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Android-based virtual laboratory with starter experiment approach for learning vertebrate organ systems in high school

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ABSTRACT

Limited laboratory equipment causes practicum of vertebrate animal organ systems to be rarely carried out so that learning is only theoretical and has an impact on student understanding that is less than optimal. This study aims to develop and test the validity and feasibility of an Android-based virtual laboratory with a starter experiment approach on vertebrate animal organ system material for high schools. This media is also equipped with LKP (Practicum Worksheet) to support virtual laboratory activities. This research uses the Research and Development (R&D) method with the ADDIE model. Data were collected through validation questionnaires from media experts, material experts, and trials to students, then analyzed descriptively, quantitatively, and qualitatively. The validation results show that the virtual laboratory has a validity level of 91% from media experts and 89% from material experts, which is included in the "very valid" category. Meanwhile, the feasibility test results showed a value of 91% in individual trials, 96% in small groups, and 94% in large groups, all of which were included in the "very feasible" category. Thus, the Android-based virtual laboratory with a starter experiment approach on vertebrate animal organ system material is very valid and feasible to use in learning. This media helps teachers deliver material, enhances student understanding, and addresses lab limitations in technology-based learning. Further development should optimize app size for low-spec devices, ensure compatibility with iOS, and improve interactive features for a more realistic practicum experience.

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INTRODUCTION

Biology is a branch of Natural Sciences that focuses on discovering and understanding concepts and principles systematically and scientifically. Biology learning allows students to develop conceptual thinking skills independently (Purwaningsih & Mubarok, 2021). Biology includes scientific concepts that are abstract and can be understood through direct observation, experiments, and simulations (Adi et al., 2016). As a science-based subject, Biology demands critical thinking skills and an understanding of concepts that can be developed through practicum activities (Suryaningsih et al., 2020).

Practicum plays an important role in improving students' understanding of scientific concepts (Andhini et al., 2024; Fitriani, 2024). Through practicum activities, students can prove the theories that have been learned directly so that learning becomes more meaningful and provides real experience (Suryaningsih et al., 2020). However, in practice, practicum activities are often rarely carried out due to various constraining factors, such as limited laboratory equipment and materials (Abdjul & Ntobuo, 2018; Adita & Julianto, 2016; Suryaningsih et al., 2020), limited time (Andhini et al., 2024; Mirawati et al., 2021; Purwanti et al., 2014), and high maintenance costs (Fitriani, 2024; Suryaningsih et al., 2020).

The results of interviews with grade XI Biology teachers at Senior High School 1 Bluto show that practicum on vertebrate animal organ system material cannot be carried out due to limited laboratory facilities. The school has a science laboratory, but the available tools and materials are not sufficient to support dissection activities. As a result, learning is still theoretical, limited to the lecture method and learning resources from textbooks and the internet. This causes the students' level of understanding of the material to be still not optimal. The results of a questionnaire to 10 out of 30 students showed that 55% had difficulty understanding the material because they could not directly see the organ structure of vertebrate animals, while 45% of students who understood the material felt that learning resources and media were still not varied. Students expect more interactive learning media, such as a hands-on practicum or virtual simulation, to improve their understanding.

Along with the development of technology in education, the utilization of Android smartphones as learning media is a potential alternative. To support the teaching and learning process, learning media innovation is needed by utilizing technological developments, one of which is through Android-based digital learning applications (Risnasari et al., 2024). Android is a Linux-based mobile operating system that is open-source, offers high flexibility, and is the dominant OS (Putri et al., 2024; Sabado, 2024). Questionnaire data shows that 100% of students in class XI-C Senior High School 1 Bluto have Android smartphones, so this device can be utilized to support learning. One solution that can be applied to learning Biology is the use of a virtual laboratory (Liana & Kurniawan, 2019; Suryaningsih et al., 2020). A virtual laboratory is a simulation-based laboratory that displays the experimental process (Pramono et al., 2019; Zaturrahmi et al., 2020). Virtual laboratories can be accessed through Android devices that many students have, thus providing flexibility in learning, where students conduct experiments and observations without space and time constraints (Abdjul et al., 2024; Mirawati et al., 2021).

Virtual laboratory as a learning media can overcome the constraints of physical practicum and can present theories or visual concepts that are abstract and difficult to explain through verbal delivery (Abdjul & Ntobuo, 2018; Zaturrahmi et al., 2020). The advantages of virtual laboratories are proven to be able to facilitate students' learning, improve their understanding of complex scientific concepts, and hone students' practical skills in applying theory to real life (Abdjul et al., 2024; Andhini et al., 2024; Suryaningsih et al., 2020). The use of virtual laboratories has been shown to produce a level of learning that is equivalent to direct practicum in the laboratory (Moosvi et al., 2020; Stahre et al., 2019). In addition, virtual laboratories can also provide virtual experiences for students that are fun and attract students' learning interests (Andhini et al., 2024; Suryaningsih et al., 2020).

Previous research shows that virtual laboratory can be an efficient alternative solution for practicum activities, (1) Suryaningsih et al., (2020) showed that Android-based virtual practicum is an alternative media for Biology practicum and helps students' creative thinking increase, (2) Liana & Kurniawan (2019) showed the results that virtual laboratory as a virtual laboratory is very helpful in overcoming laboratory limitations, thus helping students achieve competence optimally, (3) Mirawati et al., (2021) proved that the virtual laboratory is valid in supporting Biology learning, and (4) Abdjul & Ntobuo (2018) stated that the virtual laboratory is feasible to use in the learning process.

