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Innovation of biochemistry learning media in higher education with android-based booklets

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Abstract

This study aimed to produce valid, practical, and effective Android-based booklet media in Biochemistry learning. This type of research is development research (R&D) using the 4-D model. The samples used were validators consisting of media, material, and language experts, as well as all students of the biology education and chemistry education study programs at Universitas Darussalam Ambon, offering Biochemistry courses. The data were collected using validation sheets, questionnaires, and tests. The results showed that the Android application, namely Biomol, could be used by students in the biochemistry learning process. Based on the tests, a validity index of 0.84 was obtained in the valid category, a practicality value of 42.3 in the very practical category, and an effectiveness percentage of 70.39% in the quite practical category. The findings highlight that the Biomol application could significantly improve student learning outcomes. The novelty effect brought by Android-based learning media can further increase student interest in learning, particularly in chemistry subjects that include several abstract concepts. The results have implications for improving the quality of learning, flexibility, and students' digital competence in applying technology to address the challenges of education in the digital era.

Keywords: 4-D development, Android-based booklet, Biochemistry learning media, Mobile learning, Biomol, Digital literacy in higher education.

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Contents

Contribution of this paper to the literature
The paper's primary contribution is demonstrating that Biomol media offers a novel learning experience for the digital-native generation and facilitates the integration of mobile technology in higher education, particularly in abstract chemistry learning.

1. Introduction

The development of education in Indonesia is significantly influenced by the advancement of science and technology, both in the fields of curriculum, learning, methods, and support facilities. This is intended for the renewal of the education system. Information and communication technology (ICT) has a significant influence on the development of education, showing the need for technology-based learning (Oon, Pegrum, Stevenson, & Benson, 2023; Sobral, 2020).

Observations conducted on students of the Faculty of Teacher Training and Education at Universitas Darussalam Ambon showed that several models, methods, and media were used in the learning process. However, the media still primarily use simple presentations, creating problems for students to understand learning. Considering students who are proficient in using technology in the form of smartphones, there is an opportunity to enhance the learning process through more interactive methods. According to Marc Prensky, the young generation born after the 1980s is called the Digital Native generation. The majority of this generation uses personal computers (PCs), computer games, digital music players, camcorders, cellphones, and other digital devices. The average college alumnus currently spends less than 5,000 hours reading but more than 10,000 hours playing video games. This shows that technological devices are an inseparable part of their lives (Calderón-Garrido, Ramos-Pardo, & Suárez-Guerrero, 2022). The digital native generation performs several activities with technology, demonstrating skills in technological literacy. Approximately 90% of students are more interested in opening smartphones than books to study (Fahri & Samsudin, 2012). This phenomenon significantly contributes to the use of mobile ICT devices such as smartphones, enhancing the development of Android-based learning media (Astuti, Bhakti, Prasetya, & Zulherman, 2023; Fahri & Samsudin, 2012; Haryanti, Yusuf, & Agung, 2021).

The development of Android-based learning media was selected because the majority of students have Android devices. Based on the description, there is a need to develop more engaging Android-based learning media, such as a booklet, to help students easily understand the educational material being taught. Accordingly, the purpose of this study is to develop an Android-based booklet in biochemistry learning booklet that is valid, practical, and effective. This study raises three key questions to address these objectives:

1. How valid is the Android-based booklet media in biochemistry learning?
2. How practical is the Android-based booklet media in biochemistry learning?
3. How effective is the Android-based booklet media in biochemistry learning?

2. Literature Review

Technology in the current global era is developing quickly and comprehensively in all circles (Curum & Khedo, 2021). Therefore, educational institutions are required to adapt to changes from traditional methods to information technology, which is a demand of the global community (Aslan, 2021; Du, 2022; Subali, Ellianawati, Faizah, & Sidiq, 2023). The use of technology in education is expected to make learning more effective to facilitate the teaching and learning process. In the 21st century, learning is no longer centered on teachers but on students who are active in searching, understanding, and analyzing learning materials (Akayoglu, Satar, Dikilitas, Cirit, & Korkmazgil, 2020; Deiniatur, Cahyono, Ivone, & Prayogo, 2024; Mukhtar & Putri, 2021; Rahmawati, Abdullah, & Widiaty, 2024). Learning processes in the digital era are carried out using computers or ICT, which are more interactive and engaging. This process utilizes simple presentation media for learning, particularly for abstract materials, as well as computer and mobile technology (Deiniatur et al., 2024; Hasanah, Santoso, Pratiwi, Sulthoni, & Farid, 2024; Shanthi et al., 2023).

