Effectiveness of Experimental Strategies - Android-Based Drills in Mathematics Learning in Elementary Schools: A Systematic Literature Review

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Abstract: This study aims to examine the effectiveness of Android-based experiment-drill strategies in elementary school mathematics learning through the Systematic Literature Review (SLR) method for the period 2015–2025. The procedure included problem formulation, inclusion-exclusion criteria, literature search (Scopus, Dimension, Google Scholar), article selection, data extraction, and analysis using VOSviewer and R-Studio. The review results showed that this strategy contributed positively to students' conceptual understanding, engagement, and academic achievement. The approach emphasizes not only repetitive practice but also knowledge construction through virtual experiments, simulations, and active interaction. Its advantages lie in its flexibility, interactivity, and adaptability, although its successful implementation is influenced by media design, teacher skills, and infrastructure. Most studies still focus on quantitative aspects, so qualitative learning experiences are less explored. Further research is recommended to integrate qualitative approaches, adapt the media to schools with limited resources, and apply it to more abstract mathematics material. Practically, this study can be a reference for educators and application developers in optimizing Android-based experiment-drill strategies to improve the quality of mathematics learning in elementary schools.

Keywords: Experiment-Drill Strategy, Mathematics Learning, Android Application, Elementary School, Mobile Learning in Elementary Mathematics Education.

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A. INTRODUCTION

Mathematics is one of the core subjects that plays an important role in developing logical, critical, and systematic thinking skills in elementary school students (Rakic et al., 2021). At this level, students are introduced to basic concepts such as arithmetic operations, numbers, measurement, and geometry, which form the foundation for mathematics learning at the next level. Mastering mathematics from an early age not only contributes to academic achievement but is also necessary in everyday life. However, many students still have difficulty understanding mathematics material due to inappropriate learning approaches. Therefore, learning strategies are needed that can improve students' understanding and foster interest and positive attitudes towards mathematics.

Mathematics learning in elementary schools still faces a number of challenges that impact the low effectiveness of the learning process (Nurlaily et al., 2019). One of the main challenges is the abstract nature of mathematics material, which is difficult for young students to understand without the help of concrete media or appropriate approaches (Tran & Duong, 2023). In addition, the learning approach, which is still dominated by lectures and exercises, makes students less actively involved in learning. This contributes to low interest and motivation in learning mathematics, as well as anxiety or fear of the subject. The lack of innovation in learning strategies also prevents students from gaining meaningful learning experiences. Therefore, it is important for teachers to use more varied, contextual approaches that are appropriate for the developmental characteristics of elementary school students.

The development of digital technology provides great opportunities in supporting learning at the elementary school level (McKnight et al., 2016). One form of rapidly developing technology utilization is the use of Android-based devices, such as smartphones and tablets, as learning media (Siahaan et al., 2021). Through educational applications available on the Android platform, teachers can present material in a visual, interactive, and enjoyable way, which is more suited to the learning characteristics of early age students. This technology also allows students to learn independently and flexibly inside and outside the classroom (Iswara 2023). In addition, the use of Android-based media encourages variety in learning strategies and increases student engagement in the learning process. Thus, Android technology has a strategic role in improving the effectiveness and quality of learning in elementary schools, especially in subjects such as mathematics that require visualization and repeated practice.

Mathematics learning can be carried out through experimental and drill approaches, each of which has its own advantages. The experimental approach emphasizes exploration and understanding of concepts through active activities, and has been proven to improve students' problem-solving skills (Žakelj, 2018). In addition, the use of programming and symbolic computation in this approach also deepens students' understanding of mathematical structures and patterns (Dafik et al., 2022). Meanwhile, the drill method focuses on repeating material to reinforce basic skills, especially in arithmetic and fractions (Bernabeu et al., 2019). Other studies also show that video-based exercises significantly improve elementary school students' mathematics learning outcomes (Santagata et al., 2021) Thus, the integration of these two approaches is believed to create balanced and effective mathematics learning.

The integration of experimental and exercise strategies with Android-based media has the potential to improve learning effectiveness and operational efficiency in various fields. In the context of education, Android applications enable interactive and engaging learning, especially for complex subjects such as science (Malavolta et al., 2020). Furthermore, this approach supports learning that is tailored to students' learning styles, which is important for the 21st century generation (Qureshi et al., 2021). The use of mobile devices also provides flexibility in accessing learning materials independently (Eliza et al., 2023). In industrial sectors, such as oil and gas, Android applications have been used to support real-time operations and improve work safety. In the future, integration with artificial intelligence can further strengthen the adaptive functions of this media in education and technical decision-making.