In implementing the virtual laboratory in Biology learning, the right approach is needed so that students can develop scientific thinking skills optimally. One of the relevant approaches is the starter experiment approach (SEA), which was developed by Schoenher J in 1996 (Risnawati & Antari, 2019). SEA is a science approach that emphasizes the process where students can independently discover the science concepts being studied (Astawan & Agustina, 2020). As Suastra

explained in Risa et al., (2019), the starter experiment approach has the advantage of familiarizing students with scientific thinking, increasing students' activity and creativity, and showing the connection between science and the surrounding environment. This approach has eight main steps, namely initial experiments, observations, problem formulation, temporary conjectures, testing experiments, concept preparation, concept application, and evaluation (Risnawati & Antari, 2019). To support the implementation of the virtual laboratory, this media is equipped with LKP (Practicum Worksheet) as a supporting media for the results of practicum activities that have been carried out by students.

Based on these problems, this study aims to develop an Android-based virtual laboratory learning media with a starter experiment approach on vertebrate animal organ system material. The virtual laboratory is equipped with LKP (Practical Worksheet) as a supporter of virtual laboratory activities. This media is expected to facilitate teachers in delivering material, improve students' understanding, and become a solution to laboratory limitations in supporting technology-based learning according to the Merdeka Belajar curriculum.

METHOD

This research is a Research and Development (R&D) study with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model. This model was chosen because it has structured, systematic, and sequential stages, so it can be used in developing learning media that are to the characteristics and needs of students (Permana & Nourmavita, 2017). The research and development procedure of the virtual laboratory is presented in Figure 1.

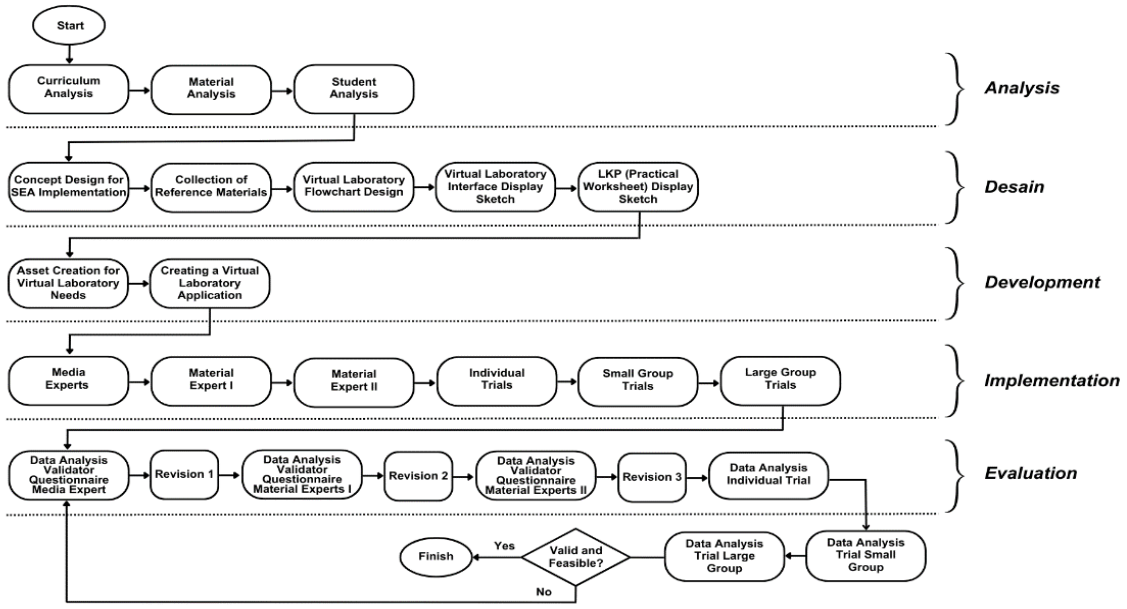


Figure 1. Research Procedure Flow

Analysis

The analysis stage is carried out to identify research needs consisting of analyzing the curriculum, the material to be presented, and the characteristics of students.

Design

The design stage is carried out to design an Android-based virtual laboratory with a starter experiment approach that will be made.

Development

At this stage, the product is developed according to the design that has been designed, resulting in the Virtual VerteLab application along with LKP (Practical Worksheet).

Implementation

At this stage, the product is tested by distributing an assessment questionnaire to determine the level of validity and feasibility. To determine the level of validity, trials were conducted with media experts and material experts. Meanwhile, to determine the feasibility level, the test was conducted on students of class XI-C Senior High School 1 Bluto.

Evaluation

The questionnaire results were analyzed quantitatively and qualitatively to determine the validity and feasibility of the product, as well as the basis for improvement before wider implementation.

The subjects of this development research consisted of media experts, material experts, and 30 students of class XI-C Senior High School 1 Bluto. The data collection techniques used in this study were interviews and questionnaires. Interviews were conducted with Biology teachers of class XI at SMAN 1 Bluto at the analysis stage as part of the preliminary study. Questionnaires were distributed to test subjects to assess the level of validity and feasibility of the product. The research instruments used include media expert questionnaire sheets, material expert questionnaire sheets, and student response questionnaires. Instruments for media experts include aspects of integration, balance, fonts, colors, language, and operation. Instruments for material experts include aspects of content feasibility, presentation feasibility, grammar, evaluation, and integration with the starter experiment approach. Meanwhile, the instrument for students includes aspects of attracting student interest, presentation of material, evaluation, and accessibility. The data analysis techniques used are quantitative descriptive analysis and qualitative descriptive analysis to process data and information obtained from the results of the questionnaire assessment by the test subjects.

