, which also fell within the *very practical* category.

These findings suggest that students generally considered the application easy to use, visually attractive, and beneficial for supporting mathematics learning. This is relevant to the intended use of SMEd as a mobile learning resource, as its usefulness depends not only on the quality of its mathematical content but also on students' ability to access and use its features effectively.

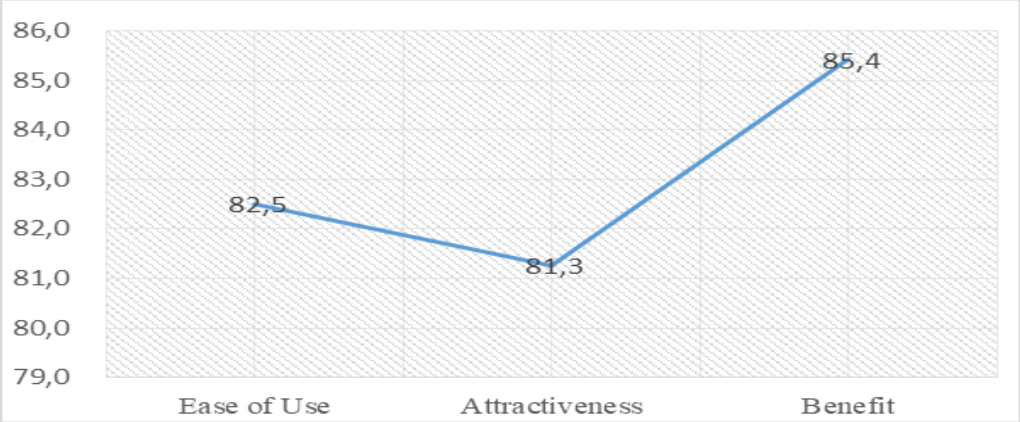


Figure 6. Teachers' Assessments of The Practicality of The SMEd Application

Figure 6 presents the teachers' assessments of the SMEd application. The mean scores were 82.5 for ease of use, 81.3 for attractiveness of presentation, and 85.4 for perceived benefits. All three aspects met the criteria for the *very practical* category. These responses indicate that the teachers considered the application suitable for supporting mathematics instruction in the classroom.

Taken together, the responses from students and teachers indicate that the SMEd application met the established practicality criteria during the field trial. The positive assessments across all three aspects suggest that the application could serve as supplementary learning material for Grade VII mathematics. Nevertheless, these findings reflect users' perceptions of the application's practicality and do not establish whether it improves students' mathematical literacy. This issue was examined separately during the implementation and evaluation stages.

Implementation and Evaluation

Following expert validation, product revision, and field testing, the final version of the SMEd application (Draft IV) was implemented in a Grade VII mathematics class at School A.

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The implementation involved 15 students from Class VII-1. This stage aimed to examine changes in students' mathematical literacy performance following mathematics instruction supported by the SMEd application.

Students completed a mathematical literacy test before and after the learning intervention. The pre-test and post-test scores were analysed using a paired-samples *t*-test to determine whether a statistically significant difference existed between students' performance before and after the implementation of SMEd.

Before conducting the paired-samples *t*-test, the normality assumption was examined. As shown in Table 3, the Shapiro–Wilk test yielded significance values of 0.063 for the pre-test scores and 0.218 for the post-test scores. Both values exceeded the 0.05 significance level, indicating that neither set of scores showed a statistically significant departure from a normal distribution. However, for a paired-samples *t*-test, the normality assumption should be assessed specifically for the difference scores between the pre-test and post-test, rather than for each set of scores separately.

Table 3. Normality Tests

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.219	15	.052	.888	15	.063
Posttest	.168	15	.200*	.924	15	.218

*. This is a lower bound of true significance.

Table 4 presents the results of the paired-samples *t*-test. The mean difference between the pre-test and post-test scores (pre-test minus post-test) was −70.667, with a standard deviation of 7.528 and a standard error of 1.944. The 95% confidence interval for the mean difference ranged from −74.835 to −66.498. The results indicated a statistically significant difference between the pre-test and post-test scores ($p < .001$). The negative mean difference indicates that the post-test scores were higher than the pre-test scores.

Table 4. Paired-Samples T-Test Results

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		T	f	Sig.(2-tailed)
					Lower	Upper			
Pair 1	Pretest - post-test	-70.667	7.528	1.944	-74.835	-66.498	-36.358	4	.000

The negative mean difference indicates that the post-test scores were higher than the pre-test scores. Thus, the findings demonstrate a statistically significant increase in students' mathematical literacy scores following mathematics instruction supported by the SMEd

application.