Recent research shows that Android-based learning media has the potential to improve student learning independence and mathematical literacy (Widiyatmoko et al., 2021). Applications designed specifically for elementary school students have also received positive responses from teachers, students, and experts (Callaghan & Reich, 2021). In addition, Android-based media developed with Smart Apps Creator has been proven effective in improving mathematical problem-solving skills in university students. These findings indicate that Android media can encourage student engagement and mastery of mathematics at various levels of education. However, further research is needed to systematically review the effectiveness of Android-based drill-and-practice strategies in elementary school mathematics learning.

Experimental and drill learning strategies in mathematics have been proven to improve students' conceptual understanding and basic skills. The experimental approach emphasizes the process of exploration and critical thinking development, while drill focuses on reinforcing material through repeated practice. On the other hand, the use of Android-based learning media is considered effective in increasing student participation, encouraging independent learning, and providing more flexible access to learning. However, most existing studies still examine the effectiveness of these approaches and media separately. There is still limited research that systematically reviews the effectiveness of integrating experimental-drill strategies and Android media, especially in mathematics learning at the elementary school level. Based on this, this study aims to conduct a systematic literature review to evaluate the effectiveness of these strategies and identify the challenges and opportunities for their implementation in the context of primary education.

B. METHOD

This study uses the Systematic Literature Review (SLR) method to analyze the effectiveness of Android-based drill-and-practice strategies in mathematics learning in elementary schools. The SLR method was chosen because it provides a comprehensive, structured, and transparent overview of previous studies that have discussed this topic over the past ten years (2015–2025). The stages of the study are shown in Figure 1.

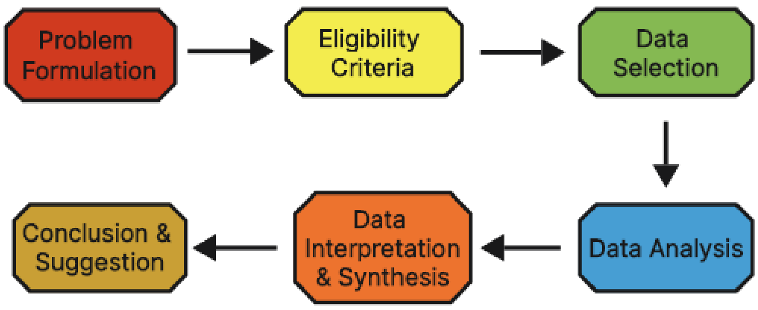

Figure 1. Research Procedure

Figure 1 shows that this study was conducted in several stages, namely: (1) problem formulation, (2) determination of inclusion and exclusion criteria, (3) literature search, (4) data selection and extraction, (5) data analysis and synthesis, and (6) conclusion drawing. The problem formulation stage focused on how Android-based drill-and-practice strategies were applied in elementary school mathematics learning, the extent to which these strategies were effective in improving students' understanding and learning outcomes, and the challenges faced in their implementation. The problem formulation became the basis for determining the scope of the study and developing a literature search strategy. The next stage is determining the inclusion and exclusion criteria to ensure that the literature analyzed is truly relevant and of high quality. The inclusion criteria used include scientific articles published in reputable journals, discussing the application of Android-based drill-experiment strategies in elementary school mathematics learning, published between 2015 and 2025, available in full text, and written in Indonesian or English. The exclusion criteria include articles that are not relevant to the topic, articles that are only opinions or non-empirical reports, and publications that do not provide data or research results that can be analyzed systematically.

Literature searches were conducted using academic databases such as Scopus, Dimension, and Google Scholar with relevant keywords, including: “Android-based learning,” “experiment-drill strategy,” “mathematics learning,” and “elementary school.” The articles found were selected through two stages: first, initial selection based on the title and abstract; second, further selection by reviewing the entire text to ensure compliance with the inclusion criteria. Data were extracted from the selected articles, including information on the title, author, year of publication, research objectives, methods used, implementation of the Android-based experiment-drill strategy, and research results and findings related to its effectiveness. The collected data were then analyzed using narrative synthesis techniques to identify key patterns, strengths, limitations, and challenges in implementing the strategy. This analysis was also supplemented with software such as VOSviewer to visualize the interrelationships between keywords and research themes, and R-Studio to analyze publication distribution, research trends, and the effectiveness of the strategy over the past ten years.

This study concludes with conclusions based on the results of literature analysis and data synthesis, as well as recommendations for future research. In addition, the results of this study are expected to provide practical contributions to teachers and learning media developers in optimizing the use of Android-based drill-and-practice strategies to improve the quality of mathematics learning in elementary schools.

C. RESULTS AND DISCUSSION

1. Data Selection Results

The search results found in the database yielded 3,896 data points relevant to the research topic. After going through the selection process, 103 articles were found to be relevant and meet the eligibility criteria. Of these, 87 were articles and 16 were proceedings. The distribution of data based on the year of publication can be seen in Figure 2, which shows the development of the number of studies related to “The Effectiveness of Android-Based Experimental Drill Strategies in Mathematics Learning in Elementary Schools: A Systematic Literature Review” in the last 10 years.