Quantitative Descriptive Analysis

Quantitative descriptive analysis was used to process numerical data from the pilot test subjects. This analysis includes two aspects, namely validity and feasibility, which are assessed using a Likert 5 scale. The validity analysis technique is used to measure the validity level of the product based on the questionnaire results from media and material experts. The determination of the validity value refers to the modification of Akbar (2013) and is calculated using the validity formula presented in Formula 1.

$$Vah = \frac{Acquisition\ Score\ (TSe)}{Maximum\ Score\ (TSh)} \times 100\% \quad (1)$$

Description:
Vah = Total expert validation
TSe = Total score of assessment results from the validator
TSh = Total maximum score

After the quantitative calculations were performed, the results were categorized based on the validity criteria presented in Table 1.

Table 1. Validity Level Categories

No.	Value Achievement (Score)	Validation Category
1	25% - 40%	Invalid
2	41% - 55%	Less Valid
3	56% - 70%	Quite Valid
4	71% - 85%	Valid
5	86% - 100%	Very Valid

(Modified Akbar, 2013)

The feasibility analysis technique is used to assess the extent to which the product is feasible to use based on data from the learner response questionnaire. The determination of the feasibility value refers to the modification of (Akbar, 2013) and is calculated using Formula 2.

$$Lau = \frac{TSe}{TSh} \times 100\% \quad (2)$$

Description:
Lau = Total respondent eligibility
TSe = Total score of the assessment results from respondents
TSh = Total maximum score

Determining the feasibility level of the product requires a large number of respondents. Therefore, the calculation of feasibility is done by combining the results of all respondents. Based on Akbar (2013), to calculate the combined feasibility, one can use Formula 3.

$$L = \frac{Lau1+Lau2+Lau3+\cdots+Laun}{N} \times 100\% \quad (3)$$

Description:
L = Total combined eligibility value
Lau = Total respondent eligibility
N = Total respondents

After the quantitative calculations were carried out, the results were categorized based on the eligibility criteria presented in Table 2.

Table 2. Categories of Feasibility Level

No.	Value Achievement (Score)	Feasibility Category
1	0% - 20%	Not feasible
2	21% - 40%	Appropriate Valid
3	41% - 60%	Appropriate Valid
4	61% - 80%	Worth
5	81% - 100%	Very Feasible

(Modified Akbar, 2013)

Qualitative Descriptive Analysis

Qualitative descriptive analysis is used to process data in the form of suggestions, criticisms, and comments from the review of media experts, material experts, and student trials. The results of the analysis became a guideline for revising and evaluating the product to improve its quality. This research is focused on product development and validation to ensure the feasibility and validity of the virtual laboratory before it is applied to learning. Therefore, the effectiveness testing stage has not been conducted in this study and will be part of further research.

RESULTS AND DISCUSSION

Results

The results of the analysis stage of the curriculum, materials, and students show that based on interviews with Biology subject teachers, Senior High School 1 Bluto applies the Merdeka Belajar curriculum. The material studied covers the organ system of vertebrate animals, which is part of the Learning Outcomes (CP) of Biology subjects for phase F, namely class XI Senior High School Program C. The subject matter in this material includes morphology, anatomy, and abnormalities in vertebrate animal organs. In addition, the analysis also includes the identification of the Pancasila Learner Profile and Learning Objectives (TP) to ensure compliance with curriculum standards.

From the analysis of students, it was found that the level of understanding of students on the material of the organ system of vertebrate animals was not optimal. The main factors that cause this are the lack of use of varied and innovative learning media and the limited school laboratory facilities that are not adequate to support practicum activities. The teacher said that students have difficulty understanding the structure and function of animal organs in depth due to a lack of practical

experience. This condition results in abstract concepts in the material being difficult to understand, which ultimately has an impact on the achievement of competencies expected in the curriculum.

To overcome these obstacles, an innovative solution is needed that can bridge the limited facilities without reducing the learning experience of students. Therefore, an Android-based virtual laboratory application with a starter experiment approach was developed as an interactive learning media. This application is designed to virtually simulate the practicum experience, allowing students to observe and understand the organ system of vertebrate animals more comprehensively, even without a complete physical laboratory. With this learning media, it is expected that student understanding will increase significantly, and the learning process will become more effective and interesting.

The design begins with conceptualizing the application of the eight stages of the starter experiment approach that will be implemented in the Virtual VerteLab application, as well as collecting reference material from e-books and Biology textbooks used as the basis for preparing learning content. Next, the application workflow design is carried out in the form of a flowchart that describes the working mechanism of Virtual VerteLab, as well as a sketch of the Android-based Virtual VerteLab application interface and LKP (Practical Worksheet) display sketch. The flowchart of the Virtual VerteLab application can be seen in Figure 2.

