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Development of Android-Based Mobile Learning Media on Cell Material to Improve Students' Learning Outcomes

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Abstract

The widespread use of Android-based devices enables the application of mobile learning as a flexible and effective learning method. The development of the Society 5.0 concept emphasizes that humans are the center of innovation in utilizing technological advances born from the Industrial Revolution 4.0 era. The purpose of this study is to develop Android-based learning media on the structure and function of cell organelles, analyze the effectiveness of the media in improving students' cognitive learning outcomes, and determine the responses of teachers and students to the application of Android-based mobile learning media on the structure and function of cell organelles. The research method Research and Development (R&D) with a modified 4-D model design (Define, Design, Development, and Disseminate). This study involved 42 students from grade XI and biology teachers. The analysis was carried out based on validation tests by experts, analysis of student and teacher questionnaire responses, and analysis of cognitive learning outcomes with N-gain. Teacher and student responses were very good to the use of learning media Structure and Function of Cell Organelles with a value of 96% and 92%. The N-gain analysis for improving cognitive learning outcomes was found to be effective with a value of 0.78 and an effectiveness of 77.95%. The development of this Android-based learning media on the Structure and Function of Cell Organelles received a very positive response from teachers and students, and was found to be feasible and effective in improving students' cognitive learning outcomes.

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INTRODUCTION

The development of digital technology in the 21st century has brought about significant changes in various aspects of life, including education. The Industrial Revolution 4.0 ushered in an era marked by the integration of information technology, the internet of things, big data, artificial intelligence, and automation. This progress has led to the emergence of Society 5.0, a concept that places humans at the center of innovation, supported by modern technology to create a higher quality of life (Usmaedi, 2021). In the context of education, Society 5.0 requires educational institutions to prepare a generation that not only possesses knowledge but also possesses the skills to utilize technology to solve real-world problems in society.

Educational transformation in the digital era is no longer solely focused on delivering material but also on developing 21st-century competencies, including critical thinking, creativity, communication, and collaboration. Students are expected to go beyond memorizing knowledge to applying, processing, and developing information into something useful. This is where technology plays a crucial role as a learning support tool that creates an active, enjoyable, and meaningful learning experience. Teachers, as facilitators, are required to integrate technology into learning activities to suit the characteristics of students living in the digital age.

One technology that is increasingly popular in education is mobile learning, which is learning based on mobile devices such as smartphones. Mobile learning offers high flexibility because it can be used anytime and anywhere. The widely used Android operating system makes developing learning applications more accessible and applicable. According to Muhimmatin & Jannah (2021), the use of smartphones in biology learning can provide students with access to interactive multimedia resources in the form of images, animations, and videos, making abstract concepts easier to understand.

In biology learning, particularly in the structure and function of cell organelles, students often face significant challenges. This material is microscopic and cannot be observed directly without the aid of special tools such as microscopes. As a result, students struggle to understand the functions and interactions between cell organelles simply by reading text or viewing static images in textbooks. Learning that relies solely on lectures tends to make students passive, bored, and unmotivated. Therefore, media that can provide more concrete and interactive visualizations is needed.

Previous research has shown that the use of Android-based media in biology learning can have a positive impact. Sitompul (2020) found that Android learning applications can increase students' motivation for independent learning due to their flexibility and accessibility. Siahaan et al., (2021) also reported that Android applications not only function as learning tools but can also be used as engaging evaluation media. Research by Kurniawan et al., (2022) confirmed that mobile learning can increase student engagement by providing a more interactive learning experience.

Another empirical evidence was provided by Rinaldi et al., (2023), who developed an Android application for mitosis and meiosis cell division. Their research findings demonstrated that the application was valid, practical, and effective, making it suitable for application in biology learning. Lestari & Saputro (2020) reported that the use of Android applications in biology learning resulted in a learning completion rate of 80.5%, with 79.2% positive student responses. Rumengan et al., (2020) showed that mobile learning in biology learning provided an N-gain value of 0.71, which is considered high. Similar results were found by Fatmawati *et al.* (2021), who recorded an increase in cognitive learning outcomes with 85% completion and an N-gain value of 0.74. Kartini & Putra (2020) also supported these findings with consistent results, namely an N-gain value of 0.74. The consistency of these findings indicates that mobile learning is indeed effective in improving the quality of biology learning.