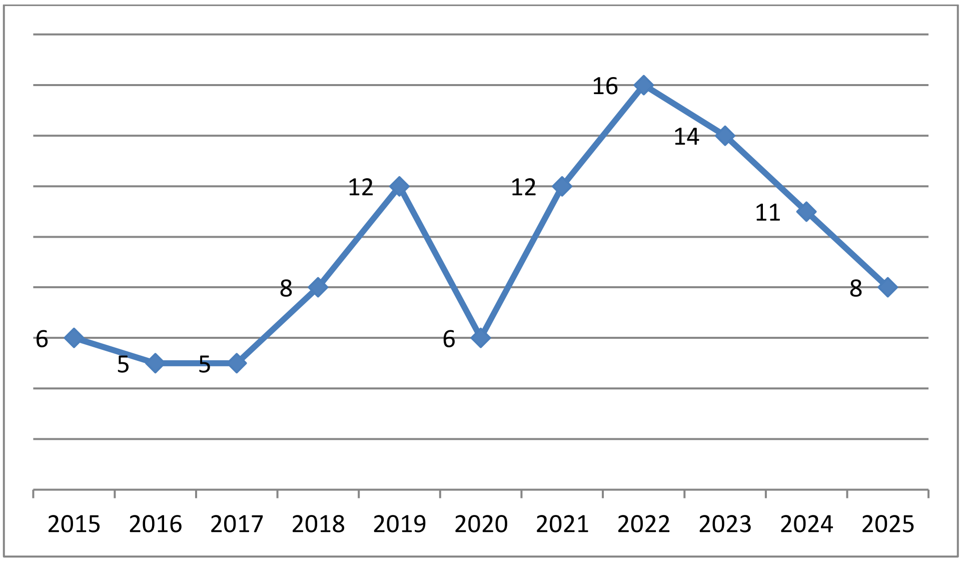

Figure 2. Annual publications

Figure 2 shows the development of the number of research publications related to "The Effectiveness of Android-Based Experimental-Drill Strategies in Mathematics Learning in Elementary Schools: A Systematic Literature Review" over the last 10 years. Based on the graph, it can be seen that publications fluctuated from year to year. In the early period (2015–2017), the number of publications was relatively stable at 5–6 articles. Entering 2018 to 2019, there was a significant increase to 12 publications. However, in 2020, there was a decline back to 6 publications. An upward trend was seen again in 2021, reaching its peak in 2022 with 16 publications. After that, publications gradually declined again until 2025 with a total of 8 publications. This pattern shows that although interest in research on this topic declined in certain years, over all there is still considerable attention from researchers, especially during the peak publication period in 2022.

2. Network Visualization of Data

Next, the researchers visualized all research results using VIOSviewer to see the research variables and the relationship between variables. The visualization results are shown in Figure 3.

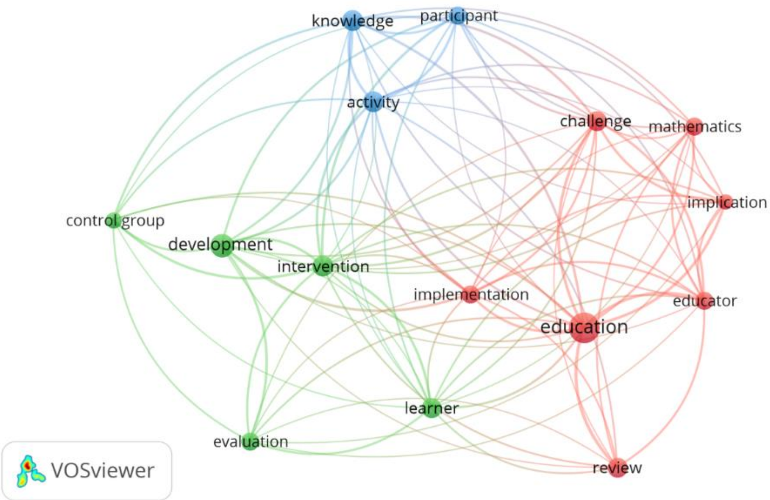

Figure 3. Network Visualization

The image above is a visualization of a bibliometric map generated using VOSviewer, which shows the relationships between keywords in related research. Keywords are grouped into three main clusters based on color: red, green, and blue. Each cluster represents a specific theme that is interconnected based on keyword coexistence.