In the digital era, the development of Android-based learning media is very much needed as a means of utilizing user-friendly technological tools, so as to achieve maximum learning outcomes and be able to repeat the material via smartphones (Astuti et al., 2023; Kravchenko, Dokuchaieva, Sbitnieva, Sakhatska, & Akinshyna, 2024; Krokhina et al., 2024; Kusuma, Suryani, & Sumaryati, 2022). The media play a significant role in learning, enhancing the communication process. The role of media suggests that the development of modern technology in modern times can provide meaningful experiences for students and facilitate the understanding of abstract topics. In this context, Android-based learning media have been proven effective in the form of applications that can be downloaded and stored on a smartphone with an Android operating system. Android-based learning media provide a new experience and motivate students to learn due to their simple form and wide access (Kang, 2024; Purba, Chao, Hwang, & Tang, 2024; Zhalgasbekova et al., 2018).

Android-based learning media have been widely developed in this digital era, including research by Lok and Hamzah (2021) on Student experience of using mobile devices for learning chemistry, research by Calderón-Garrido et al. (2022) on The Use of Mobile Phones in Classrooms: A Systematic Review, Kusuma et al. (2022) on Mobile application-based media learning and its' effect on pupils' learning motivation, Kravchenko et al. (2024) on Efficiency of generative learning strategies based on mobile learning technologies in higher education. Furthermore, Handoyono and Rabiman (2020) conducted a study on the development of an Android-based learning application in EFI materials for vocational schools. The research results indicate that Android media as a learning tool enhances students' enthusiasm for learning, making the learning process more engaging and enjoyable. Additionally, it increases the interest in the material being studied. Mobile-based learning media demonstrates potential to improve students' learning outcomes by allowing them to easily manage their learning conditions and boost their motivation.

A booklet is a type of printed media to conveys material in the form of summaries and interesting images (Puspitasari & Sunarsih, 2021; Zulekah, Mutalazimah, Soetomo, & Muwakhidah, 2023). It has the potential to communicate feasibility that acts as a message deliverer, expanding information being designed attractively for students to read carefully (Iriyani, Chairunnisa, & Kamba, 2015; Pudyastuti, 2016; Yuliwati & Afiah, 2022).

Android-based booklet applies current technology that facilitates easy use for learning purposes (Nirmala, Nisa, & Hulopi, 2022).

3. Method

3.1. Research Design

This type of research is development research (research and development). The research and development (R&D) process uses the 4-D model, namely Define, Design, Develop, and Disseminate. This is based on the formulation of the problem and the objectives of the study to be achieved, namely, producing an Android-based booklet media in a valid, practical, and effective biochemistry learning (Putra, Asi, Anggraeni, & Karelius, 2020). A development study was selected because of its potential to produce certain products and test their effectiveness (Handoyono & Rabiman, 2020; Siahaan, Manurung, & Siahaan, 2021).

3.2. Research Subjects

The subjects in this development study were validators consisting of media, material, and language. At the dissemination stage, the subjects were all students of the biology and chemistry education study programs of the Faculty of Teacher Training and Education at U, who offered the biochemistry course for the 2024/2025 academic year, comprising 20 individuals.

3.3. Research Stages

This study was conducted in several stages as follows;

1. Define Stage

This stage aims to identify and determine the basic problems faced in learning, demonstrating the need for the development of learning media. An analysis of student needs was conducted during the learning process with a curriculum relevant to current developments.

2. Design Stage

The results of the analysis from the definition stage were used, where a prototype was produced in the form of an Android-based booklet media in biochemistry learning that would be validated.

3. Develop Stage

The development stage aims to produce valid learning media. At this stage, a validation test was carried out on the Android-based booklet media produced. The validators used were material, media, and language experts. Suggestions and input from experts were used as material for improving the Android-based booklet media to meet the valid criteria.

4. Dissemination Stage

The dissemination stage is for the promotion of development products so that they can be accepted by users, including individuals, groups, and systems. Dissemination can occur in other classes with the aim of assessing the effectiveness of the device's use in the learning process in different settings. This form of dissemination is conducted to obtain input, suggestions, and evaluations through observation sheets to improve the final product development, ensuring it is ready for adoption by users of the product (Siahaan et al., 2021). At this stage, to meet the criteria of practicality and effectiveness, tests will be carried out on students enrolled in biochemistry courses at the Faculty of Teaching and Education, Universitas Darussalam Ambon.

3.4. Data Collection Instrument

The results of validation by validators, practicality, and effectiveness tests were analyzed to produce a valid, practical, and effective Android-based booklet media. Data collection methods used validation sheets, questionnaires, and tests. Validation sheets were distributed to experts in material, media, and language, which facilitated their assessments and suggestions for improving instrument design to evaluate the validity of Android-based booklet media using the Aiken Validation Analysis (Siahaan et al., 2021).

Table 1. Validity index category.

No.	Validity index	Category
1	≤ 0.40	Less
2	0.41-0.80	Moderate
3	0.83	Valid

The response questionnaire contained an assessment of the practicality of Android-based booklet media by students and was analyzed using the practicality criteria by Ermiana, Parwati, Sudiarta, and Sudatha (2024). Table 2 presents the practicality criteria for the Android-based booklet media. This table classifies the average scores obtained from the student questionnaire responses.