Unfortunately, real-world conditions still demonstrate a gap between technological potential and learning practices. Based on initial observations at SMA NU Hasyim Asy'ari Tarub, biology learning is still dominated by conventional, teacher-centered methods. Teachers tend to use textbooks and lectures as the primary learning resources. Students often struggle to understand cell organelle material because it is limited to static text and images, while dynamic visualizations are rarely provided. Several students expressed boredom and lack of motivation when learning cell material using traditional methods. As a result, student learning outcomes are suboptimal, particularly in cognitive aspects.

Teachers recognize the need for innovation, but limited skills in developing digital media and the habit of using outdated methods are major obstacles. However, nearly all students own Android-based smartphones, offering immense potential for use as learning media. This underscores the urgent need to develop Android-based learning media that can visualize the structure and function of cell organelles interactively, easily accessible, and tailored to student characteristics.

In addition to providing solutions for students, the development of mobile learning also benefits teachers. Teachers can utilize these applications as additional teaching resources to support their teaching methods. Thus, teachers are not only tasked with delivering material but also facilitating students' exploration of knowledge through digital media. This aligns with the role of 21st-century teachers, which emphasizes mentoring and facilitation, rather than simply transmitting knowledge.

However, the development of mobile learning is not without challenges. Punithavathi & Geetha (2020) warn that many learning applications fail to be utilized effectively because they fail to consider pedagogical aspects. Applications that simply contain collections of digital materials without good learning design are often unengaging for students. Therefore, the mobile learning media to be developed must consider the principles of instructional design, interactivity, readability, and visual appeal. This way, applications become not only collections of information, but also effective, enjoyable learning tools that can enhance conceptual understanding.

The urgency of developing this media is further strengthened when linked to the challenges of 21st-century learning. Students need to be prepared to face global challenges that demand critical thinking skills, technological adaptation, and independent learning. Mobile learning can support this by providing a flexible, personalized learning experience that aligns with the learning styles of the digital generation. If utilized effectively, mobile learning can bridge the gap between boring traditional learning methods and students' need for innovative learning.

Based on the above description, it can be concluded that developing Android-based mobile learning media for the structure and function of cell organelles is crucial. This media is expected to address the issues of low student motivation and learning outcomes, while also providing an innovative tool for teachers to improve the quality of biology learning.

Based on this background, this study is entitled "Developing Android-Based Mobile Learning Media for Cells to Improve Student Learning Outcomes." The research questions include: (1) how the process of developing Android-based mobile learning media for the structure and function of cell organelles works; (2) how effective this media is in improving students' cognitive learning outcomes; and (3) how teachers and students respond to the application of mobile learning in biology learning.

RESEARCH METHOD

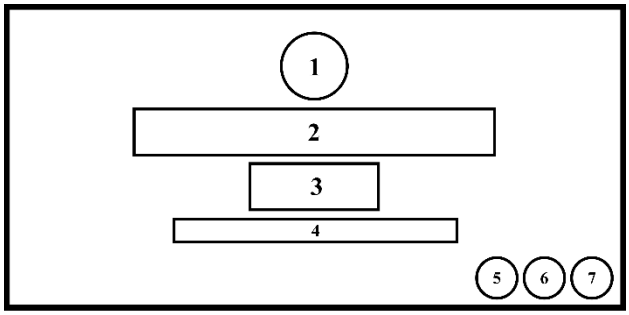
This research employed a Research and Development (R&D) method, with a learning media development design based on the 4-D model (Define, Design, Development, and Disseminate) proposed by Thiagarajan et al. (1974). The 4-D model was chosen because it is considered appropriate for developing learning media that goes beyond the design stage and also through validation and testing. Thus, the resulting media is of reliable quality, both in terms of content, design, and effectiveness of its use in the classroom. The development process for the Android-based mobile learning material on cell learning took place from March 2025 until the completion of this research, following each stage of the 4-D model in a coherent and systematic manner.

