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Development of Mobile Learning on Solar System Material to Enhance Students' Cognitive Abilities

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Abstract: The teaching of Solar System material at SMP Wahidiyah Kepanjen rarely utilizes technology-based media, resulting in incomplete material, passive learning activities, and suboptimal cognitive learning outcomes. However, students are familiar with smartphones, making Android-based mobile learning a viable solution to enhance their understanding. This study employs the Lee & Owens development model, consisting of analysis, design, development, implementation, and evaluation stages. To assess the instruments used, validity and reliability tests were conducted. The validity test results showed that the calculated r value exceeded the r table value (0.374 for N = 29), confirming that all 20 tested items were valid. A reliability test using Cronbach's Alpha was also conducted, yielding a value of 0.489, higher than 0.374, indicating the instrument's reliability. Expert validation showed high validity scores, with material experts rating 97.5% and media experts 95%. A small-scale trial with three students resulted in a 97.5% validity score and an N-Gain of 0.84 (high category). A larger test with 26 students yielded an 88.9% validity score and an N-Gain of 0.58 (moderate category). The findings suggest that Android-based mobile learning is highly effective for individual learners, as seen in the higher N-Gain score from the small-scale trial.

Keywords: Mobile Learning, Solar System Material, Cognitive Abilities

Abstrak: *Pembelajaran materi Tata Surya di SMP Wahidiyah Kepanjen masih jarang menggunakan media berbasis teknologi, sehingga materi kurang lengkap, aktivitas belajar pasif, dan hasil belajar kognitif kurang optimal. Namun, siswa sudah terbiasa menggunakan smartphone, sehingga pembelajaran berbasis mobile Android menjadi solusi yang tepat untuk meningkatkan pemahaman mereka. Penelitian ini menggunakan model pengembangan Lee & Owens, yang mencakup tahap analisis, desain, pengembangan, implementasi, dan evaluasi. Untuk mengukur instrumen penelitian, dilakukan uji validitas dan reliabilitas. Hasil uji validitas menunjukkan bahwa nilai r hitung lebih besar dari nilai r tabel (0,374 untuk N = 29), sehingga semua 20 butir soal yang diuji dinyatakan valid. Uji reliabilitas menggunakan Cronbach's Alpha menghasilkan nilai 0,489, lebih tinggi dari 0,374, sehingga instrumen dinyatakan reliabel. Validasi oleh ahli materi menunjukkan skor 97,5%, sedangkan ahli media memberikan skor 95%, keduanya dengan kriteria valid. Uji coba skala kecil pada tiga siswa menunjukkan skor validitas 97,5% dan N-Gain sebesar 0,84 (kategori tinggi). Uji coba skala besar dengan 26 siswa menghasilkan skor validitas 88,9% dan N-Gain sebesar 0,58 (kategori sedang). Hasil penelitian menunjukkan bahwa pembelajaran berbasis mobile Android sangat efektif untuk pembelajaran individu, sebagaimana terlihat dari skor N-Gain yang lebih tinggi pada uji coba skala kecil dibandingkan uji coba skala besar.*

Kata Kunci: *Mobile Learning, Materi Sistem Tata Surya, Penguatan Kognitif*

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INTRODUCTION

Many students face difficulties in understanding the material of the Solar System, especially due to its abstract concepts that are hard to visualize, such as the distance between planets, the movement of celestial bodies, and the structure of the solar system. Conventional learning, which relies on text and static images, is often insufficient to explain these concepts thoroughly. To overcome these limitations, an innovation in learning media is needed that can present the material in a more interactive and comprehensible way. One solution that can be implemented is the use of technology-based learning media, which allows the integration of various elements such as images, videos, and text, capturing students' attention and enhancing their engagement in the learning process. Technology-based learning media, particularly mobile learning, has great potential to improve students' understanding of the material and provide them with the experience of using information technology during the learning process, helping them grasp abstract concepts more effectively.

Learning media are tools or physical forms that assist educators in achieving learning objectives, enabling the material delivered to students to be well understood (Rahmi & Samsudi, 2020). In the 4.0 era, technological advancements are progressing rapidly, and the education sector must keep up with these developments by adopting technology in the learning process. The use of technology, which offers new features such as the integration of images, videos, and text, can attract students' interest in learning activities. Technology-based learning media contribute to enhancing students' understanding of the material and provide experience in using information technology during the learning process.

Observations at SMP Wahidiyah Kepanjen show that the classroom learning process tends to rely on the lecture method, where the teacher explains the material in front of the class while students simply listen. This approach rarely incorporates technology-based media or innovative methods in teaching. Most of the learning material still depends on textbooks provided by the school, which generally consist of lengthy readings without engaging visualizations, making it ineffective in explaining complex concepts. For example, in the sub-chapter on Earth's rotation and revolution, the explanations in the textbooks are considered incomplete and difficult for students to understand. This can cause students to feel bored and struggle to achieve an optimal understanding of the material.

On the other hand, the use of technology in teaching can encourage students to actively participate and directly interact with the learning material. With the rapid advancement of technology, students must now be equipped with the skills to utilize technology in classroom learning activities. The use of technology-based media, such as videos, simulations, and 3D models, can help students understand difficult material in a more engaging and interactive way. This aligns with the constructivist theories proposed by Piaget and Vygotsky, which emphasize the importance of active interaction between students and learning material in building a deeper understanding (Pappano, 2020; Clark & Mayer, 2020). Technology-based learning also supports more independent learning, which can be adjusted to the individual pace of each student, thereby increasing their motivation and understanding of the material.