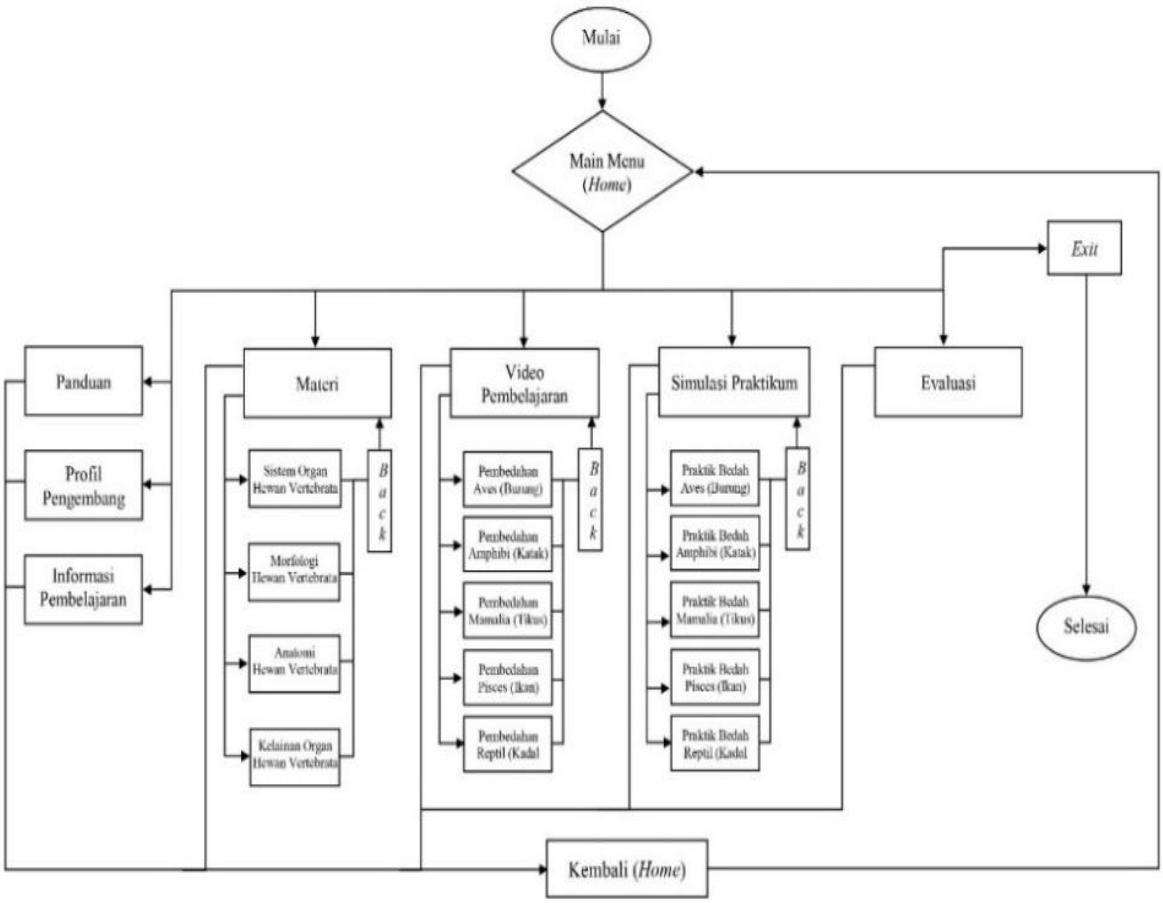
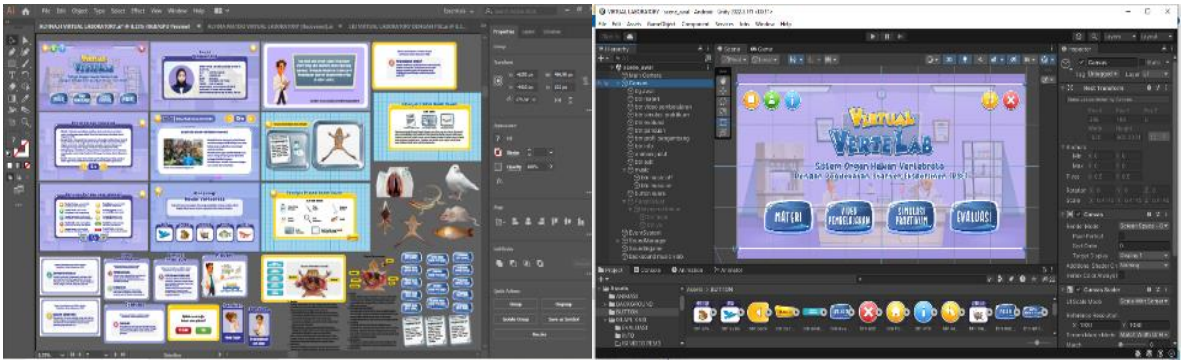


Figure 2. Flowchart of Android-based Virtual VerteLab with Starter Experiment Approach

At the development stage, a product is made in the form of a virtual laboratory application called Virtual VerteLab (Virtual Vertebrate Laboratory) and is equipped with LKP (Practical Worksheet). The manufacturing process begins with the creation of assets using Adobe Illustrator 2019. Furthermore, the Android-based Virtual VerteLab application was developed by combining assets using Unity Hub 3.3.0 and Unity 2022.3.1f1. The process can be seen in Figure 3.



(a) (b)

Figure 3. (a) Assets Creation; (b) Virtual VerteLab Application Assets Merging

The results of the development stage are presented in Figures 4, 5, 6, 7, and 8.