Table 2. Practical criteria.

No.	Interval	Criteria
1	$X > 42$	Very practical
2	$34 < X \leq 42$	Practical
3	$26 < X \leq 34$	Quite practical
4	$18 < X \leq 26$	Less practical
5	$X \leq 18$	Not practical

Subsequently, tests were conducted to obtain the effectiveness through pretests and posttests (Nirmala & Darmawati, 2021). Table 3 presents the effectiveness categories based on the N-gain value. This table categorizes the percentage increase in student learning outcomes.

Table 3. N-gain effectiveness category.

No.	Percentage (%)	Criteria
1	> 76	Effective
2	56 - 76	Quite effective
3	40 - 55	Less effective
4	< 40	Not effective

Data were analyzed descriptively, qualitatively, and quantitatively. Qualitative data in the form of descriptive data were obtained from the results of validation by experts, which were used as a reference for product revision. Furthermore, quantitative data were obtained by converting qualitative data using a Likert scale with a scale of 4 (very good), 3 (good), 2 (bad), and 1 (very bad).

4. Results

The development of Android-based booklet media in biochemistry learning referred to the 4-D development model, comprising Define, Design, Develop, and Disseminate. The results obtained are as follows:

4.1. Define Stage

The stage was carried out through free interviews with students who had taken biochemistry courses by asking questions verbally to students. The results of interviews and direct observations are shown in Table 4.

Table 4. Previous biochemistry learning facts.

No.	Fact	Description
1	Biochemistry learning uses discussion and presentation methods.	Advantages
2	Biochemistry learning only uses simple presentations with PowerPoint.	Disadvantages
3	Monotonous learning makes students feel bored and tired.	Disadvantages
4	Biochemistry material is mostly structured, hence it is difficult to understand.	Disadvantages
5	Assessment based on student activity and presentation.	Advantages

Table 4 shows the deficiencies in the biochemistry learning process, which include the use of simple presentations, monotonous learning, and difficulty understanding the structure of the material. This indicates the need for further analysis to ensure that the learning process aligns with curriculum demands relevant to technological developments.

4.2. Design Stage

Biochemistry booklet content is designed using the Canva application on the material of carbohydrates, proteins, nucleic acids, and lipids, as shown in Figure 1. After the content design is complete, the last step is to create Prototype I of the Android-based Biochemistry booklet, namely Biomol.