- Red Cluster

The red cluster represents a more comprehensive dimension of educational theory, practice, challenges, and implications. The keywords "education" and "mathematics" indicate that the main focus is on the application of learning strategies in the context of mathematics education. The implementation of Android-based drill-and-practice strategies in elementary schools is not limited to the use of technology, but also includes the role of educators in integrating these strategies into the curriculum, learning methods, and classroom management. However, the implementation of these strategies is not without challenges. Some of the obstacles that often arise include the limited availability of Android devices in schools, low digital literacy among both teachers and students, and the potential for distraction when devices are used in the learning process. These obstacles need to be anticipated so that the learning strategy can be implemented optimally. In terms of implications, Android-based strategies have the potential to have a positive impact, particularly in increasing student motivation, learning outcomes, and critical thinking skills.

Furthermore, the red cluster also emphasizes the importance of systematic literature reviews as a basis for evaluating the effectiveness of digital learning strategies. Through such reviews, researchers can synthesize various previous findings, identify research gaps, and formulate practical recommendations for development and implementation in the field. Thus, the red cluster emphasizes the urgency of scientific reflection, educator readiness, and educational policy support in supporting the successful application of digital technology in mathematics learning at the elementary school level.

➢ Green Cluster

The green cluster represents the methodological dimension in educational research, particularly those that apply experimental and quasi-experimental approaches. The existence of control and intervention groups is an important basis for researchers in comparing the effectiveness of a learning strategy, such as the application of Android-based drill experiments on mathematics learning outcomes. Through this design, the effectiveness of the media can be analyzed more objectively by reviewing the differences in achievement between the experimental and control groups.

In addition, the development of learning media is an integral part, as the quality of application design greatly influences student engagement and learning outcomes. An evaluation process is also necessary to assess the success of strategy implementation, both through learning outcome tests and non-test instruments such as observation, questionnaires, and interviews. The emphasis on the position of learners as the main subjects of research shows that all forms of intervention need to be directed at improving their learning experiences and academic achievement. Thus, the green cluster emphasizes that research on the effectiveness of Android-based learning strategies requires a robust research design, the use of valid instruments, and comprehensive evaluative analysis so that the conclusions obtained can be scientifically justified.

➢ Blue Cluster

The blue cluster represents aspects of learning activities and knowledge construction acquired by students. In the context of mathematics learning integrated with technology, active student involvement is an essential factor in improving learning outcomes. The application of Android-based experiment-drill strategies provides space for students to not only receive information passively, but also to be directly involved through various exploratory activities, repetitive exercises, and reflection processes. This type of learning pattern supports the formation of deeper conceptual and procedural knowledge.

Furthermore, high student participation correlates with increased motivation and confidence in solving mathematical problems. The use of Android-based applications allows students to practice independently without being bound by time and place, making learning more flexible and tailored to individual needs. Previous research shows that active engagement in digital activities contributes to strengthening knowledge retention and developing problem-solving skills. Thus, the blue cluster confirms that digital activity-based learning strategies play a strategic role in building sustainable knowledge. Based on the interpretation of each cluster, researchers can formulate several important potentials as a synthesis of the Effectiveness of Android-Based Experiment-Drill Strategies in Mathematics Learning in Elementary Schools: A Systematic Literature Review:

a. Learning Activities and Knowledge Construction in Android-Based Drill Experiment Strategies

   Advances in Android-based digital technology provide vast opportunities for the development of interactive and adaptive learning media. The application of the experiment-drill strategy is considered relevant because it combines repetitive practice activities with the process of meaningful knowledge construction. Thus, this strategy not only serves to train skills but also increases students' active participation in understanding concepts. Figure 3 illustrates the application of this strategy, covering aspects of validation and effectiveness, the learning media used, the impact, and the strategies and approaches applied.