Figure 4. Main Menu (Home) Page

Figure 5. Developer Profile Page

Figure 4 displays the main menu page, which contains the name of the application and various navigation buttons, namely Guide, Profile, Information, Material, Learning Video, Practical Simulation, Evaluation, Music, and Exit. Figure 5 displays the developer profile page, which contains information about the developer of the Virtual VerteLab application.

Figure 6. Surgical Practice Instructions Page

Figure 7. Surgical Simulation Page

Figure 6 displays the instructions page for vertebrate animal surgery, namely amphibians (frogs), which contains information about the tools and materials that will be used in surgical practice. Figure 7 displays an amphibian (frog) surgery simulation page consisting of seven work steps. On this page, learners can perform virtual surgical practices with object displays that resemble live animal surgical practices. In addition, there is a work step guide as a reference for learners in performing each stage of surgery. The concept of surgical practice on this simulation page applies a drag-and-drop mechanism. Learners perform surgery by moving surgical tools from the equipment tray to the specimen on the surgical tray, according to the steps in the guide. Surgical tools can be positioned on the part of the specimen marked with a dashed red line. Each learner must follow a

series of predefined work steps. After completing one step, the system will display the next step until the animal dissection process is complete.

Figure 8. Display of Practical Worksheet (LKP)

Figure 8 shows the LKP (Practical Worksheet), which consists of a cover page and a content page that includes learning information and the application of the eight-stage starter experiment approach. Learners can write answers as a result of practicum activities according to the instructions contained in the Virtual VerteLab application and LKP.

At the implementation stage, product assessment is carried out on the test subjects through distribution questionnaires. The first assessment was given to media experts and material experts to determine the validity of the product. After the product is declared valid, the next assessment is given to students to assess the feasibility of the product. In addition, the trial results were used as the basis for evaluation to improve the product. Media expert trials were conducted by lecturers of the Informatics Education Study Program at Trunojoyo Madura University. Material expert trials involved lecturers from the Natural Science Education Study Program at Trunojoyo Madura University and Biology teachers at Senior High School 1 Bluto. Meanwhile, student trials were conducted on students of class XI-C Senior High School 1 Bluto, which was divided into three categories, namely, individual trials consisting of 3 students, small group trials consisting of 6 students, and large group trials consisting of 21 students.

At the evaluation stage, the results of the questionnaire assessment administered to the test subjects were analyzed. The data obtained consisted of quantitative data and qualitative data. In addition, revisions were made based on suggestions and comments given by validators to improve the product. The results of validation by media experts can be seen in Figure 9.

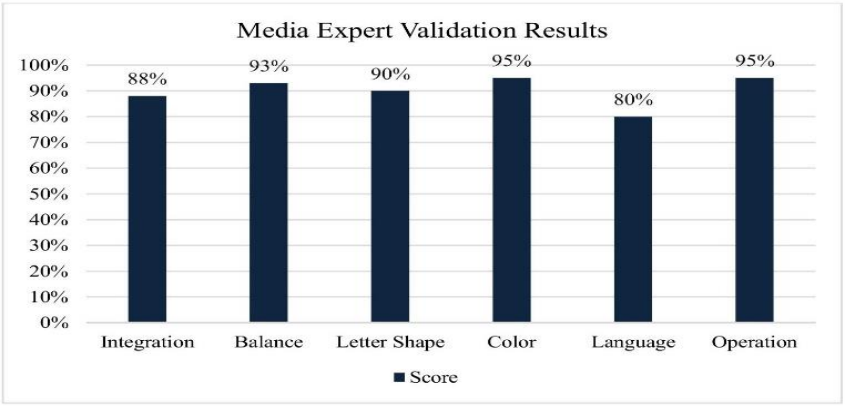


Figure 9. Diagram of Media Expert Validation Results

Based on Figure 9, five aspects of the Virtual Vertelab and LKP media fall into the highly valid category, namely, aspects of integration, balance, font, color, and operation, while the language aspect falls into the valid category. Thus, the average level of validity obtained from media experts is 91%, which is classified as very valid.

There are several suggestions from media expert validators, one of which is to add a Back button on the "Surgery Simulation" page so that users can return to the previous page, namely the "Veterinary Surgery Practice Instructions" page. The addition of this button aims to facilitate users in re-reading the instructions for veterinary surgery practice if there are things that have not been understood. Modifications based on media expert validator suggestions can be seen in Figure 10.

(a) (b)

Figure 10. (a) Before Revision; (b) After Revision

The results of validation by material experts can be seen in Figure 11.

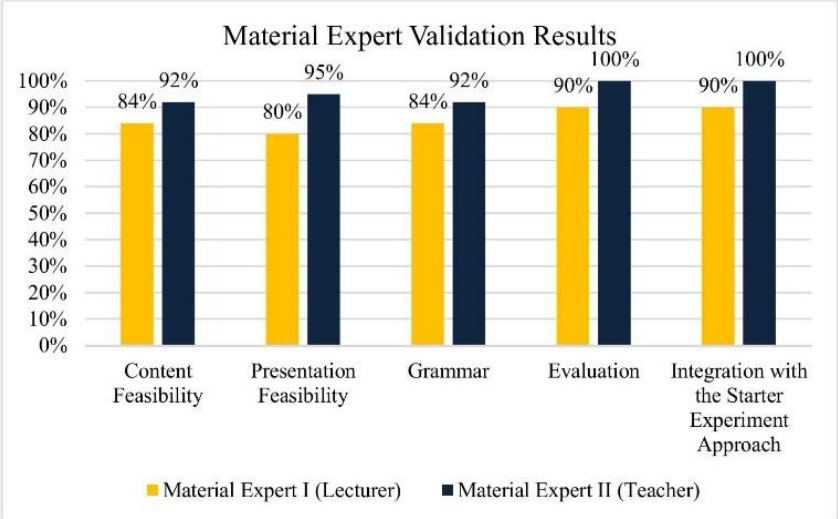


Figure 11. Diagram of Material Expert Validation Results

Based on Figure 11, all aspects of the Virtual Vertelab and LKP materials show a very valid category. Thus, the average level of validity obtained from material experts is 89%, which is classified as very valid.