The 4-D approach was chosen because it has simple, structured steps that are easy for educational researchers to understand. The Define stage helps researchers identify learning needs, student difficulties, and competency standards to be achieved. The Design stage allows learning media design to be carried out in accordance with the results of the needs analysis, ensuring that the product is truly relevant to the learning objectives. The Development phase emphasizes initial product creation and validation by experts, while the Disseminate phase focuses on disseminating and implementing the media in broader learning contexts. With clear stages, researchers have methodological guidance that can reduce the potential for errors during development.

Furthermore, the use of the 4-D model in this research is strengthened by the fact that this model is widely used in educational research, thus enjoying high academic legitimacy. The abundant literature makes the research results more easily scientifically accountable. Learning media products produced through this model are expected to meet three main criteria: validity, practicality, and effectiveness. Therefore, the selection of the 4-D model is considered appropriate because it can produce mobile learning media for cell material that is not only theoretically feasible but also practically beneficial for improving the quality of biology learning in the classroom.

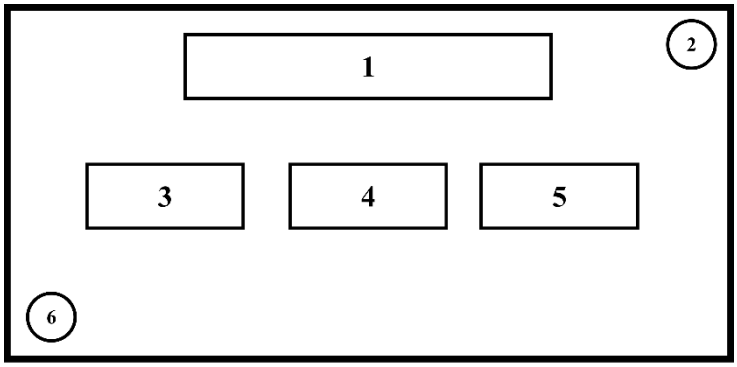
The Define phase is the initial step in the research, focusing on a needs analysis to identify various problems that arise in the field. This analysis was conducted through interviews with biology teachers on May 7, 2025. The results of the interviews showed that the biology learning process, especially on cell material, still faces several obstacles, including limited interactive learning media, the dominance of lecture methods, and low student active involvement in the learning process. This condition has an impact on students' less than optimal understanding of abstract and complex material. Therefore, the define stage resulted in the conclusion that innovation in learning media is needed that is more interesting, interactive, and easily accessible to students. Based on these needs, researchers developed an initial design for Android-based mobile learning that includes cell material, especially on the structure and function of cell organelles. This media is expected to facilitate student understanding and improve their learning outcomes.

The next stage is design, which is the stage carried out after the needs analysis is clearly formulated. At this stage, researchers began designing Android-based learning media for the Structure and Function of Cell Organelles. The initial design was prepared by considering the analysis results from the define stage, so that the designed product truly fits the learning problems and needs. The design is visualized in Figures 4.1 and 4.2, which serve as conceptual designs as well as references in the subsequent development process. With the initial design, the direction of media creation becomes more structured, focused, and in line with the established objectives, thus facilitating the development stage.



Keterangan Gambar
No. 1 Ikon *Home page*
No. 2 Nama aplikasi
No. 3 Ikon untuk "Mulai"
No. 4 "Sebelum memulai belajar, jangan lupa untuk berdoa"
No. 5 Ikon untuk menghidupkan/mematikan musik
No. 6 Ikon menuju profil pengembang
No. 7 Ikon menuju petunjuk aplikasi

Figure 4.1 Homepage Design



Keterangan Gambar
No. 1 "Menu Utama"
No. 2 Ikon menuju *Home page*
No. 3 Ikon menuju Kompetensi
No. 4 Ikon menuju Materi
No. 5 Ikon menuju Kuis

Figure 4.2 Main Menu Design

The development phase is a crucial step in this research because it is during this stage that the Android-based mobile learning media for the Structure and Function of Cell Organelles is created. Development was based on the initial design drafted in the previous phase, then validated by experts, and tested on a small scale. This phase aimed to produce an initial product that not only conformed to the design but also possessed good quality in terms of appearance, content, and ease of use for students. Through validation and testing, the developed product was expected to meet the criteria of validity, practicality, and effectiveness in supporting the learning process.