According to interviews with teachers, students' cognitive learning outcomes on the Solar System material, particularly on the sub-chapters of Earth's rotation and revolution, are lower compared to other subjects. This is due to students' difficulty in understanding complex and abstract concepts in the material. Furthermore, the limited visualizations in textbooks do not adequately support students' understanding. Passive learning, with few activities involving active student participation, also contributes to poor student comprehension of the material. Therefore, an interactive and technology-based approach is needed to increase student engagement and improve their understanding, especially for materials that require understanding of abstract concepts like the Solar System (Sari & Nugraha, 2021; Hamid & Kamil, 2021).

The solar system topic was chosen because it involves complex and abstract concepts, such as the rotation and revolution of the Earth, as well as the interactions between celestial bodies that can affect life on Earth. A good understanding of this material is important as it not only provides scientific knowledge but also develops students' cognitive abilities, including critical thinking, memory, and problem-solving skills. These abilities are necessary for students to achieve optimal learning outcomes. In this context, the solar system is a relevant topic to sharpen students' cognitive skills in analyzing, connecting, and explaining concepts related to astronomy and the natural phenomena occurring around them.

According to Micklich (2011), the cognitive domain includes thinking processes that involve remembering or recognizing learned information, as well as developing intellectual abilities such as critical thinking, problem-solving, and decision-making. Basic Competency 3.11, which involves analyzing the solar system, Earth's rotation and revolution, and their impacts on life on Earth, falls within the cognitive domain of understanding (C2). This understanding process involves students' ability to delve into information, whether through reading materials or teacher explanations, and practicing skills such as explaining, exemplifying, classifying, summarizing, and drawing conclusions (Magdalena et al., 2020). Therefore, this material plays a significant role in improving students' cognitive skills, which will benefit their intellectual development in the future.

However, based on observations and interviews with teachers, several obstacles were found in the learning process of the solar system material. One of the main challenges is students' difficulty in understanding abstract concepts, particularly in the sub-chapters on Earth's rotation and revolution, which require more in-depth visualization. The material is often presented in long text form without supporting visual elements, which tends to make students feel bored and disengaged, resulting in suboptimal understanding of the material. This reflects a lack of student involvement in the learning process and highlights the need for a more interactive, technology-based approach to teaching.

To address this issue, one possible solution is the development of technology-based learning media, such as mobile learning. The use of technology can provide a more engaging and interactive learning experience, helping students better understand abstract concepts in solar system material. By utilizing technology-based media such as videos, simulations, and 3D models, students can observe the movement of planets, the Earth's rotation, and other phenomena in a clearer and more realistic way. This aligns with the constructivist theory, which emphasizes the importance of active interaction between students and the material to build deeper understanding (Pappano, 2020; Clark & Mayer, 2020). A technology-based approach can increase student engagement and assist in understanding complex material, while also enhancing their cognitive abilities.

Overall, the development of technology-based learning media for solar system material has a positive impact, not only on improving students' understanding of the material but also on enhancing their cognitive skills, which will be valuable for their intellectual development in the future. With a more interactive approach that meets the needs of the times, students are expected to be better prepared to face the challenges of an ever-evolving world.

Based on the problem analysis above, it was found that the lack of student learning activities is due to the dominance of the lecture method by teachers, the lack of learning media that provides engaging and varied visualizations, and the incomplete material in the teaching resources. This results in students' understanding of the solar system material being less than optimal. One possible media development is utilizing smartphones by integrating media such as images, text, and videos to help students better understand the material through engaging visualizations. The use of smartphones is relevant because students frequently use them in their daily activities, allowing them to use them for individual learning. In Indonesia, the most widely used mobile learning platform is Android (Ilman et al., n.d.). Additionally, almost all students at SMP Wahidiyah Kepanjen own Android smartphones, but their usage is mostly limited to gaming and social media.

In the context of learning about the Solar System, mobile learning is essential for addressing several challenges students face in understanding abstract concepts that are difficult to visualize. For example, concepts such as Earth's rotation and revolution, the positions of planets within the solar system, and the movement of celestial bodies require a deep spatial understanding. These topics can be challenging to grasp using only static text and images from textbooks. Therefore, mobile learning provides an effective solution by offering more interactive learning media, such as planetary motion simulations, visual animations, and 3D models that help students better visualize and comprehend these concepts (Nurmadiah & Asmariani, 2019).

Additionally, mobile learning allows students to learn independently and with greater flexibility. Using mobile devices such as smartphones or tablets, students can access learning materials anytime and anywhere. They can review challenging topics, revisit lessons as needed, and seek additional information to deepen their understanding. Repetition reinforces memory, which is crucial for mastering complex material. Furthermore, mobile learning helps overcome time constraints in the classroom, as students are not limited to scheduled lessons and can continue learning beyond school hours (Nurmadiah & Asmariani, 2019).

This study is crucial in providing a deeper understanding of the benefits of mobile learning for subjects requiring abstract concept comprehension, such as the Solar System. By integrating mobile learning, students are expected to engage more actively in the learning process, enhance their understanding, and overcome difficulties in grasping complex concepts. Moreover, this research contributes to the development of more innovative and flexible learning approaches that align with the needs of today’s digital generation, where technology plays a vital role in supporting the teaching and learning process (Purnama, 2017).

The selection of media should align with the intended purpose of its use (Abidin, 2016). In the context of education, the selection of media aims to support individual learning, as students will use smartphones individually to access materials as part of their learning activities. The purpose of using this media is to achieve better understanding, as it presents content not available in textbooks and provides visualizations in the form of images and videos to explain concepts that cannot be demonstrated directly in the classroom. By incorporating media that includes images, text, video, and audio, the material can be presented more clearly, enriching understanding, concretizing concepts, and correcting misconceptions (Prameswari, 2022). The use of text and images in learning media has cognitive processing benefits because the symmetry between text and images allows students to understand information in a complementary way, where text and images serve different but mutually supportive functions (Schnotz & Wagner, 2018).