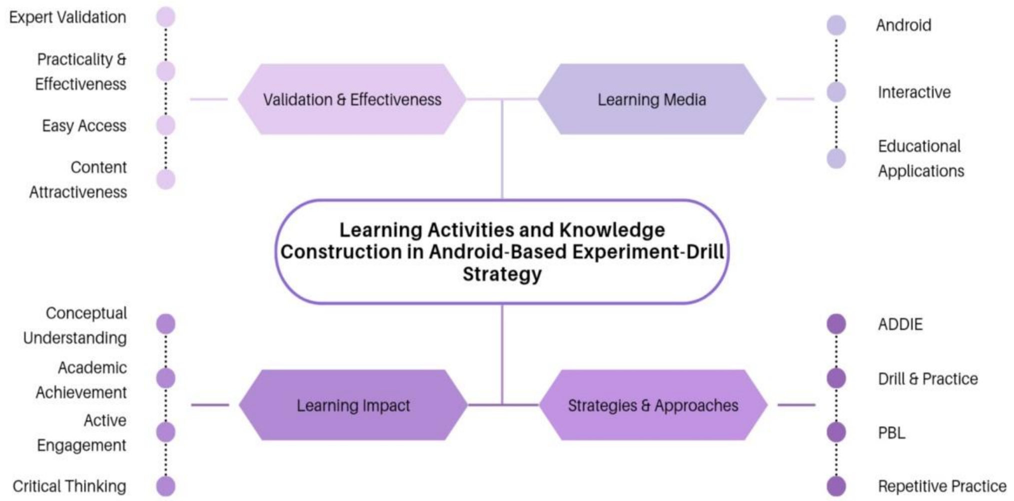

Figure 4. Experiment-Drill Strategy

Figure 4 shows that the Android-based experimental-drill strategy in learning activities and knowledge construction is based on four main components, namely validation and effectiveness, learning media, learning impact, and strategies and approaches. In terms of validation and effectiveness, this strategy must undergo a feasibility test by experts to ensure that the material and methods are suitable for the students' needs. In addition, factors such as practicality, effectiveness, ease of access, and attractiveness of the material are important indicators for the optimal use of Android learning media. Android was chosen as the medium because of its open nature, ease of access, and support for the integration of interactive educational applications. This technology allows for more dynamic learning and encourages active student engagement.

Furthermore, the learning impact aspect emphasizes the ultimate goal of the drill-and-practice strategy, namely improving conceptual understanding, academic achievement, engagement in the learning process, and the development of critical thinking skills. This shows that Android-based strategies are not only oriented towards repetitive practice, but also aimed at strengthening cognitive competencies. The strategy and approach aspect emphasizes the application of systematic methods through the ADDIE model (analysis, design, development, implementation, evaluation). The drill and practice strategy serves to strengthen skills through repeated exercises, while the problem-based learning (PBL) approach is used to train students' problem-solving abilities. The combination of these strategies allows learning to not only focus on repetition, but also encourages students to think critically and build a deep conceptual understanding.

Educational games and Android-based learning media have been developed for various subjects, such as economics, social sciences, mathematics, and physics, and have been proven to improve student learning outcomes. In their development, the ADDIE model is often applied, which includes the stages of analysis, design, development, implementation, and evaluation, to ensure that the resulting learning media are in line with educational objectives (Rakimahwati et al., 2022). The drill and practice strategy has been proven effective in increasing student engagement and cognitive achievement, especially when combined with a problem-based learning approach. This strategy provides repeated exercises tailored to the learning needs of each student, thereby strengthening understanding through systematic practice and repetition (Yusuf et al., 2023). In addition, Android-based learning applications can support the development of critical thinking skills in elementary school students through structured learning steps, such as the ability to analyze, ask questions, and draw conclusions. This allows students to actively participate in the knowledge construction process (Widiyatmoko et al., 2021).

Android-based interactive learning media in certain subjects, such as computer assembly and mathematics, are considered feasible and effective because they facilitate access to learning and increase the appeal of learning materials (Arliza et al., 2019). In addition, the integration of technology with drill techniques to improve mastery of material, such as vocabulary, has been implemented at the elementary education level with positive results. Based on these findings, Android-based experiment-drill strategies support active learning activities by combining repetitive exercises and tools that enhance cognitive engagement. These applications and media provide an interactive environment for students to practice, analyze, ask questions, and apply concepts, thereby promoting a more meaningful learning experience and strengthening in-depth knowledge construction.

Recent studies have examined the effectiveness of Android-based mobile learning in various educational contexts. The results show that Android-based interactive learning media can improve student understanding through virtual experiments, particularly in physics learning (Kustijono et al., 2019). In addition, Android-based mobile learning has been proven to significantly improve students' academic performance in learning strategy courses (Ningsih & Adesti, 2020). These mobile learning applications have undergone a validation process by experts and have demonstrated a high level of practicality and effectiveness (Isrokatun et al., 2023). Furthermore, the application of Android-based learning models, including the use of Google and Google Forms, has a positive influence on student learning activities and learning outcomes in research methodology courses (HR et al., 2022). Overall, these findings confirm that Android-based mobile learning has significant potential to improve student engagement, conceptual understanding, and academic performance in various courses at the higher education level.

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b. Intervention, Evaluation, and the Role of Control Groups in Measuring Learning Effectiveness

In educational research, the design of technology-based learning strategies must have a structured framework so that interventions can be carried out effectively and measurably. The use of Android-based media, such as educational games and interactive applications, not only serves to increase learning motivation, but also requires a planned experimental approach, instrument evaluation, and comprehensive data analysis. Figure 5 is presented to illustrate the mapping of interventions, strategies, evaluations, results, and factors that influence the success of technology-based learning.