The development process utilized several supporting applications, namely Microsoft PowerPoint 2019, iSpring Suite 11, and Website 2 APK Builder Pro v5.0. Microsoft PowerPoint was used to compile the initial content, which included text, images, and material on the structure and function of cell organelles. The slide presentation was carefully designed to engage students and featured a proportional layout between text and images. The placement of navigation buttons was also carefully arranged to facilitate user interaction and prevent confusion when operating the application.

After the content is compiled, the next step is to publish the PowerPoint file into HTML format using the iSpring Suite 11 application. At this stage, the display scale is adjusted so that the media can adjust to the smartphone screen size. This is important so that users can access all application features comfortably. Next, the publication folder results are converted into an APK (Android Package) file using the Website 2 APK Builder Pro v5.0 application, so that it can be installed and run on Android-based devices. The initial display of the development of the mobile learning media Structure and Function of Cell Organelles is visualized in Figure 4.3 and Figure 4.4 as the results of the development stages.

Figure 4.3 Home Pages View

Figure 4.4 Main Menu Display

The dissemination phase was conducted after the mobile learning media for the Structure and Function of Cell Organelles was developed. At this stage, a series of validity and feasibility tests were conducted to ensure that the resulting product was truly suitable for use in biology learning. The validation

process involved two assessment aspects: assessment by material experts and assessment by media experts. The material experts were tasked with assessing the content's suitability to basic competencies, the accuracy of biological concepts, the completeness of the material, and its relevance to learning objectives. Meanwhile, the media experts assessed technical aspects such as visual appearance, text readability, ease of navigation, and the practicality of the application.

The assessment results from both experts were then used as a reference for product improvements. Some input provided included clarity of illustrations, consistency of layout, and adjustments to language for greater communication. This revision process was crucial to ensure that the developed learning media was not only materially valid but also engaging, easy to understand, and practical for students to use.

After the validation process was completed, the next stage was a small-scale trial. This trial was conducted at SMA NU Hasyim Asy'ari Tarub, involving a sample of 10 grade 12 Mathematics and Natural Sciences students. The trial participants were selected because they had previously studied cell material and owned Android smartphones, enabling them to operate the application effectively. In this trial, students were asked to respond by completing a 15-question questionnaire covering aspects of the media's appearance, content, and ease of use.

The data obtained from the trial results were then analyzed descriptively. The results were used as considerations for further revisions before the media was used on a wider scale. Therefore, the dissemination stage not only served to disseminate the product but also to ensure that the mobile learning platform for the Structure and Function of Cell Organelles truly met student needs and learning objectives.

The Android-based mobile learning platform for the Structure and Function of Cell Organelles that had been developed was not only assessed from the perspectives of subject matter experts and media experts, but also analyzed based on the results of a questionnaire response from biology teachers at SMA NU Hasyim Asy'ari Tarub. Analyzing teacher responses was crucial because teachers are the primary users who will directly utilize this learning platform in teaching and learning activities. Teacher assessments provided a practical overview of the extent to which the developed platform met classroom learning needs, both in terms of content and technical use.

Through a systematically compiled questionnaire, teachers provided responses regarding several aspects, such as material clarity, curriculum alignment, ease of use, attractiveness of the application, and the media's usefulness in supporting student understanding of cell material. Furthermore, teachers were also asked to assess the potential of this mobile learning platform in increasing student motivation and engagement. Teacher responses indicated that this platform was considered quite effective, practical, and relevant to learning needs, although there were still several improvements that could be used for further development.

The positive teacher responses reinforced the validation results previously conducted by material experts and media experts. With the teacher assessments, this mobile learning platform was further confirmed as having a high level of feasibility for wider implementation. This also indicated that the developed learning platform was not only theoretically valid but also practically applicable in the classroom to improve the quality of biology learning, particularly on the Structure and Function of Cell Organelles.