This research is significant in enhancing the quality of learning at SMP Wahidiyah Kepanjen by utilizing mobile learning technology. The purpose of this study is to develop an Android-based learning media that can improve students' cognitive understanding of Solar System material. Through the use of Android smartphones, it is expected that students will gain individualized learning experiences, become more engaged in the learning process, and better understand complex concepts in a more interactive way. This research aims to provide a solution to the limitations of existing learning media and improve students' learning outcomes in science subjects, particularly those related to abstract concepts such as the movement of planets and Earth's revolution.

RESEARCH METHODS

This research uses an R & D (Research and Development) approach with the aim of producing an effective product as a learning medium. The product developed in this study is Android-based mobile learning for the Solar System material to strengthen students' cognitive understanding. The development model applied is the Lee & Owens model (2004), which specifically focuses on multimedia.

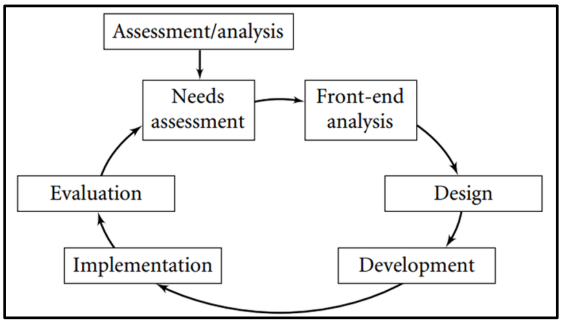

Figure 1. Development Model (Lee & Owens, 2004)

Need Asessment

The needs analysis stage is conducted to identify the gap between the current condition and the desired ideal condition. The ideal condition for the Solar System material includes the knowledge and skills required at the C2 cognitive level, which is understanding, with skills such as explaining, providing examples, classifying, summarizing, and concluding. However, in reality, students' cognitive outcomes for this material are still unsatisfactory based on the scores obtained, indicating that students' knowledge and skills have not yet reached the expected level of understanding.

Front-end Analysis

This research was conducted at SMP Wahidiyah Kepanjen, involving 29 7th-grade students in the IPA subject. Based on the audience analysis, the majority of students have a visual learning style, especially in the IPAS subject, which often introduces concepts that are difficult to present directly. To support students' understanding, Android-based mobile learning is highly relevant because each student already has a smartphone and is capable of operating it. The situational analysis indicates that in class, the teacher still dominates the explanation of the material, which leads to a lack of active interaction between the teacher and students, thus limiting students' learning activities. Therefore, the learning material is tailored to the students' abilities, with the expectation that they will reach an understanding at the C2 level, which means being able to explain, classify, and apply concepts related to the solar system.

The critical incident analysis identifies the skills that students need during the learning process, such as the ability to explain, differentiate, and demonstrate concepts about Earth's rotation and revolution, the structure and function of the solar system, and their impacts on life on Earth. The formulated learning objectives are for students to master the material in-depth using Android-based technology. Students are expected to accurately explain these processes after watching videos or visual presentations through mobile-based learning. The use of interactive learning media is expected to enhance students' understanding in a more engaging and easily comprehensible manner.

However, the problem analysis results show that students feel bored due to the lack of variety in learning activities, incomplete teaching materials, and limited visualizations in textbooks, leading to a low understanding of the solar system material. This forms the basis for conducting a media analysis, which aims to select the appropriate type of media for learning activities. Although each student has a smartphone, the IPAS teacher at SMP Wahidiyah Kepanjen rarely utilizes technology in classroom learning. The existing data analysis shows that mobile-based learning material on the solar system can be developed using available resources, such as textbooks at the school, images from the internet, and videos from YouTube. Additionally, software such as Lectora, Figma, Audacity, and Filmora required for developing Android-based learning materials is available for free, making the development process more efficient and affordable.

Design

The design phase includes planning the product from the development schedule to evaluation, as well as assembling the project team, which will be managed by the researcher as the developer of the Android-based mobile learning. This phase also includes media specifications, including a description of the SolarSystem Explorer application and the structure of the material within the application. This design phase serves as a guide for the product development process to ensure the resulting product meets the standards.

Development and Implementation

The development phase involves implementing the planned design to produce the final product. During this phase, the storyboard development for the SolarSystem Explorer application is carried out, including creating content such as material images, videos from YouTube processed using Filmora, and interface design using Figma for user instructions, concept maps, materials, and quizzes. Once all elements are completed, integration is performed using Lectora software to create an interactive application for Android. Subsequently, the product will be reviewed and revised after validation testing by subject matter experts and media experts. If the product is deemed acceptable by the experts, the next stage is testing the application with students.

Evaluation

After the product implementation, evaluation is conducted through four stages. First, Level 1 - Reaction, involves assessing feedback by collecting questionnaire results from students using the SolarSystem Explorer application. At Level 2 - Knowledge, evaluation is performed by comparing pre-test results before using the application with post-test results after using it to assess the increase in students' knowledge. Next, Level 3 - Performance, involves evaluating changes in students' attitudes and behaviors through interviews with teachers to assess students' performance using the application. Finally, Level 4 - Impact, evaluates the effect of using the SolarSystem Explorer application on students by conducting interviews with teachers. The results of this evaluation will be analyzed to determine the extent to which students' understanding of the Solar System material has improved after using the application. Formula for calculating questionnaire data (Arikunto, 2010):

$$P = \frac{\sum x}{\sum xi} \times 100\%$$

Explanation:

P : Percentage

$\sum x$: The total number of responses across all items

$\sum xi$: The total number of ideal scores across all items

100% : Constant

Table 1. Validity Level Criteria (Arikunto, 2010)

Category	Validity level criteria		
	Percentage (%)	**Explanation**	**Score**
A	81-100	Valid	4
B	61-80	Fairly Valid	3
C	41-60	Less Valid	2
D	<40	Not Valid	1

Pre Test - Post Test

To evaluate students' understanding of using Android-based mobile learning on the Solar System material, a Pre-Test and Post-Test were conducted. The Pre-Test was administered before the learning process to assess students' initial knowledge of the fundamental concepts of the Solar System material, while the Post-Test was given after the learning to evaluate the impact of the learning media on students' understanding. Both the Pre-Test and Post-Test consist of 20 multiple-choice questions that cover important aspects of the Solar System material, such as Earth's rotation and revolution, the structure of the solar system, and the impact of Earth's rotation and revolution on life on Earth.