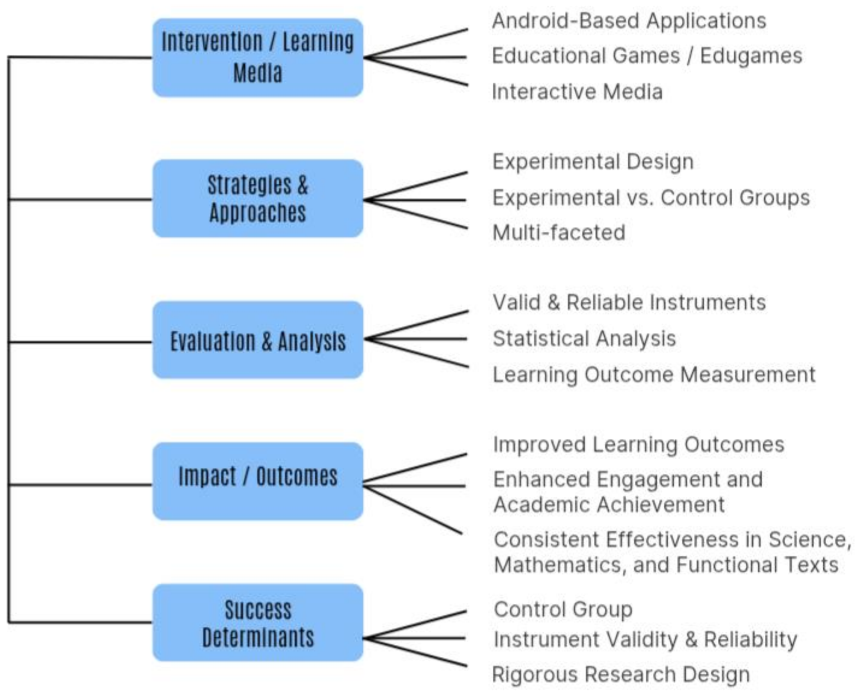

Figure 5. Android-Based Educational Intervention

Figure 5 illustrates the conceptual framework for implementing technology-based learning interventions through a systematically designed experimental approach. The first component, namely intervention or learning media, emphasizes the role of Android applications, educational games (edugames), and interactive media as the main instruments designed to facilitate a more engaging and adaptive learning process tailored to the needs of students. In terms of strategy and approach, the mind map emphasizes the importance of using experimental design involving experimental and control groups in order to obtain measurable, valid results that are supported by diverse perspectives and methods.

Furthermore, the evaluation and analysis aspect emphasizes the need for valid and reliable research instruments, the application of appropriate statistical analysis techniques, and comprehensive measurement of learning outcomes so that research findings can be scientifically justified. In terms of impact or results, the mind map shows that technology-based interventions can improve learning outcomes, student engagement, academic achievement, and learning effectiveness in various fields of study, including science, mathematics, and functional texts. The determining factors for success include the existence of a control group for comparison, the quality of the validity and reliability of the instruments, and a rigorous research design, so that the research results not only have high accuracy but can also be replicated in various learning contexts.

Interventions in the context of education usually involve the development and application of learning media or tools, such as Android-based applications, designed to improve specific learning outcomes, for example, knowledge of functional texts, science concepts, or mathematical skills. For example, (Sutrisni et al., 2022) developed an Android-based educational game to improve the science learning outcomes of fourth-grade students using a pretest-posttest experimental design involving a control group. The impact of the intervention was evaluated by measuring changes in participants' knowledge or skills using pre-tests and post-tests. Data were collected using instruments such as tests, questionnaires, and expert validation of media content before implementation. In a study by Nazarnia et al., (2023), the effect of mobile applications on health media literacy was measured using a validated MeHLit questionnaire, with two follow-up points after the program was completed. The control group played an important role as a comparison, as they did not receive the intervention or follow conventional teaching, so that the effects of the new media could be isolated.

For example, in the study Hidayat et al., (2023), the control group did not use the Android-based educational game application, allowing for a direct comparison with the experimental group that used it. Data analysis used statistical methods, such as paired t-tests, to compare pre-test and post-test scores in the experimental and control groups. The results of the study also showed a significant increase in the post-test scores of the experimental group compared to the control group, with a t-value of 8.803 and a significance level of $0.000 < \alpha = 0.05$. The reliability and validity of the instruments, for example through Cronbach's Alpha, were used to ensure that the measuring instruments could assess learning outcomes accurately and consistently. Testing the reliability and validity of the MeHLit questionnaire before using it in their research. Student engagement and independence were also important indicators of the success of the intervention. Positive feedback on the aesthetics and usability of the application often correlated with improved learning outcomes.