Then, in the dissemination phase, a large-scale trial was conducted by implementing the mobile learning platform on the Structure and Function of Cell Organelles in class XI MIPA at SMA NU Hasyim Asy'ari Tarub. This trial involved two classes with a total of 42 students who had already received the relevant material. This stage is a crucial part of the 4-D development model because it aims to determine the extent to which the validated and improved media can be applied in real-life learning situations, as well as its effectiveness in improving student learning outcomes.

The data collection process was conducted using several instruments, namely learning outcome tests in the form of pre- and post-tests, as well as student response questionnaires. The tests were administered to determine improvements in student understanding before and after using mobile learning. The test results were analyzed using the N-gain calculation, which is used to measure the effectiveness of media use in achieving learning outcomes. Through N-gain analysis, the extent of improvement in student learning outcomes can be determined, whether it falls into the low, medium, or high category.

In addition to the tests, a response questionnaire consisting of 15 statements was also administered to students to assess the quality of the media from a user perspective. Aspects assessed included appearance, ease of use, clarity of material presentation, media appeal, and the usefulness of mobile learning in aiding understanding of biology concepts. Data from this response questionnaire provide insight into student acceptance of the learning media used and can therefore be used as additional considerations in assessing the product's feasibility and effectiveness. Thus, the dissemination phase focuses not only on media dissemination but also on a comprehensive evaluation process. The results of this large-scale trial are expected to demonstrate that mobile learning on the Structure and Function of Cell Organelles is feasible and effective as an alternative biology learning medium in schools.

RESULTS AND DISCUSSION

This research resulted in the development of an Android-based mobile learning media for cell material titled "Structure and Function of Cell Organelles." This learning media was designed to provide an innovative alternative to support students' learning in Biology, particularly in material considered quite complex. Before being tested with students, the mobile learning media first underwent a validity test involving material experts and media experts. This validation process is crucial to ensure that the developed media is truly suitable for use in learning, both in terms of content, presentation, and language.

The eligibility criteria for learning media refer to assessment standards, which state that media is considered suitable if it obtains a minimum score of ≥60% (Pranatawijaya *et al.*, 2019). The validation results by material experts showed that the media achieved a feasibility percentage of 92%. This score falls into the "feasible" category with very good criteria. This assessment was based on several considerations, including the material's suitability to the applicable curriculum, clarity of learning objectives, and the accuracy of the concepts presented. The experts assessed that the media content aligns with the basic competencies that students must achieve, does not give rise to misconceptions, and has a coherent presentation flow.

Furthermore, in terms of language, this mobile learning media was deemed communicative and easy to understand. The language used was clear, straightforward, and appropriate for the cognitive development level of high school students. The use of simple sentences without diminishing the depth of the material made the media more student-friendly. This is important because appropriate language can reduce barriers to understanding, allowing students to focus more on the substance of the material being studied.

Meanwhile, the assessment results from media experts also gave a score of 93%. This score confirms that in terms of design, appearance, and interactivity, this media met the eligibility criteria. The media's appearance was deemed attractive, utilizing a variety of visual elements, such as illustrations, navigation icons, and a systematic layout. The placement of interactive buttons was considered to facilitate students' exploration of the material without causing confusion. Media experts also assessed the media as practical to use because it can be run on Android devices without requiring complex technical skills. Teachers and students can immediately operate the media independently, thus supporting the effectiveness of the learning process.

Furthermore, the experts assessed that the developed mobile learning media has significant potential for increasing student learning motivation. Interactive and engaging presentation of material is believed to facilitate students' independent learning and improve their learning outcomes. In accordance with learning theory that emphasizes the importance of media as a tool to clarify material, this medium is considered an alternative solution to address students' learning difficulties, particularly on cell topics that require high visualization.

By meeting the validity criteria for content, language, display, and usability, it can be concluded that the Android-based mobile learning medium, "Structure and Function of Cell Organelles," is deemed suitable for use in high school biology instruction. The high validation results from both experts reinforce the belief that this medium is not only feasible but also effective for implementation in the next trial phase as part of the development of technology-based learning products.

Students responded positively to the use of the Android-based mobile learning media, "Structure and Function of Cell Organelles." Therefore, the design research for the Android-based learning media, "Structure

and Function of Cell Organelles," can proceed to a large-scale trial with minor improvements. These improvements were made to accommodate students' perspectives regarding perceived deficiencies in the mobile learning media.