The questions in the Pre-Test and Post-Test are designed to test students' understanding of key concepts and their ability to explain and apply the knowledge they have learned. In the Pre-Test, the questions focus more on students' initial knowledge, while the Post-Test questions are aimed at measuring how much the Android-based mobile learning media has improved students' understanding after they have been engaged in the learning process. In this way, a significant difference between the results of the Pre-Test and Post-Test is expected to reflect the improvement in students' understanding after using mobile learning media.

To measure the instruments in this study, validity and reliability tests were conducted to ensure the quality and consistency of the measurement tools used. The purpose of the validity test is to assess the extent to which the instrument measures what it is intended to measure. Below are the results of the validity test.

The decision-making basis for the Product Moment validity test is that if $r_{count} > r_{table}$, then the item or question is considered valid. For N = 29, the degrees of freedom (df) are N - 2 = 29 - 2 = 27.

Based on the Product Moment table at a 5% significance level (α = 0.05), the r table value for df = 27 is 0.374. Therefore, if r count is greater than r table (0.374), the item or question can be considered valid.

Table 2. Results of Instrument Validity Test

Items	Analysis		
	r_{count}	r_{table}	Explanation
item 1	.506*	0.374	Valid
item 2	.426*	0.374	Valid
item 3	.461*	0.374	Valid
item 4	.645**	0.374	Valid
item 5	.424*	0.374	Valid
item 6	.495*	0.374	Valid
item 7	.467*	0.374	Valid
item 8	.424*	0.374	Valid
item 9	.740**	0.374	Valid
item 10	.671**	0.374	Valid
item 11	.565**	0.374	Valid
item 12	.533**	0.374	Valid
item 13	.467*	0.374	Valid
item 14	.429*	0.374	Valid
item 15	.687**	0.374	Valid
item 16	.406*	0.374	Valid
item 17	.715**	0.374	Valid
item 18	.429*	0.374	Valid
item 19	.496*	0.374	Valid
item 20	.532*	0.374	Valid

Based on the results of the statistical test, it was identified that the calculated r value is greater than the r table value, thus the items or test questions are considered valid. The r table value for N = 24 is 0.374. Based on the validity test results for 20 items tested on 29 students, it can be seen that all the items fall into the valid category and can be used as an instrument for measuring students' cognitive abilities.

After the instrument is declared valid, the next step is to conduct a reliability test to ensure the consistency of the measurements provided by the instrument. The purpose of the reliability test is to assess the extent to which the instrument can produce consistent results when used at different times or under different conditions. A reliable instrument will yield similar results when used to measure the same ability in similar situations. Here are the results of the reliability test on the instrument.

Table 3. Results of Instrument Reliability Test

Cronbach's Alpha	N of Items
.489	20

The decision rule for the Cronbach's Alpha reliability test is that if the calculated r value is greater than the table r value, the instrument is considered reliable. For N = 29, the table r value is 0.374. Based on the statistical results, it was identified that the Cronbach's Alpha value is 0.489, which is greater than 0.374, so it can be concluded that the research instrument used to measure students' cognitive abilities is reliable.

To measure the improvement in students' understanding after participating in the learning, the N-gain test is used. This test compares the results of the Pre-Test and Post-Test to determine how much Android-based learning has enhanced students' comprehension of the Solar System material. In this case, the N-gain test provides a more objective view of the impact of the learning media on students' cognitive improvement. The results of this test are expected to provide a clear picture of the effectiveness of Android-based mobile learning in improving students' understanding of the material being studied.

RESULTS AND DISCUSSION

The development of the Android-based mobile learning application, *SolarSystem Explore*, begins with an analysis stage to identify the needs and objectives of the learning material. This mobile learning tool is designed to improve students' cognitive abilities by providing educational content about the solar system. The application, developed using Lectora Inspire software, presents information in multiple formats, including text, images, and videos, to engage different learning styles and enhance students' understanding of material that may not be fully addressed in traditional textbooks. The development process follows the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), starting with an analysis of the needs, goals, and characteristics of the target learners.

In the *SolarSystem Explore* application, the structure and function of the solar system are presented with accompanying images, while videos demonstrate the Earth's and Moon's rotation and revolution. Additionally, the application highlights the impact of the solar system on life on Earth. The main menu of the application includes buttons for usage instructions, a concept map, material content, and quizzes. The concept map provides an overview of the solar system content, while the material page features interactive elements such as images that link to specific topics such as the structure and function of the solar system, its processes, and related phenomena.

The app also includes a quiz section with 20 questions designed to test students' understanding of the material, and the results are displayed at the end of the quiz. The development of this mobile learning application aligns with the goal of enhancing students' cognitive abilities, fostering a deeper understanding of the solar system, and providing an interactive learning experience that goes beyond traditional classroom methods.

By integrating multimedia and interactive elements, the *SolarSystem Explore* application is designed to improve students' engagement and motivation, leading to better cognitive outcomes in understanding complex scientific concepts. Through this approach, the mobile learning tool aims to provide an effective and engaging alternative to conventional learning methods, enabling students to learn at their own pace and in a more personalized manner.