This increase may be associated with the learning opportunities provided by SMEd, which presents mathematical content through contextual problems and activities related to statistics and probability. These activities may encourage students to connect mathematical concepts with real-life situations and engage in mathematical interpretation and problem-solving.

Nevertheless, the findings should be interpreted in light of the research design. Since the implementation employed a one-group pre-test–post-test design without a comparison group, the observed improvement cannot be attributed exclusively to the use of SMEd. Other factors, including students' prior learning experiences, classroom instruction, and familiarity with the test format, may also have contributed to the improvement. Further research involving a comparison group and a larger sample is therefore recommended to provide stronger evidence of the application's effectiveness.

The validation results presented in Figure 2 indicate that the media experts considered the SMEd application feasible for use after minor revisions. Similarly, the practitioners' ratings, presented in Figure 3, indicate that the application met the feasibility criteria established in this study. Following the recommendations provided by the experts and practitioners, the researchers revised the application and prepared the subsequent draft. These findings support the conclusion that the application was considered suitable for further testing (Shaikh et al., 2023).

The application was revised in response to feedback from the media experts and mathematics teachers. Their recommendations addressed several aspects of the product. Regarding content quality, the experts suggested including examples of higher-order thinking skills (HOTS) questions and providing a wider variety of practice items. The mathematics teachers recommended improving the visual presentation of the learning materials and using clearer colours in the concept map (Victoria, 2019). The researchers also refined the colour combinations throughout the application and improved the organisation of its menus.

In the small-group trial involving eight junior high school students, the mean attractiveness score was approximately 3.6 (SD = 0.2748), as shown in Table 2. According to the interpretation criteria established in this study, this score fell within the *very interesting* category.

The field trial involved 24 junior high school students and three mathematics teachers. The students assessed the application in terms of ease of use, attractiveness of presentation,

and perceived benefits. The overall practicality score was 82.16, which fell within the *very practical* category according to the assessment criteria used in this study. Regarding the perceived benefits dimension, 11 students obtained scores below 81%, whereas 13 students obtained scores above 81%. Overall, the findings suggest that the students considered the SMEd application practical (Putri & Ariani, 2020).

The three mathematics teachers also evaluated the practicality of the SMEd application in terms of ease of use, attractiveness of presentation, and perceived benefits. The mean scores for all three dimensions met the practicality criteria established in this study. These assessments indicate that the teachers considered the application suitable for use by Grade VII students (Setyawan, 2020).

The effectiveness of the SMEd application was examined by comparing students' mathematical literacy test scores before and after its implementation. The paired-samples *t*-test indicated a statistically significant increase in students' scores following the implementation. These findings suggest that the SMEd application may support the development of mathematical literacy among the participating junior high school students (Harahap et al., 2020).

The SMEd application incorporates problem-solving activities and higher-order thinking skills (HOTS) questions related to statistics and probability. These activities are intended to provide students with opportunities to develop conceptual understanding and construct mathematical knowledge. Rather than relying solely on memorising theoretical information, students are encouraged to understand mathematical concepts and apply them when solving problems. Therefore, the application may serve as an additional learning resource for junior high school teachers and students.

The SMEd application was designed to be accessible offline, allowing students to use it at different times and in different locations. This feature is consistent with the findings of Sisouvong and Pasanchay (2024) who highlighted the potential of mobile technology to provide flexible access to learning resources. The application contains learning materials on statistics and probability, together with student activities and questions intended to support conceptual development in these topics (Ardina et al., 2019). The researchers anticipate that mathematics teachers will be able to use SMEd as an additional resource to support mathematics instruction and provide students with opportunities to engage with PISA-style mathematical literacy tasks. This recommendation is consistent with previous calls for further research into improving mathematics learning and students' literacy skills.

CONCLUSION

This study resulted in the development of Smart Mathematics Education (SMEd), a mobile learning application designed to support mathematics learning and students' mathematical literacy. Expert validation indicated that the application met the validity criteria established in this study following minor revisions. The field-trial results also indicated that the application met the practicality criteria, with students and teachers providing positive assessments of its ease of use, presentation, and perceived benefits.

During the implementation stage, students' mathematical literacy test scores were higher after using the application than before its implementation. These findings suggest that SMEd, developed using the ADDIE model, is a potentially useful and practical resource for supporting mathematical literacy among junior high school students. However, because the effectiveness analysis employed a one-group pre-test–post-test design involving only 15 students, the findings should be interpreted cautiously. This research design does not establish that the application alone caused the observed improvement. Further research involving larger samples and comparison groups is needed to investigate the longer-term effects of SMEd on students' mathematical reasoning, problem-solving, critical thinking, and mathematical literacy.

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