Analysis of teacher responses to the mobile learning media, "Structure and Function of Cell Organelles," indicated the media was in the "very good" category, with a score of 96%. This positive response was derived from teachers' assessments, who observed that the media supported the learning process by facilitating the presentation of material more concisely and clearly, with attractive and interactive visuals. Furthermore, the media was deemed appropriate for student needs and increased student motivation and enthusiasm for learning. Therefore, this media was deemed highly suitable for use in biology learning on cells, particularly on the structure and function of cell organelles.

Analysis of the large-scale trial showed that student responses to the media were in the "very good" category, with a score of 92%. The majority of students stated that the mobile learning interface for the Structure and Function of Cell Organelles was engaging, easy to use, and helped them understand concepts previously considered difficult. This positive response was due to the media being designed to suit student characteristics, adapting to learning needs, and utilizing visual and interactive elements that make learning more enjoyable. Learning motivation theory explains that engaging with media will foster students' intrinsic motivation, making them more active in learning. Therefore, this media received a positive response and resulted in improved student learning outcomes. This aligns with the statement by Astuti et al. (2024), who stated that media plays a central role as a tool and aid in the learning process, facilitating teachers' delivery of material to students and is expected to improve learning outcomes. Furthermore, learning media can be beneficial in reducing student boredom during learning activities. Therefore, the use of learning media is believed to foster positive interactions between teachers and students and create a conducive learning environment. The achievement of student learning outcomes is reflected in the acquisition of scores that meet the Minimum Completion Criteria (KKM) with a standard score of 70. Based on data analysis, before the use of learning media, only 9.52% of students achieved scores above the KKM. After the implementation of the Android-based mobile learning media Structure and Function of Cell Organelles, there was a significant increase, where 93% of students successfully achieved learning completion. Table 4.1 shows the analysis of the results of student learning completion after learning using the Android-based mobile learning media Structure and Function of Cell Organelles with a KKM of 70.

Components	Outcome
Number of students	42
Minimum Competency Criteria (KKM)	39
Highest score	100
Lowest score	40
Average score	86,79
% Completion percentage	93%

Table 4.1 Analysis of Completeness Results After Treatment

A total of 39 out of 42 students achieved a passing grade (KKM) after learning using the Android-based mobile learning media for the Structure and Function of Cell Organelles. The average score obtained by the 42 students after the treatment was 86.79, with a learning completion percentage of 93%. The results can be seen in Figure 4.5.

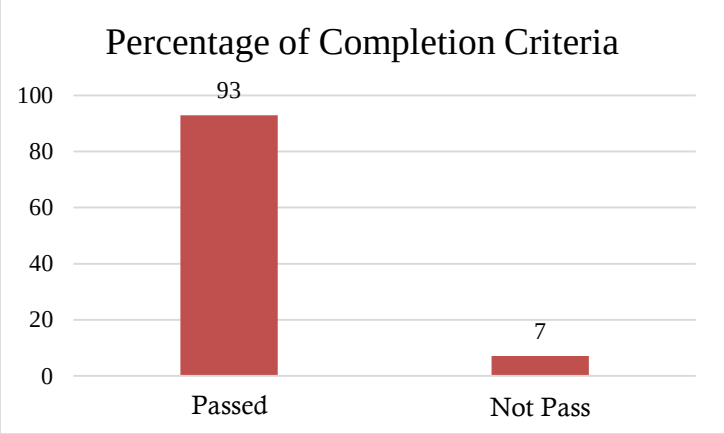


Figure 4.5 Percentage of Completion Criteria

The improvement in student learning outcomes was analyzed using the N-gain test to see the effectiveness of the use of learning media. The results of the analysis of the N-gain value criteria are shown in Table 4.2 and Figure 4.6, which illustrate the level of improvement in students' cognitive abilities after using the Android-based mobile learning media for the Structure and Function of Cell Organelles.