The development of the Android-based mobile learning application named 'SolarSystem Explore' is provided in an APK format. This application includes material on the structure and function of the solar system presented through images, the processes of Earth's and Moon's rotation and revolution accompanied by videos, and the impact of the solar system on life on Earth. The integration of text, images, and videos is designed to enhance students' understanding of solar system material that may not be fully covered in textbooks. This Android-based mobile learning development uses Lectora Inspire software, which is a tool for creating educational media programs (Wulandari et al., 2017). The advantage of this software is its ease of development and its ability to produce educational media in various formats such as HTML, Single file, Executable, and CD-ROM, as well as for creating e-learning, presentations, websites, and educational media.

The initial screen of the 'SolarSystem Explore' application displays a login page that requires a username and password to access. After logging in, users are directed to the main menu page, which includes buttons for usage instructions, concept maps, material, and quizzes. The usage instructions page provides explanations of the functions of each button in the application. The concept maps page features a concept map illustrating the solar system material. The material page includes image buttons representing elements of the solar system, and when one is selected, users are taken to a page displaying material options such as structure and function, processes, and related impacts and phenomena. The quiz menu presents 20 questions, and the results will be displayed after the quiz is completed.

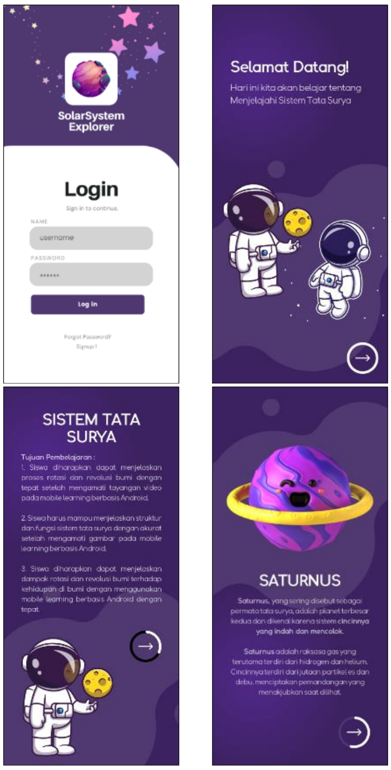

Figure 2. Application Form

Here is the analysis result from the media expert regarding the Mobile learning application. Overall, the application has been well-designed, considering user comfort and ease of access to learning materials. However, there are a few areas that could be improved to enhance the user experience, particularly in terms of instruction clarity and content accessibility. The media expert provided evaluations based on ten key indicators covering important aspects such as layout, navigation, visual quality, and button functionality. Below is a detailed analysis of each evaluated indicator:

Table 4. Media Expert Evaluation Result

Indicator	Media Expert	Explanation
Clear and easy-to-follow application usage instructions	4	Very Suitable
No modification required on the smartphone system settings	4	Very Suitable
Accuracy of layout or placement of elements within the app	4	Very Suitable
Ease of identifying button functions within the app	4	Very Suitable
Clarity of menu instructions and navigation within the app	3	Very Suitable
Presence of home and exit buttons	4	Very Suitable
Appropriateness of images and videos related to the excretory system material	4	Very Suitable
Clarity of image and video quality within the app	4	Very Suitable
Clarity of font selection, size, and color for readability	3	Very Suitable
Application access speed is good	4	Very Suitable
Average	**3.8**	**Very Suitable**

The evaluation results of the Android-based Mobile Learning product by the subject matter expert show a score of 95%, which is deemed valid. Out of 10 questions in the questionnaire, 8 questions received a score of 4 (very appropriate), while 2 questions received a score of 3 (appropriate). The comments from the subject matter expert indicate that the content and questions are in line with the Basic Competencies for the solar system material. The review results from the media expert also show a score of 95%, classified as valid. Although most questions received favorable scores, revisions were needed for the usage instructions, which did not adequately explain the buttons on the app. After corrections were made, the media expert commented that the media is suitable for use. If calculated based on the average score of 3.9, the result in percentage form is 95%. Here is the diagram of the results from the media expert evaluation.

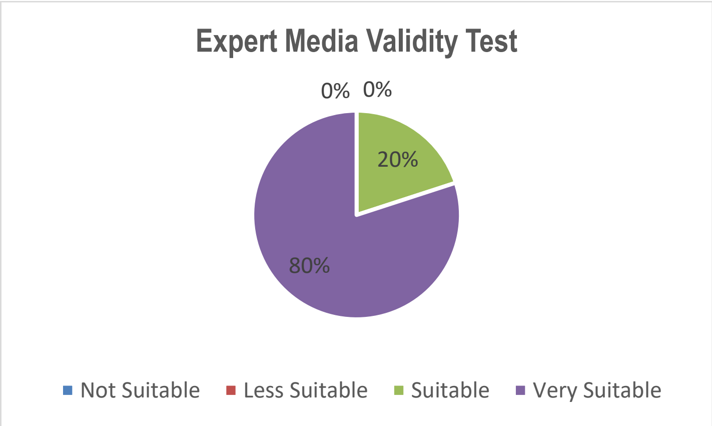

Figure 3. Diagram of Expert Media Validity Test

Next, the expert material review was conducted to assess the alignment of the content in the application with the applicable Basic Competencies. The subject matter expert evaluated whether the material, questions, and instructions in the application are accurate and relevant to the learning objectives outlined in the curriculum. This review aims to ensure that the application is not only easy to use but also effective in delivering information that meets the existing educational standards. The results of this review provide valuable insights to improve the quality and relevance of the application in supporting the learning process. Below is the table of the results from the expert material review:

Table 5. Material Expert Evaluation Result

Indicator	Material Expert	Explanation
Alignment of the material with KI (Core Competencies), KD (Basic Competencies), indicators, and learning objectives	4	Very Suitable
Alignment of learning objectives with the cognitive development level of understanding (C2)	4	Very Suitable
Sequencing of material presentation in a logical order	4	Very Suitable
Clarity of explanation or description of the Excretory System material	4	Very Suitable
Consistency in the use of key terms in the Excretory System material	3	Very Suitable
Sufficient number of practice questions covering all the material	4	Very Suitable
Alignment of the practice questions with the Excretory System material	4	Very Suitable
Appropriateness of images and videos in relation to the Excretory System material	4	Very Suitable
Alignment of questions in practice exercises with the learning objectives	4	Very Suitable
Suitability of interactivity with the material being presented	4	Very Suitable
Average	**3.9**	**Very Suitable**

The evaluation results of the Android-based Mobile Learning product by the subject matter expert show a score of 97.5%, which is considered valid and indicates that the application is suitable for use as an educational media. Out of 10 questions in the questionnaire, 9 questions received a score of 4 (very appropriate), indicating that most aspects of the application, such as the alignment of the content with the Basic Competencies (KD), learning objectives, as well as the relevance of the questions and supporting media, were rated very highly. Meanwhile, 1 question received a score of 3 (appropriate), indicating that while this aspect is adequate, there is still room for improvement to make it more optimal. The comments from the subject matter expert indicate that the content presented in the application is aligned with the learning objectives and effectively supports students' understanding of the solar system material, in accordance with the Basic Competencies established in the curriculum. Additionally, the questions provided in the application were deemed relevant and able to measure students' understanding, considering the appropriate cognitive levels, namely C1 (knowledge) and C2 (comprehension), as outlined in Bloom's Taxonomy. When calculated based on the average score of 3.9, the result in percentage form is 97.5%, showing that overall, the application meets the expected standards in terms of content alignment with the curriculum, question quality, and the application's ability to support the teaching and learning process. Here is the diagram of the results from the material expert evaluation.

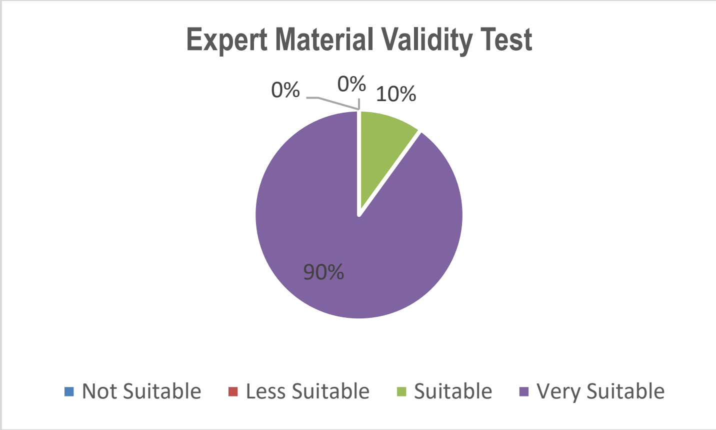

Figure 4. Diagram of Expert Material Validity Test

After the application was deemed suitable by the subject matter and media experts, a trial was conducted with students as users. An initial validity test was carried out on a small scale involving 3 students, resulting in a score of 97.5%, which is classified as valid. Additionally, pre-tests and post-tests were conducted to evaluate the level of understanding of students regarding the solar system material using the SolarSystem Explore application. Each question in the test was designed with C1 and C2 thinking levels in accordance with Bloom's Taxonomy and the Basic Competencies of the solar system material.

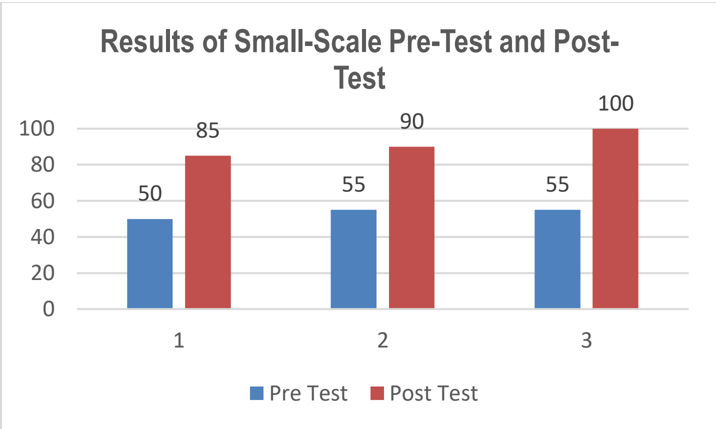

Figure 5. Diagram of Pre-Test and Post-Test Comparison on a Small Scale

The results of the pre-test and post-test on a small scale show an N-Gain value of 0.8, which falls into the high criterion category. Before using the SolarSystem Explore application, the pre-test scores of the 3 students were below 70, indicating that they had not met the Minimum Competency Criteria. However, after using the application, the post-test scores of all three students increased to above 70, indicating that they had met the Minimum Competency Criteria. After the small-scale results showed a good category, the trial was continued to the entire population to obtain feedback from a larger scale.