There are several suggestions from material expert validators, one of which is to change the detailed content on the dissection simulation menu, especially in the detailed information section of vertebrate animal anatomy organs. The suggested change is to change the display that previously presented organ images along with descriptions and explanations of organ functions to only display organ images without descriptions and explanations of functions. It is intended that students can find their concepts of the material studied through the thinking process in practicum learning by the objectives of the experimental starter approach. Modifications based on material expert validator suggestions can be seen in Figure 12.

(a) (b)

Figure 12. (a) Before Revision; (b) After Revision

The results of the feasibility assessment conducted by students can be seen in Figure 13.

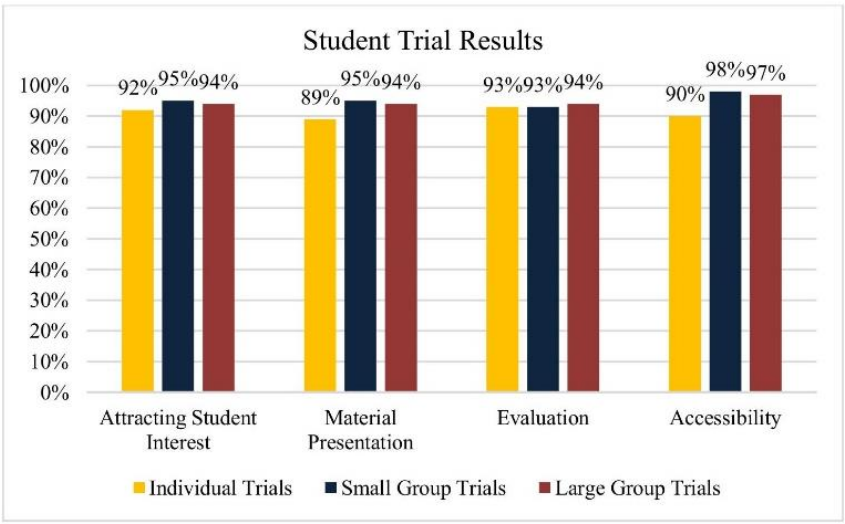


Figure 13. Diagram of Student Trial Results

Figure 13 displays the results of the learner trial assessment, which consists of individual trials, small-group trials, and large-group trials. Individual trials were conducted on 3 learners with an assessment result of 91%, including a very feasible category. Small group trials involving 6 learners obtained 96% with a very feasible category. Meanwhile, the large group trial, which was attended by 21 learners, received 94% with a very feasible category. In addition, in the learner trial, there were no suggestions or comments from the learners, which indicates that the product has been well-received and can be used without revision.

Discussion

The results of this study indicate that the development of an Android-based virtual laboratory with a starter experiment approach is an innovative solution for overcoming the constraints of physical practicum on vertebrate animal organ system material. In line with previous research, the use of virtual laboratories has proven to be an alternative to replacing the role of physical laboratories, especially in conditions of limited facilities and practicum equipment (Fitriani, 2024). The application of virtual laboratories in learning has succeeded in improving students' understanding of scientific concepts and providing a more interactive learning experience (Andhini et al., 2024; Suryaningsih et al., 2020).

Validation by media experts and material experts showed that Virtual VerteLab has a very high level of validity. Media experts assessed aspects of integration, balance, fonts, colors, language, and application operation, with an average result of 91% (very valid category). Some previous studies by Stahre et al., (2019) and Moosvi et al., (2020) showed that virtual laboratories can replace hands-

on experiments with some equivalent learning outcomes. Learning with virtual laboratories can help the learning process without having to rule out actual experiments (Adita & Julianto, 2016). The Virtual VerteLab application has an attractive laboratory room interface design with a harmonious color presentation so that students seem to feel the atmosphere of learning in a real laboratory (Syahfitri et al., 2019).

Material experts also gave an average rating of 89% (very valid category), which indicates that the content presented is by curriculum standards and can help students understand the material better. These results are in line with the research of Mirawati et al., (2021), which proves that virtual laboratories that can be accessed with Android smartphones are valid in supporting Biology learning. The use of virtual laboratories helps teachers deliver material more interactively and makes it easier for students to understand abstract concepts, especially in learning conditions with limited facilities.

The results of the learner trial showed a very high level of feasibility, with an average assessment of 91% for individual trials, 96% for small group trials, and 94% for large group trials (very feasible category). This supports the findings of Abdjul & Ntobuo (2018), which state that virtual laboratories are feasible to use in the learning process to improve student learning activities and outcomes. Virtual laboratories can provide students with tools, materials, and lab sets that are displayed on the screen to conduct experiments independently (Babateen in Pramono et al., 2019). Students can perform a virtual animal surgery practicum through the Virtual VerteLab application in the practicum simulation menu. The virtual laboratory can provide flexibility in learning, where students conduct experiments and observations without space and time constraints (Abdjul et al., 2024; Mirawati et al., 2021).