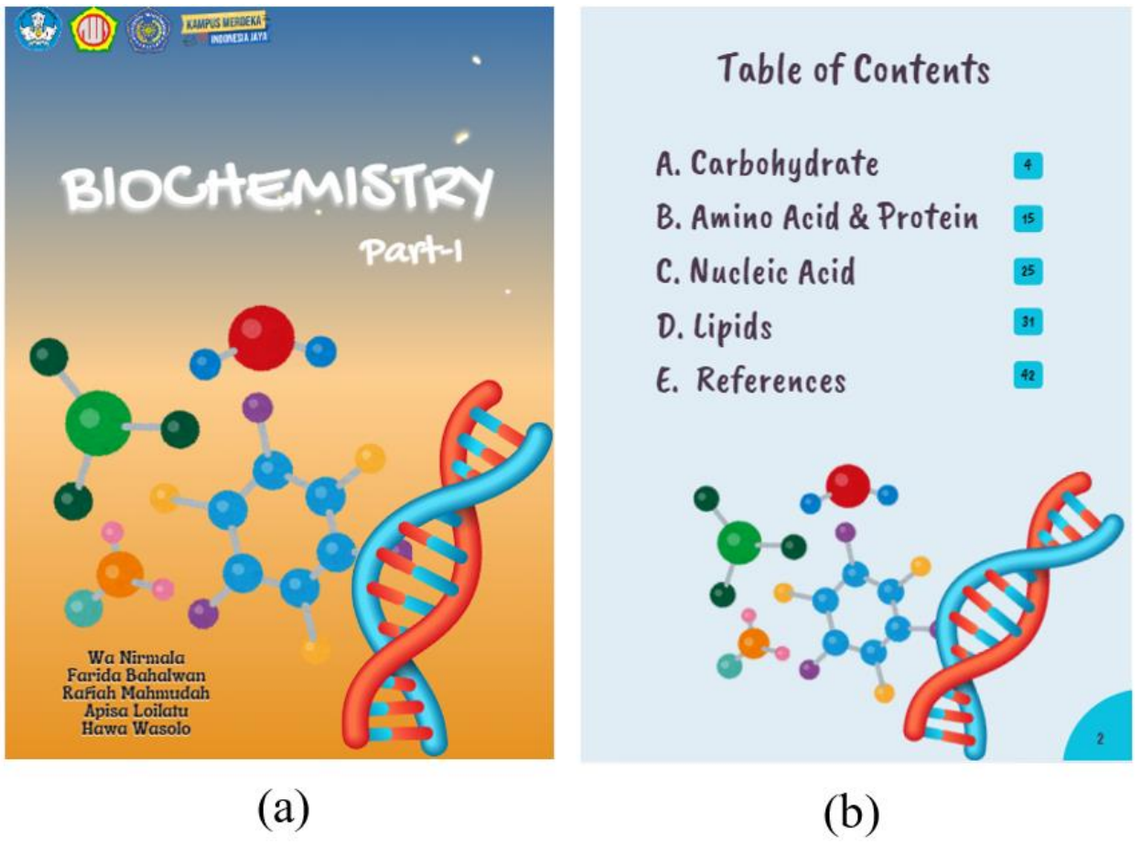

Figure 1. Biochemistry booklet media (Biomol) for (a) Cover and (b) Table of contents.

After the completion of the content design, the last step will be the creation of a prototype of the Android-based biochemistry booklet. This prototype will be in the form of a simple application that includes all the planned

elements and can be used on an Android smartphone. This Android-based booklet design uses the Android Studio application and Visual Studio Code, utilizing the Flutter framework as the programming language.

4.3. Develop Stage

At the development stage, a validation test was conducted on Android-based booklet media produced, comprising two experts from the material, media, and language validators. Suggestions and input from the experts were used as material for improving the Biomol application to meet valid criteria. The validation results are shown in Table 5.

Table 5. Biomol application validation results.

No.	Expert validation	Validity index	Category
1	Material	0.77	Moderate
2	Language	0.90	Valid
3	Media	0.83	Valid
Average		**0.84**	**Valid**

Based on the validation results of the Biomol application, three main aspects were validated by experts, namely material, language, and media. This validation is performed to ensure that the Biomol application meets the validity criteria in terms of content accuracy, language clarity, and quality of media presented (Astuti et al., 2023).

4.4. Dissemination Stage

The dissemination stage is carried out to promote the Biomol application so that it can be accepted by students, both individuals and groups. In this stage, the practicality test and effectiveness test will be conducted on students who will offer Biochemistry courses at the Faculty of Teacher Training and Education, Universitas Darussalam Ambon, for the academic year 2024/2025, in order to meet the practicality and effectiveness criteria. Based on the research results, the practicality test and effectiveness test were conducted to provide an overview of the acceptance of the application by students and its effectiveness in improving their understanding of biochemistry material. To obtain practicality criteria, a practicality questionnaire was given to the students after the biochemistry learning process was completed. The results of the practicality are shown in Table 6.

Table 6. Practical results of using the Biomol application.

Interval	Criteria	Frequency	Average	
			Value	Category
$X > 42$	Very practical	11	42.3	Very practical
$34 < X \leq 42$	Practical	7		
$26 < X \leq 34$	Quite practical	2		
$18 < X \leq 26$	Less practical	0		
$X \leq 18$	Not practical	0		
Total		20		

In Table 6, the practical results of the Biomol application showed that the majority of students gave very positive responses regarding the ease of use of the application. A total of 11, 7, and 2 students rated this application as "Very Practical," "Practical," and "Quite Practical," respectively. The average practicality score obtained was in the "Very Practical" category, with an average score of 42.3. This indicated that students found the application easy to access, use, and relevant to support biochemistry learning. Overall, the Biomol application can be categorized as a very practical learning medium for students.

Meanwhile, the effective criteria were obtained by calculating the N-Gain value from the pre-test and post-test of students after using the Biomol application in the learning process, with the results shown in Table 7 and 8.

Table 7. N-Gain Calculation Results.

No.	N-gain criteria	Frequency (F)	Percentage (%)	Average N-gain	
				Value	Category
1	High	12	60	0.70	High
2	Medium	8	40		
3	Low	0	0		
Total		20	100		

Two approaches were used to measure the effectiveness of the Biomol app: N-Gain calculation, which measures the improvement in students' understanding before and after using the application, and percentage assessment of effectiveness based on established criteria.

A total of 60% of the students were in the "High" N-Gain category, indicating a significant increase in their understanding after using the Biomol application; 40% of the students were in the "Medium" category, and no students were in the "Low" category, indicating that the Biomol application was effective enough to improve student understanding.

Based on the results of the N-Gain calculation, an average N-Gain of 0.70 was obtained, which falls into the "High" category. This indicates that the use of the Biomol application can significantly improve students' understanding of biochemical concepts. This is in line with the research of Kusuma et al. (2022), which states that this Android application-based learning media is proven to increase students' learning motivation.

Table 8. Effectiveness of using the Biomol application.