For example, (Can et al., 2022) found that students showed increased engagement and academic achievement after using Android-based educational game applications. Another study involving junior high school students in functional text learning through Android-based applications showed a significant increase in test scores compared to the control group, with the experimental group's post-test average being much higher than the pre-test, and statistical tests confirmed this significance. Similar research in elementary education shows that Android-based educational games are consistently effective in improving learning outcomes in science and mathematics subjects with moderate to high effect sizes. Overall, Android-based interventions are evaluated using rigorous experimental designs, involving control groups, valid and reliable measurement instruments, and statistical analysis to assess their effectiveness. The existence of a control group is essential to ensure that improvements in learning outcomes can be directly attributed to the intervention, rather than external factors or the natural learning process. This methodological approach provides a robust framework for measuring impact and forms the basis for further development of Android-based learning media.

Various studies have explored educational interventions and their evaluation methods, emphasizing the important role of control groups in assessing learning effectiveness. (Hutchins et al., 2015) showed that relatively small control groups can still provide reliable estimates of intervention effectiveness, for example in immunization studies, thereby encouraging more practitioner-led research. Conversely, (Lugosi & Uribe, 2022) found that active learning interventions in mathematics unexpectedly resulted in lower performance in the treatment group compared to the control group. (Sidhu & Srinivasan, 2018) reported an average increase in learning effectiveness of 30.06% in the experimental group that used a multi-faceted teaching approach in statistical process control. Meanwhile, (Bertram et al., 2017) examined the application of oral history methods in history learning and found that the intervention group performed better on most achievement tests than the control group, although there were variations between intervention methods. These findings underscore the complexity of educational interventions and highlight the importance of control groups in objectively evaluating the impact of an intervention.

c. Implementation, Challenges, and Implications of Mathematics Education through Digital Technology

The integration of digital media into learning requires comprehensive planning that not only focuses on the use of technology but also considers pedagogical strategies, the resulting impact, potential challenges, and relevant supporting factors. In the field of mathematics education, Android-based media and educational games serve as a means of visualizing abstract concepts. However, their effectiveness is greatly influenced by the quality of implementation, achievement of results, obstacles encountered, and the underlying strategic support. In this regard, Figure 5 is presented to represent the mapping of the roles of media, learning strategies, impacts, challenges, and supporting factors in technology-based learning.

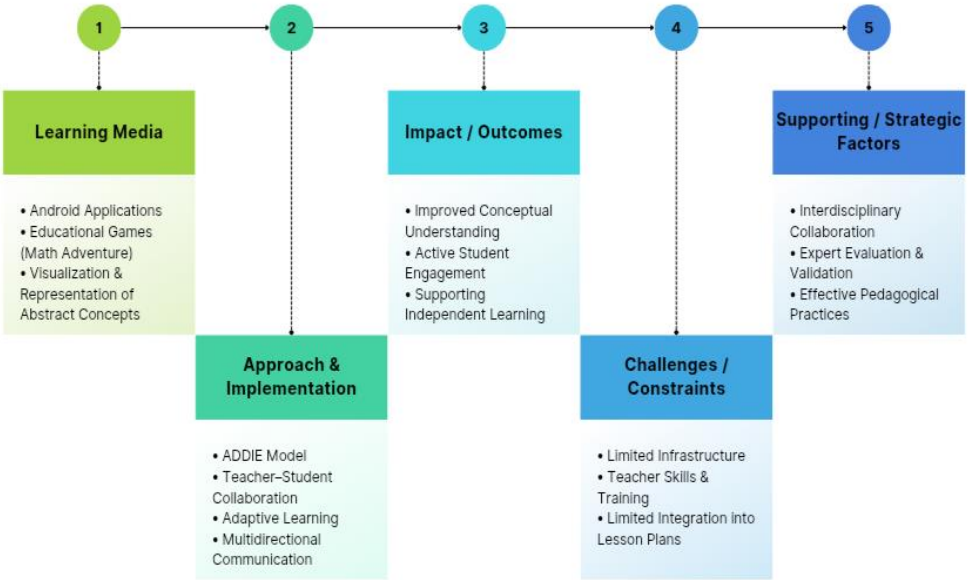

Figure 6. Android-based Mathematics Learning Application

Figure 6 illustrates the conceptual framework of technology-based learning that integrates digital media, implementation strategies, and supporting factors and challenges. In the learning media component, the use of Android applications and educational games, such as Math Adventure, plays an important role in presenting visualizations and representations of abstract concepts so that they are more concrete and easier for students to understand. Furthermore, in terms of approach and implementation, the strategy used is the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation in a systematic manner. This process is supported by active collaboration between teachers and students, adaptive learning, and multidirectional communication to create more dynamic learning interactions.

The impact aspect shows positive results from the implementation of this strategy, in the form of increased conceptual understanding, active student engagement, and support for independent learning. However, the implementation of this strategy also faces a number of obstacles, including limited infrastructure, a lack of teacher competence and training in operating digital media, and limited integration with the formal curriculum. On the other hand, the success of this strategy is largely determined by supporting factors, including cross-disciplinary collaboration, expert evaluation and validation to ensure media quality, and the application of effective pedagogical practices. Thus, the mind map in Figure 5 confirms that technology-based learning has great potential to improve the quality of learning, but its success is highly dependent on infrastructure readiness, teacher competence, and continuous strategic support.