In addition, there is LKP (Practical Worksheet) as a companion media for students to write down the results of the practicum that has been carried out. Practical worksheets that are arranged systematically and interestingly can help students to be more active independently or in groups during practicum learning activities (Widayanti et al., 2018).

In the context of this research, the experimental starter approach is applied through eight stages of the scientific method, namely initial experiments, observations, problem formulation, temporary conjectures, testing experiments, conceptualization, applying concepts, and evaluation (Risnawati & Antari, 2019). The application of the experimental starter approach successfully encourages students to discover scientific concepts independently, as revealed in the research of Risa et al., (2019) and Astawan & Agustina (2020), which emphasizes the importance of investigation-based experiments in improving students' scientific thinking skills. In the learning process, this approach uses events that occur in students' daily lives as experiments so that learning becomes more interesting and helps foster students' scientific performance in studying and analyzing science problems in their surrounding environment (Dibia & Adiasih, 2017).

In this study, the experimental starter approach offers unique advantages over previous research, especially in encouraging students to discover concepts independently through exploration. If the virtual laboratory developed in Liana & Kurniawan (2019) research focuses more on the application of the scientific approach with the stages of observing, questioning, gathering information, reasoning, and communicating, then the experimental starter approach emphasizes the initial exploration stage before students obtain further information from the teacher or other sources. In Virtual VerteLab, the initial experimentation stage is implemented through a practical demonstration of animal dissection in the form of a learning video. The purpose of this demonstration is to arouse curiosity and increase students' interest in learning (Risnawati & Antari, 2019). Thus, students can gain a more concrete understanding because the concepts learned are observed directly through initial practice guided by the teacher. One of the limitations of this study is the relatively large size of the Virtual VerteLab application (50 MB), which can be an obstacle for students with low-specification Android devices.

Based on the results of this study, it can be interpreted that the development of Virtual VerteLab is valid and feasible to be an effective alternative in learning Biology, especially in the material of vertebrate animal organ systems in class XI Senior High School. The implementation of an Android-based virtual laboratory not only helps students understand concepts more deeply but also provides a more interesting and flexible learning experience. Future research is recommended

to evaluate the long-term impact of using Virtual VerteLab on student learning outcomes as well as to develop additional features that are more interactive to increase learning effectiveness.

CONCLUSION

This research has developed an Android-based Virtual VerteLab with a starter experiment approach as an innovative solution to overcome the limitations of physical practicum on the material of the organ system of vertebrate animals in class XI Senior High School. The validation results show that this application has a very high level of validity, with a media expert assessment of 91% and a material expert assessment of 89%, both of which are included in the "very valid" category. In addition, the results of the learner trial showed a high level of feasibility, with an individual trial of 91%, a small group trial of 96%, and a large group trial of 94%, all included in the "very feasible" category.

The use of Virtual VerteLab, which is equipped with LKP (Practical Worksheet), contributes to improving students' understanding, providing an alternative to virtual practicum amid limited laboratory facilities, and supporting the implementation of technology in learning by the principles of Merdeka Belajar curriculum.

This research also provides implications for the development of technology-based learning models, especially in providing a more interactive and flexible practicum experience. For further development, it is recommended that the size of the application be optimized so that it can run more lightly on devices with low specifications. In addition, further development can include application compatibility on various platforms such as iOS, as well as enhancing interactive features to make the learning experience closer to real practicum.

REFERENCES

Abdjul, T., & Ntobuo, N. (2018). Developing a device of learning based on virtual laboratory through Phet simulation for physics lesson with sound material. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, *39*(2), 105–115. https://www.gssrr.org/index.php/JournalOfBasicAndApplied/article/view/9002

Abdjul, T., Yusuf, M., & Nurhayati. (2024). Development of interactive learning media crossword puzzle integrated virtual laboratory in science learning vibrations and waves material. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5662–5672. https://doi.org/10.29303/jppipa.v10i8.8414

Adi, W. C., Suratno, & Iqbal, M. (2016). Pengembangan virtual laboratory sistem ekskresi dalam meningkatkan motivasi belajar siswa SMA. *Jurnal Pendidikan Sains*, *4*(4), 130–136. https://doi.org/10.17977/jps.v4i4.8193

Adita, A., & Julianto, T. (2016). Penyusunan virtual laboratory sebagai media pembelajaran biologi. *Jurnal Penelitian dan Pengabdian Kepada Masyarakat UNSIQ*, *3*(2), 69–73. https://doi.org/10.32699/ppkm.v3i2.339

Akbar, S. (2013). *Instrumen perangkat pembelajaran*. PT Remaja Rosdakarya.

Andhini, A. R., Mahmudah, H. A., Al Maudrey, L. I., Wahyuni, R., & Sulistina, O. (2024). Systematic literature review: Penggunaan media pembelajaran virtual lab pada pembelajaran kimia. *UNESA Journal of Chemical Education*, *13*(2), 100–107. https://doi.org/10.26740/ujced.v13n2.p100-107

Astawan, I. G., & Agustina, I. G. A. T. (2020). *Pendidikan IPA di sekolah dasar di era revolusi industri 4.0*. Nilacakra Publishing House.