No.	Effectiveness criteria	Frequency (F)	Percentage (%)	Average	
				Percentage	Category
1	Effective	4	20	70.39%	Quite effective
2	Quite effective	16	80		
3	Less effective	0	0		
4	Not effective	0	0		
Total		20	100		

The effectiveness of the Biomol application in Table 5 showed that 80% and 20% of students rated this application as "Quite Effective" and "Effective." From these results, overall, the Biomol application could be categorized as a fairly effective learning medium in improving student understanding by 70.39%.

5. Discussion

The development of Android-based booklet media in biochemistry learning begins with the Define stage. The main objective was to understand the needs and constraints faced by students, followed by a correlation with the demands of the curriculum relevant to technological development. The stage was carried out through free interviews with students who had taken biochemistry courses by asking questions verbally to the students. Table 4 shows the deficiencies in the biochemistry learning process, which include the use of simple presentations, monotonous learning, and difficulty understanding the structure of the material. This indicates the need for further analysis to ensure that the learning process aligns with curriculum demands relevant to technological developments. According to the National Guidelines for Higher Education (Permendikbud No. 3 of 2020), curriculum development should include the application of relevant technology in the teaching and learning process, which improves students' competence. This highlights the need to replace simple presentations with sophisticated interactive learning media and to allow students to learn with methods that are more efficient and adaptive to the digital era. The younger generation born after the 1980s are Digital Natives, surrounded by individuals using technology as a part of their lives (Fahri & Samsudin, 2012). The average college alumni currently spends less than 5,000 hours reading but more than 10,000 hours playing on smartphones. Technological devices are an inseparable part of their lives (Calderón-Garrido et al., 2022). Similarly, Ibrahim (2024) reported a high level of student engagement with the mobile application. Among the participants, 85% used educational material at least once a week, with 45% using it daily, and 60% reported increased motivation during learning (Ibrahim, 2024). A study by Shanthi et al. (2023) stated that using smartphones as learning tools was beneficial due to the increase in students' cognitive capacity and self-confidence, motivation to learn in formal and informal settings (Shanthi et al., 2023). Based on the results of this analysis, Android-based learning media are needed in biochemistry to enhance a new level of the learning experience (Gupta, Khan, & Agarwal, 2021; Lin, Hsu, & Chen, 2023).

In the Design stage, steps are taken to design an initial prototype (prototype I) in the form of an Android-based booklet media for Biochemistry learning. This stage functions as a bridge between needs analysis (definition) and the development of a product that can be tested. The following are the steps taken in the design stage to develop Android-based booklet media in Biochemistry learning: (1) Preparation of Semester Learning Plan (RPS) for Biochemistry. RPS is an important guide in the biochemistry learning process. The main purpose of creating the biochemistry RPS is to provide clear direction on what will be taught during one semester, including learning outcomes, teaching methods, materials to be discussed, and evaluation. Based on the needs analysis at the define stage, learning outcomes and competencies should be formulated clearly and adjusted to the curriculum relevant to current developments. This objective will serve as the basis for designing booklet content, ensuring the material aligns with the curriculum and helps students achieve competency in understanding complex biochemical structures and reactions. (2) Preparation of Biochemistry Booklet Learning Media. The content of the biochemistry booklet is designed using the Canva application, covering materials such as carbohydrates, proteins, nucleic acids, and lipids. In this activity, the material is broken down into structured topics to facilitate student understanding of each part. Additionally, illustrations are added to support explanations of structures and biochemical reactions. At the end of each chapter, exercises are included in the form of project assignments and games. (3) Making a biochemical android-based booklet media. After the content design is complete, the final step is to create Prototype I of the Android-based biochemistry booklet. This prototype will be a simple application that includes all planned elements and can be used on Android smartphones. The Biomol application is an Android-based biochemistry booklet learning media that can be used on Android smartphones. This application is named after the biochemistry course, namely biomolecular, abbreviated as biomol. The Biomol application will be used as Prototype I to conduct trials and validation. Therefore, improvements can be made before the Android application is officially released to ensure its effectiveness and ease of use.

At the development stage, a validation test was conducted on Android-based booklet media produced, comprising two experts from the material, media, and language validators. Suggestions and input from the experts were used as material for improving the Biomol application to meet the valid criteria. Based on the validation results of the Biomol application, three main aspects were validated by experts, namely material, language, and media. This validation was carried out to ensure that the Biomol application met the validity criteria in terms of content accuracy, language clarity, and media quality (Astuti et al., 2023). In the material aspect, the Biomol application obtained a validity index of 0.77, which is included in the "moderate" category. This shows that the material content presented in the application is quite good, but still needs improvement. Suggestions from material experts for material completeness include adding more detailed information or explanations to make the material more comprehensive. Additionally, the learning outcomes need to be clarified for whom and aligned with the Semester Learning Plan. By improving these aspects, the validity of the material can be enhanced, enabling the Biomol application to provide a better and more comprehensive understanding to students. The language aspect received a validity index of 0.90, which is categorized as "valid." This indicates that the language used in the application is very clear, precise, and easily understood by users, effectively conveying the material. Meanwhile, the media aspect received a validity index of 0.83, which is in the "Valid" category. This shows that the media

presented is of very good quality. The average validity index obtained from the validation results is 0.84, which is in the "Valid" category. Overall, the Biomol application has met the required validity criteria for content, language, and media. The validation results demonstrate that the Biomol application is very good and valid for use in learning biochemistry. This is in line with previous research (Iriyani et al., 2015; Puspitasari & Sunarsih, 2021; Tenggara & Tenggara, 2020; Zulekah et al., 2023), which states that the provision of booklet media has an effect on increasing students' knowledge and understanding in learning.