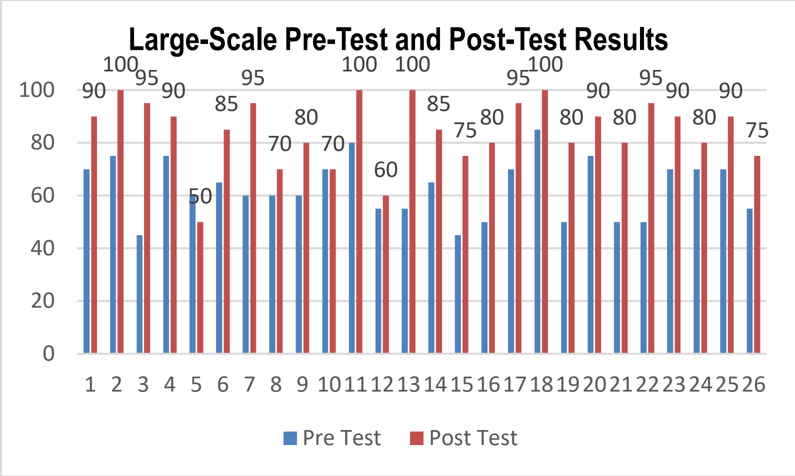

Figure 6. Diagram of Pre-Test and Post-Test Comparison on a Large-Scale

The results of the pre-test and post-test on a large scale show an N-Gain value of 0.58, which falls into the moderate criterion category. Before using the SolarSystem Explore application, the pre-test indicated that 14 students scored below 70, while 12 students scored above 70, suggesting that many students had not met the Minimum Competency Criteria. After using the application, the post-test results showed an increase in the number of students who scored above 70, reaching 25 students, indicating that they had met the Minimum Competency Criteria. The improvement in scores was also evident after students used the SolarSystem Explore application. The validity test on a large scale conducted with 26 students yielded a score of 88.9%, which is categorized as valid.

The N-Gain test was conducted to measure the extent of cognitive improvement in students after using the Android-based mobile learning media on the Solar System material. This test aims to provide an objective view of the media's effectiveness in enhancing students' understanding. Initially, a small group consisting of three students was tested to observe the impact of using this media in the learning process. The results of the N-Gain test for this small group are expected to provide an early indication of the media's effectiveness and serve as a foundation for further testing in a larger group. Below are the results of the N-Gain test for the small group.

Table 6. Results of the N-Gain test for the small group.

Students	Skor Ideal	N-Gain Score	Average
1	55	0,73	0,84
2	50	0,8	
3	50	1	

The N-Gain test was conducted to measure the extent of cognitive improvement in students after using the Android-based mobile learning media on the Solar System material. This test aims to provide an objective view of the media's effectiveness in enhancing students' understanding. Initially, a small group consisting of three students was tested to observe the impact of using this media in the learning process. The results of the N-Gain test for this small group are expected to provide an early indication of the media's effectiveness and serve as a foundation for further testing in a larger group. Here are the results of the N-Gain test for the large group.

Table 7. Results of the N-Gain test for the larger group.

Students	Skor Ideal	N-Gain Score	Average
1	30	0,5	0,58
2	25	1	
3	50	0,9	
4	25	0,6	
5	40	-0,25	
6	35	0,57	
7	40	0,88	
8	40	0,25	
9	40	0,5	
10	30	0	
11	20	1	
12	45	0,11	
13	45	1	
14	25	0,4	
15	55	0,55	
16	50	0,6	
17	25	0,8	
18	15	1	
19	50	0,6	
20	25	0,6	
21	50	0,6	
22	50	0,9	
23	30	0,67	
24	30	0,33	
25	30	0,6	
26	45	0,4	

According to Junita (2019), mobile learning is the process of delivering information and communication by instructors to students as recipients of the information. Ibrahim & Ishartiwi (2017) explain that Android is a Linux-based operating system that is publicly available at no cost and can be used by various groups, including as a learning medium. Therefore, Android-based mobile learning is the process of delivering information through telecommunication devices, specifically Android smartphones, which are used as learning media. Conventional learning, typically conducted by teachers using lecture methods, can be replaced with Android-based mobile learning, where students directly use smartphones in their learning process. Android-based mobile learning has several advantages, including its small and lightweight size, relatively affordable price, and support for distance learning. This media also allows students to learn independently and integrates text, images, and videos as tools to enhance understanding of the material more effectively (Junita, 2019). Additionally, the flexible nature of mobile learning allows for access anytime and anywhere, enabling students to access material outside of class hours and review or revisit content that is not fully understood. Therefore, mobile learning can strengthen students' comprehension and provide a different learning experience (Arifani, 2021).

Mobile learning in the form of practical applications facilitates students, as they only need to install the app on their smartphones to access it. This application allows direct interaction between the media and active students, which can enhance student motivation. By using this application, it is hoped that the conventional lecture method usually employed by teachers can be replaced with self-directed learning through each student's smartphone. The use of smartphones as a learning medium also aims to balance the negative impact of content or applications that may not be beneficial to students. Technology in smartphones as a learning medium encourages student engagement because they can individually explore media through enjoyable classroom activities, physical activities, and social interactions (Zamuri et al., 2020). Cognitive refers to the domain that focuses on the development of thinking skills and abilities (Degeng & Sudana, 1989). Cognitive can be understood as the intellectual capability that enables students to acquire the knowledge needed to support the learning process (Hernawati, 2019). According to Piaget's developmental theory, 7th-grade students are at the Formal Operational stage of cognitive development. At this stage, students are capable of abstract thinking, applying logic, analyzing, and drawing conclusions from the material being studied (Syar, 2020).

An effective method to enhance understanding is by providing individual learning activities through Android-based mobile learning, which supports students in thinking, reasoning, and drawing conclusions. This approach makes students feel more engaged and responsible in their learning process. Learning activities include physical components, such as students' presence in learning activities, and mental components, such as thinking processes and attitudes (Sardiman, 2019). By utilizing Android-based mobile learning, students can learn independently. In this case, direct communication between teachers and students is not required, as the media functions as an aid, while the teacher's role is to guide and supervise to ensure effective understanding of the material (Rahmawati, 2016). This aligns with the findings of the study “Development of Android-Based Mobile Learning as a Learning Media for Computer Architecture Organization”. The results of this study show that the learning media used is considered practical and accessible, more engaging, and offers updates in teaching methods, which in turn enhances students' understanding in the subject of computer architecture organization.