Criteria	N-gain		
	High	Medium	Low
Number of Students	31	11	0
Percentage	74%	26%	0%

Table 4.2 Analysis of N-gain Score Criteria

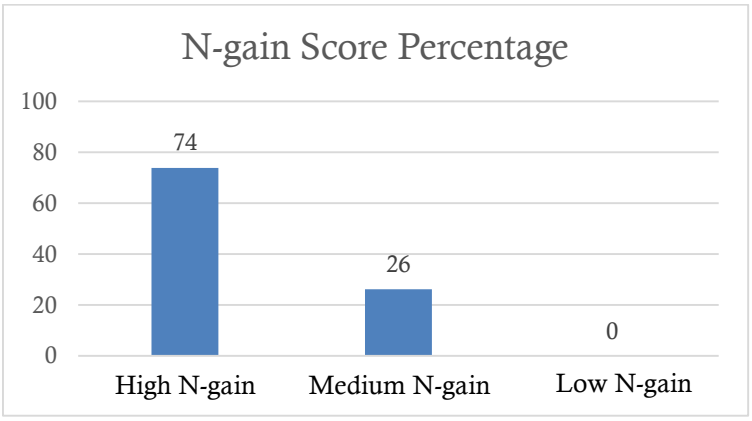


Figure 4.6 Percentage of N-Gain Scores of Learning Outcomes

Referring to Hake in Nashiroh *et al.* (2020), the analysis calculation results obtained an average N-gain value of 0.78 and is included in the "high" category. A total of 74% of students obtained an N-gain score in the "high" category, while the remaining 26% were in the "moderate" category, with an effectiveness percentage based on the n-gain score of 78%. These findings indicate that Android-based mobile learning on the Structure and Function of Cell Organelles is effective in improving student learning outcomes through the learning activities that have been implemented. The improvement in learning outcomes occurs in accordance with the results of the analysis of student responses which show that the application of the mobile learning media on the Structure and Function of Cell Organelles in learning is considered interesting and not boring like learning that only uses books and is centered on the teacher. The use of mobile learning on the Structure and Function of Cell Organelles with an Android-based smartphone also feels like playing, thus making the learning process fun and keeping up with the times. Its systematic display with clearly summarized material also makes the material easy for students to understand. According to constructivist

learning theory, students will more easily build their understanding when they receive stimuli in the form of interesting visual and interactive media. Thus, media not only serves as a conveyor of information but also as a tool that facilitates the thinking process, motivates students, and strengthens student retention of the material.

In their research, Putri *et al*. (2021) demonstrated that the implementation of Android-based learning media was effective in improving student learning outcomes, as evidenced by the N-gain value analysis of 0.65, categorized as "high." This finding aligns with the research conducted by Fatmawati et al. (2021), which revealed that the use of Android-based learning media also had a positive impact on improving learning outcomes, with an N-gain score of 0.74, classified as "high." Therefore, the results obtained in this study align with previous research.

CONCLUSION

Based on the analysis, it can be concluded that the Android-based mobile learning media, "The Structure and Function of Cell Organelles," has proven to be both feasible and effective for use in Biology learning. This media was not only validated by subject matter and media experts, but also directly implemented with students in various trial stages. The trial results demonstrated that the media was able to help students understand the material, making learning more engaging, interactive, and understandable.

In terms of user feedback, both teachers and students responded very positively to the use of this media. A 92% student response indicated that they found this mobile learning platform helpful. Meanwhile, the Biology teachers involved in the assessment process responded even higher, at 96%. This confirms that this media is appropriate for learning needs, practical to use, and aligned with curriculum objectives.

In addition to the positive response, the effectiveness of this media can also be seen in the improvement in students' cognitive learning outcomes. The analysis of pre-test and post-test scores showed an N-gain of 0.78, which falls into the "high" category. These values indicate that the use of mobile learning media significantly contributes to improving students' understanding of cell material, particularly the structure and function of cell organelles. When converted into a percentage, the media's effectiveness reached 77.95%, confirming its highly effective integration into learning.

Thus, it can be confirmed that the development of Android-based mobile learning media on the Structure and Function of Cell Organelles is not only valid and practical, but also proven effective in improving the quality of learning, both in terms of user responses and student learning outcomes.

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