At the dissemination stage, practicality and effectiveness tests will be carried out. Based on the research results, the practicality test and effectiveness test were conducted to provide an overview of the acceptance of the application by students and its effectiveness in improving their understanding of biochemistry material. To obtain practicality criteria, a practicality questionnaire was given to the students after the biochemistry learning process was completed. The practical results of the Biomol application showed that the majority of students gave very positive responses regarding the ease of use of the application. This indicated that students felt the application was easy to access, use, and relevant to support biochemistry learning. Overall, the Biomol application can be categorized as a very practical learning tool for students. This demonstrates that the application has been designed with an intuitive interface, good navigation, and ease of use so that students can use it effectively during the learning process. As for the effectiveness criterion, it was obtained by calculating the N-gain value of the students' pre- and post-tests after using the BioMol application in the learning process. Based on the practicality test, the results showed that the use of the Biomol application can significantly improve students' understanding of biochemistry concepts. Similarly, Kusuma et al. (2022) stated that this Android application-based learning media increased students' learning motivation (Kusuma et al., 2022). Further research by Ray and Ilangovan (2024) states that mobile-based learning media shows the potential to improve students' learning and allows students to easily manage learning conditions and increase their learning motivation. Android-based media such as these really help students to review material independently and at any time, which in turn can effectively improve comprehension (Fahri & Samsudin, 2012). The effectiveness of the Biomol application in Table 8 showed that 80% and 20% of students rated this application as "Quite Effective" and "Effective." From these results, overall, the Biomol application could be categorized as a fairly effective learning medium in improving student understanding by 70.39%. The results of the effectiveness test showed that the Biomol application could significantly improve student learning outcomes. However, there was potential for further development to achieve optimal effectiveness. The novelty effect brought by Android-based learning media can further increase student interest in learning, particularly in chemistry subjects that include several abstract concepts (Lok & Hamzah, 2021).

The use of technology in biochemistry learning is very important, considering the needs of the digital native generation who prefer smartphone-based media. Therefore, using applications such as the Biomol application facilitates access to materials, increasing engagement in independent and repetitive learning outside the classroom. El-Sofany and El-Haggar (2020) showed that the use of Android-based media increased positive student perceptions, facilitated concentration, and flexibility of access to services for learning materials, and improved student skills in using technology. Other studies reported that Android-based media was effective in improving student learning outcomes with a more interactive and engaging learning experience (Kusuma et al., 2022; Subali et al., 2023). It was also reported that interactive and dynamic learning tools, such as mobile applications, contributed significantly to student engagement in the learning process. The interactive nature of the application appeared to promote a more participatory learning environment, thereby motivating students to actively explore and apply concepts (Ibrahim, 2024).

6. Conclusion

In conclusion, this study successfully developed Android-based booklet learning media in biochemistry learning, namely Biomol application. Through the Biomol application, students can engage in biochemistry learning flexibly and are able to train their thinking skills to always remember what they have learned. In addition, through the Biomol application, digital literacy skills can be developed, providing new experiences and making it easier for students to learn due to its simple form and wider access.

References

Akayoglu, S., Satar, H. M., Dikilitas, K., Cirit, N. C., & Korkmazgil, S. (2020). Digital literacy practices of Turkish pre-service EFL teachers. *Australasian Journal of Educational Technology, 36*(1), 85-97. https://doi.org/10.14742/ajet.4711

Aslan, S. (2021). Analysis of digital literacy self-efficacy levels of pre-service teachers. *International Journal of Technology in Education, 4*(1), 57-67. https://doi.org/10.46328/ijte.47

Astuti, I. A. D., Bhakti, Y. B., Prasetya, R., & Zulherman, Z. (2023). Android-based 4-tier physics test app to identify student misconception profiles. *International Journal of Evaluation and Research in Education, 12*(3), 1356-1363. https://doi.org/10.11591/ijere.v12i3.25536

Calderón-Garrido, D., Ramos-Pardo, F. J., & Suárez-Guerrero, C. (2022). The use of mobile phones in classrooms: A systematic review. *International Journal of Emerging Technologies in Learning, 17*(6), 194-210. https://doi.org/10.3991/ijet.v17i06.29181

Curum, B., & Khedo, K. K. (2021). Cognitive load management in mobile learning systems: Principles and theories. *Journal of Computers in Education, 8*(1), 109-136. https://doi.org/10.1007/s40692-020-00173-6

Deiniatur, M., Cahyono, B. Y., Ivone, F. M., & Prayogo, J. A. (2024). English teachers' beliefs and practices in integrating digital literacy in the language classroom. *International Journal of Evaluation and Research in Education, 13*(2), 1242–1251. https://doi.org/10.11591/ijere.v13i2.25733

Du, D. (2022). Using mobile apps in vocal training to develop creative thinking. *Thinking Skills and Creativity, 44*, 101020.