Android-based mathematics learning applications are developed through systematic models such as ADDIE (Analysis, Design, Development, Implementation, and Evaluation), which enable the presentation of abstract mathematical concepts, such as algebra and function composition, in a more concrete, interesting, and accessible way for students (Hawu et al., 2023). This application is generally implemented in junior high and high school classrooms, either as a supplement or replacement for conventional teaching media. Some of the features included are visual aids, such as algebra tiles, educational games, for example Math Adventure, and concept comprehension tests. Active student interaction with the application is combined with communication between students and interaction with teachers, so that the learning process remains collaborative (Niswati et al., 2020). Although smartphone ownership is relatively widespread, the use of technology in the classroom still faces a number of obstacles, including a lack of teacher training, limited integration into lesson plans, and limited supporting infrastructure.

Students still need guidance from teachers, especially when dealing with complex or abstract topics that cannot be fully answered by the application alone (Fajrin, 2016). Maintaining student attention and engagement is a challenge in itself, so the application design needs to be adjusted, for example, by shortening the duration of learning sessions or increasing interactive features to maintain interest in learning (Wahid et al., 2020). Cross-disciplinary collaboration between educators, application developers, and educational psychologists is also important to create comprehensive and pedagogical learning media. In addition, the process of evaluating and validating media requires sufficient resources, including expert reviews and repeated improvements based on user feedback (Muhaimin & Juandi, 2023). The use of Android-based mathematics applications has been proven to improve students' conceptual understanding and learning outcomes compared to traditional methods, especially when the application provides visualizations and concrete representations of abstract ideas.

This medium encourages active student engagement and multidirectional communication, thereby deepening conceptual understanding and collaboration among students. Although the application supports independent learning, the role of the teacher as a facilitator remains essential. The use of these digital tools also helps overcome difficulties in understanding complex material and bridges gaps in access and quality of learning. Mature technology integration, when combined with effective pedagogical practices, has the potential to make mathematics learning more engaging, interactive, and meaningful. With proper design and implementation, digital media can transform mathematics learning by visualizing abstract concepts and supporting diverse learning styles, although the success of its implementation depends on attention to technological, pedagogical, and logistical challenges.

The integration of digital technology in mathematics education has experienced rapid development, mainly driven by the COVID-19 pandemic and the Society 5.0 era (Dermawan & Sumarni, 2024). This technology offers various benefits, including interactive visualization and adaptive learning capabilities, but its implementation still faces a number of challenges. Some of the main obstacles include limited infrastructure, especially in rural areas, as well as variations in teachers' abilities and skills in utilizing technology (Muhazir & Retnawati, 2020). Factors that influence the level of technology adoption include teacher employment status, teaching experience, and school level, where more experienced teachers or those teaching at higher levels of education tend to integrate technology more intensively (Fitrah et al., 2024). In addition, other obstacles include inappropriate learning materials, limited school institutional support, and limited training for teachers. To overcome this, it is recommended that there be a continuous training program for all teachers regardless of their employment status. Despite various challenges, mathematics education continues to move towards a more advanced adaptive learning approach, which integrates computational thinking and requires a mature implementation strategy that takes into account the local cultural context (Mcculloch et al., 2018).

D. CONCLUSIONS AND SUGGESTIONS

Based on the results of the literature review, it can be concluded that Android-based experiment-drill strategies and digital education interventions have significant effectiveness in improving students' mastery of material, cognitive engagement, and knowledge construction. The success of implementation is highly dependent on mature pedagogical design, the integration of concept visualization, the active involvement of teachers as facilitators, and training and institutional support. Android-based interactive media provides an adaptive, collaborative, and participatory learning environment, thereby strengthening students' conceptual understanding and academic achievement in greater depth. However, there are several gaps that need to be addressed in future research. First, most studies still emphasize quantitative aspects, so that students' subjective experiences, critical thinking processes, and knowledge construction mechanisms have not been analyzed in depth. Second, obstacles related to infrastructure, device access, and variations in teacher skills are still rarely addressed systematically, so the real impact on schools with limited resources is not yet fully known. Third, research on the effectiveness of integrating digital media in cross-subject learning, especially on complex or abstract topics, is still limited.

Based on these gaps, urgent research topics for future study include: developing experiment-drill learning models that combine qualitative measurements of student learning experiences, technology adaptation strategies for schools with limited infrastructure, and exploring the integration of digital media in teaching abstract concepts across subjects. Further research also needs to examine the mechanisms of teacher-student collaboration in digital environments and their impact on the development of critical thinking skills, problem solving, and more holistic knowledge construction.

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