The learning process through Android-based mobile learning can enhance students' cognitive abilities because it is equipped with various features such as text, images, and videos that support individual learning experiences. Material or explanations not found in the main textbook, such as textbooks, can be provided in this media, such as through explanatory images and videos, to strengthen students' understanding. This is very beneficial for students with various learning styles. By integrating three types of learning styles—visual, auditory, and kinesthetic—into one medium, the understanding of the material by each student with different learning styles can develop simultaneously (Rusman, 2013).

The benefits of using mobile learning in educational activities include the ease of accessing learning materials anytime and the engaging presentation of content for students. By providing media that includes images, text, and videos, mobile learning can clarify verbal symbols, enhance understanding, concretize material, and correct misunderstandings. Additionally, research by Schnotz and Wagner on "Construction and Elaboration of Mental Model Through Strategic Conjoint Processing of Text and Picture" (Schnotz & Wagner, 2018) reveals that the use of text and images in learning media improves cognitive processing. This is due to the inherent symmetry between text and images, where both serve different but complementary functions, thus helping students remember information more effectively.

This research resulted in four levels of evaluation according to the Lee & Owen development model. At Level 1 - Reaction, the small-scale evaluation involving 3 students yielded a result of 97.5%, while the large-scale evaluation with 26 students produced a result of 88.9%, both deemed valid. At Level 2 - Knowledge, the small-scale evaluation showed an N-Gain value of 0.84 with a high criterion, while the large-scale evaluation showed an N-Gain value of 0.58 with a moderate criterion. At Level 3 - Performance, there were changes in student attitudes and behaviors when using the SolarSystem Explore application, where students were able to focus on independent learning thanks to material explanations accompanied by images and videos that reinforced cognitive understanding. At Level 4 - Impact, the use of Android-based mobile learning demonstrated that students have become accustomed to using Android smartphones as a learning medium.

Normalized gain or N-Gain is used to measure the effectiveness of mobile learning media by comparing pre-test and post-test results. By calculating the difference between the pre-test and post-test scores, or gain, we can determine whether the use of mobile learning improves students' understanding. Based on the N-Gain calculations, the small-scale evaluation shows a high improvement compared to the large-scale evaluation. The questions in the pre-test and post-test cover C1 and C2 domains, which are levels of understanding. Therefore, the Android-based mobile learning developed, namely the SolarSystem Explore application, can be used effectively for individual student learning.

Based on the previous studies that have been discussed, the results of the research on the development of Android-based mobile learning provide a clear picture of the effectiveness of mobile applications in enhancing students' cognitive abilities. These studies indicate that the use of Android-based learning media has a positive impact on students' learning outcomes in various subjects, such as digital literacy, physics, geometry, number patterns, and social studies. For instance, the research by Wahyuni et al., (2022) shows that the developed mobile learning module is highly valid, practical, and effective in improving students' digital literacy. The study by Atika et al., (2022), also demonstrates that Android-based learning media is effective in enhancing students' understanding of physics. Other research, such as that conducted by Wahyudi et al., (2022), confirms that mobile applications for geometry materials have proven to be highly effective and efficient. Similarly, the research by Agustin & Wintarti, (2021) proves the effectiveness of mobile learning media in the number patterns topic, with sufficient mastery of the Minimum Competency Standard (KKM). Finally, Utomo, (2021) shows that Android-based mobile learning plays a significant role in improving students' cognitive learning outcomes in social studies. Therefore, the findings from these studies support the notion that Android-based mobile learning is highly effective in enhancing students' cognitive learning outcomes, including in the development of Android-based learning on the solar system topic to improve students' cognitive abilities.

Individual refers to a person as an individual or a self (Akhmadi et al., 2019). The term "learner" can be understood as someone who is in the process of learning regardless of educational levels. A learner individual is someone who engages in learning activities independently or as an individual, without being bound by formal educational stages. The learner individual aligns with the concept of learning in the Society 5.0 era, which is related to changes in the education system during this period (Sinaga & Imansyah, 2021). This era of revolution is highly relevant to 21st-century skills, which are associated with rapid technological advancements. Society 5.0 emphasizes an integrated, efficient, and rapid life. This makes human life more instantaneous and automated, with technology supporting people to achieve a better quality of life.

The Society 5.0 learning concept is closely related to 21st-century skills, which focus on skills, innovation, and technology utilization. This concept must align with the competencies expected to be achieved according to the relevant skills in the Society 5.0 era, namely 21st-century skills. According to experts and the Director General of Basic Education at the Ministry of Education and Culture, Bernie Trilling and Charles Fadel (Sinaga & Imansyah, 2021), the competencies of 21st-century skills include three main aspects: (1) life and career skills, (2) learning and innovation skills, and (3) media and information technology skills. This is in line with the development of mobile learning that utilizes media technology through smartphones.

CONCLUSIONS AND RECOMMENDATIONS

This research produced an Android-based mobile learning application for the Solar System topic in the 7th-grade IPAS subject at SMP Wahidiyah Kepanjen. The application, available in (apk) format, was validated with high scores from material experts (97.5%), media experts (90%), small-scale trials (97.5%), and large-scale trials (88.9%), all meeting valid criteria. The mobile learning media effectively improved students' understanding, as shown by the Pre-test and Post-test results, with an N-Gain of 0.84 (high) in the small-scale trial and 0.58 (moderate) in the large-scale trial. Additionally, 28 students met the Minimum Completeness Criteria, showing improved learning outcomes. The findings confirm that Android-based mobile learning is highly effective for individual use, given the significant improvement seen in the small-scale trial. Future developers can use this research as a reference to enhance mobile learning media, ensuring proper image alignment, clear font choices, accessible navigation, and comprehensive content. Teachers at SMP Wahidiyah Kepanjen are encouraged to implement this mobile learning media for students at higher educational levels to further support learning on the Solar System topic.

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