El-Sofany, H. F., & El-Haggar, N. (2020). The effectiveness of using mobile learning techniques to improve learning outcomes in higher education. *International Journal of Interactive Mobile Technologies, 14*(8), 4–18. https://doi.org/10.3991/ijim.v14i08.13125

Ermiana, I., Parwati, N. N., Sudiarta, I. G. P., & Sudatha, I. G. W. (2024). Ethnocultural wisdom and development of e-comic. *International Journal of Evaluation and Research in Education, 13*(6), 3618-3627. https://doi.org/10.11591/ijere.v13i6.29176

Fahri, H. H., & Samsudin, K. (2012). Mobile learning environment system (MLES): The case of android-based learning application on undergraduates' learning. *International Journal of Advanced Computer Science and Applications, 3*(3), 63–66. https://doi.org/10.14569/ijacsa.2012.030311

Gupta, Y., Khan, F. M., & Agarwal, S. (2021). Exploring factors influencing mobile learning in higher education - A systematic review. *International Journal of Interactive Mobile Technologies, 15*(12), 140–157. https://doi.org/10.3991/ijim.v15i12.22503

Handoyono, N. A., & Rabiman, R. (2020). Development of android-based learning application in EFI materials for vocational schools. *Journal of Physics: Conference Series, 1456*(1), 012050. https://doi.org/10.1088/1742-6596/1456/1/012050

Haryanti, A., Yusuf, M., & Agung, L. (2021). Students' perceptions about the use of android-based learning media in physical education learning. *AL-ISHLAH: Jurnal Pendidikan, 13*(2), 836–842. https://doi.org/10.35445/alishlah.v13i2.633

Hasanah, U., Santoso, A., Pratiwi, Y., Sulthoni, S., & Farid, M. (2024). Exploring the correlation of self-perception on the use of digital literacy in learning. *International Journal of Evaluation and Research in Education, 13*(6), 4354–4364. https://doi.org/10.11591/ijere.v13i6.27114

Ibrahim, U. (2024). Assessing the impact of mobile applications on student engagement in ICT and computer science education. *International Journal of Applied and Advanced Multidisciplinary Research, 2*(3), 221–232. https://doi.org/10.59890/ijaamr.v2i3.1533

Iriyani, K., Chairunnisa, E., & Kamba, I. (2015). Effectiveness of booklet media on mothers' knowledge and attitude regarding exclusive breastfeeding and breastfeeding practice at Manggar Baru health center Balikpapan. *International Journal of Sciences: Basic and Applied Research, 21*, 11-15.

Kang, J. (2024). Benefits and challenges of mobile-learning brought to student learning outcomes in higher education: A systematic review from 2014-2023. *International Journal of Academic Research in Progressive Education and Development, 13*(1), 2107-2123. https://doi.org/10.6007/ijarped/v13-i1/20698

Kravchenko, O., Dokuchaieva, V., Sbitnieva, L., Sakhatska, V., & Akinshyna, I. (2024). Effectiveness of generative learning strategies based on mobile learning technologies in higher education. *International Journal of Evaluation and Research in Education, 13*(4), 2279-2287. http://doi.org/10.11591/ijere.v13i4.28372

Krokhina, J. A., Kruse, I. I., Khairullina, E. R., Ibragimov, G., Kochneva, L. V., & Pashanova, O. V. (2024). An examination of mobile learning adoption in higher education: Research trends in twenty years. *Contemporary Educational Technology, 16*(4), ep542. https://doi.org/10.30935/cedtech/15612

Kusuma, F. I., Suryani, N., & Sumaryati, S. (2022). Mobile application-based media learning and its' effect on students' learning motivation. *International Journal of Evaluation and Research in Education, 11*(3), 1353-1359. https://doi.org/10.11591/ijere.v11i3.22481

Lin, E. Y.-C., Hsu, H.-T., & Chen, K. T.-C. (2023). Factors that influence students' acceptance of mobile learning for EFL in higher education. *Eurasia Journal of Mathematics, Science and Technology Education, 19*(6), em2279. https://doi.org/10.29333/ejmste/13219

Lok, W. F., & Hamzah, M. (2021). Student experience of using mobile devices for learning chemistry. *International Journal of Evaluation and Research in Education, 10*(3), 893-900. https://doi.org/10.11591/ijere.v10i3.21420

Mukhtar, S., & Putri, K. (2021). Technology integrated on media literacy in economic studies on higher education. *Journal of Social Studies Education Research, 12*(1), 95-123.

Nirmala, M., Nisa, K. R., & Hulopi, F. (2022). Aromatherapy soap innovation from clove leaves as an Android-based Booklet media in applied chemistry learning. *Jurnal Penelitian Pendidikan IPA, 8*(2), 429-435.

Nirmala, W., & Darmawati, S. (2021). The effectiveness of discovery-based virtual laboratory learning to improve student science process skills. *Journal of Education Technology, 5*(1), 103-112. https://doi.org/10.23887/jet.v5i1.33368

Oon, P. T., Pegrum, M., Stevenson, M., & Benson, S. (2023). Exploring science pedagogy on the web 2.0/mobile border: Teachers' views of a mobile wiki-based inquiry approach. *Eurasia Journal of Mathematics, Science and Technology Education, 19*(1), em2218. https://doi.org/10.29333/ejmste/12820

Pudyastuti, R. R. (2016). The influence of booklet print and leaflet print media to improve reproductive health knowledge in adolescent. *International Journal of Advanced Engineering, Management and Science, 2*(5), 373–379.

Purba, S. W. D., Chao, H.-C., Hwang, W.-Y., & Tang, Y.-Q. (2024). Empowering vocational students: Exploring mobile learning for sustainable high-level cognition in authentic contexts. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(8), em2491. https://doi.org/10.29333/ejmste/14917

Puspitasari, D., & Sunarsih, T. (2021). *The effectiveness of education video and booklet media for pregnant mothers knowledge on preparation of breastfeeding practice.* Paper presented at the International Conference on Health and Medical Sciences (AHMS 2020). Atlantis Press. https://doi.org/10.2991/ahsr.k.210127.049

Putra, P. S., Asi, N. B., Anggraeni, M. E., & Karelius. (2020). Development of android-based chemistry learning media for experimenting. *Journal of Physics: Conference Series, 1422*(1), 012037. https://doi.org/10.1088/1742-6596/1422/1/012037

Rahmawati, S., Abdullah, A. G., & Widiaty, I. (2024). Teachers' digital literacy overview in secondary school. *International Journal of Evaluation and Research in Education, 13*(1), 597-606. https://doi.org/10.11591/ijere.v13i1.25747

Ray, M., & Ilangovan, A. (2024). Digital game-based learning in higher education: ESL teachers and students perceptions. *World Journal of English Language, 14*(5), 638-653.

Shanthi, A., Heng, L. T., Sharminnie, E., Purwarno, P., Suhendi, A., & Xavierine, J. (2023). Do types of gadgets used for online learning have a bearing on student academic performance? *International Journal of Evaluation and Research in Education, 12*(4), 2222-2229. https://doi.org/10.11591/ijere.v12i4.25288

Siahaan, K. W. A., Manurung, H. M., & Siahaan, M. M. (2021). Android-based learning media development strategies during pandemic times to improve student science literature. *International Journal of Education and Humanities, 1*(1), 34-42. https://doi.org/10.58557/ijeh.v1i1.4

Sobral, S. R. (2020). Mobile learning in higher education: A bibliometric review. *International Journal of Interactive Mobile Technologies, 14*(11), 153–170. https://doi.org/10.3991/ijim.v14i11.13973

Subali, B., Ellianawati, E., Faizah, Z., & Sidiq, M. (2023). Indonesian national assessment support: Can RE-STEM Android app improve students' scientific literacy skills. *International Journal of Evaluation and Research in Education, 12*(3), 1399-1407. https://doi.org/10.11591/ijere.v12i3.24794

Tenggara, S., & Tenggara, S. (2020). Application of virtual laboratory-based learning to improve students' knowledge on dynamic electricity in grade IX of SMPN 17 Kendari. *Journal of Physics Education Research, 5*(1), 65–71.

Yuliwati, N., & Afiah, E. S. (2022). Monitoring intervention of video media extension and booklet to improving adolescent reproductive health knowledge. *International Journal of Health and Pharmaceutical, 2*(4), 708-713.

Zhalgasbekova, Z. K., Shakhanova, G. A., Karymsakova, A. E., Tutkyshbayeva, S. S., Kutpanova, Z. A., Abdualiyeva, R. E., & Shyndaliyev, N. (2018). Creating and using mobile physics and mathematics applications in the learning process as one of teaching methods to increase the quality of student's knowledge. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(12), em1646. https://doi.org/10.29333/ejmste/97837

Zulekah, S., Mutalazimah, M., Soetomo, H., & Muwakhidah, M. (2023). Validity of E-Booklet media and its effect on increasing obesity prevention knowledge in adulthood. *Journal of Health Education, 8*(1), 80-90.