Dibia, I. K., & Adiasih, M. M. (2017). Penerapan pendekatan starter eksperimen (PSE) untuk meningkatkan hasil belajar mata pelajaran IPA. *International Journal of Elementary Education*, *1*(1), 72–85. https://doi.org/10.23887/ijee.v1i1.11442

Fitriani, A. (2024). Comparison of the effect of using virtual laboratory based on PhET simulation and real laboratory in improving mastery of electronic concepts of physics education students. *Tekno-Pedagogi: Jurnal Teknologi Pendidikan*, *14*(2), 22–28. https://doi.org/10.22437/teknopedagogi.v14i2.37487

Liana, D., & Kurniawan, N. A. (2019). Pengembangan virtual laboratory berbasis pendekatan saintifik pada mata pelajaran biologi untuk siswa SMA. *Pedagogi Hayati*, *2*(2), 6–12. https://doi.org/10.31629/ph.v2i2.834

Mirawati, Z. S., Supratman, Z., & Iswantir. (2021). Pengembangan virtual laboratory berbasis Android pada mata pelajaran biologi di SMAN 1 Abung Semuli Lampung Utara. *Jurnal Teknologi Informasi*, *5*(2), 149–156. https://doi.org/10.36294/jurti.v5i2.2380

Moosvi, F., Reinsberg, S., & Rieger, G. (2019). Can a hands-on physics project lab be delivered effectively as a distance lab? *IRRODL: The International Review of Research in Open and Distributed Learning*, *20*(1), 20–42. https://doi.org/10.19173/irrodl.v20i1.3782

Permana, E. P., & Nourmavita, D. (2017). Pengembangan multimedia interaktif pada mata pelajaran IPA materi mendeskripsikan daur hidup hewan di lingkungan sekitar siswa kelas IV sekolah dasar. *Jurnal PGSD: Jurnal Ilmiah Pendidikan Guru Sekolah Dasar*, *10*(2), 79–85. https://doi.org/10.33369/pgsd.10.2.79-85

Pramono, S. E., Prajanti, S. D. W., & Wibawanto, W. (2019). Virtual laboratory for elementary students. *Journal of Physics: Conference Series, Volume 1387, International Conference on Education, Science and Technology 2019 13–16 March 2019, Padang, Indonesia*, *1387*, 1–6. https://doi.org/10.1088/1742-6596/1387/1/012113

Purwaningsih, S. D. A., & Mubarok, I. (2021). The implementation of the BSCS 5E model based on multiple representations in ecosystem materials on problem solving and metacognitive abilities. *Journal of Biology Education*, *10*(1), 63–69. https://doi.org/10.15294/jbe.v10i1.43394

Purwanti, T., Habibah, N. A. S., & Supriyanto. (2014). Pengembangan media pembelajaran sistem pencernaan makanan disertai virtual laboratory di SMP. *Journal of Biology Education*, *3*(1), 93–100. https://doi.org/10.15294/jbe.v3i1.4162

Putri, W. A., Irwan, D., & Lubis, H. (2024). Design and build an Android-based customer menu recorder application on Benu Coffee Shoop using agile methods. *Instal: Jurnal Komputer*, *16*(3), 453–462. https://doi.org/10.54209/jurnalinstall.v16i03.265

Risa, N. M., Indiarini, M., Wira Bayu, G., Pendidikan, J., & Sekolah Dasar, G. (2019). Pengaruh starter experiment approach (SEA) terhadap hasil belajar IPA. *Jurnal Mimbar Ilmu*, *24*(1), 124–133. https://doi.org/10.23887/mi.v24i1.17469

Risnasari, M., Adhani, D. N., Dellia, P., & ... (2024). Pelatihan media pembelajaran sesuai gaya belajar menggunakan I-Spring untuk Siswa SMP Negeri 4 Kamal Bangkalan. *Jurnal Ilmiah Pengabdhi*, *10*(1), 1–7. https://doi.org/10.21107/pangabdhi.v10i1.22646

Risnawati, N. K. A., & Antari, N. K. Y. (2019). Pendekatan starter eksperimen berbantuan lembar kerja siswa untuk meningkatkan hasil belajar IPA. *Jurnal Ilmiah Sekolah Dasar*, *3*(4), 458. https://doi.org/10.23887/jisd.v3i4.21781

Sabado, W. B. (2024). Education 4.0: Using web-based Massachusetts Institute of Technology (MIT) App Inventor 2 in Android application development. *International Journal of Computing Sciences Research*, *8*, 2766–2780. https://doi.org/10.25147/ijcsr.2017.001.1.188

Stahre, W. B., Eriksson, T., Karlsson, G., Sunnerstam, M., Axelsson, M., & Billger, M. (2019). Design considerations for virtual laboratories: A comparative study of two virtual laboratories for learning about gas solubility and colour appearance. *Education and Information Technologies*, *24*(3), 2059–2080. https://doi.org/10.1007/s10639-018-09857-0

Suryaningsih, Y., Gaffar, A. A., & Sugandi, M. K. (2020a). Pengembangan media pembelajaran praktikum virtual berbasis Android untuk meningkatkan berpikir kreatif siswa. *BIO EDUCATIO: (The Journal of Science and Biology Education)*, *5*(1), 74–82. https://doi.org/10.31949/be.v5i1.2243

Syahfitri, F. D., Manurung, B., & Sudibyo, M. (2019). The development of problem based virtual laboratory media to improve science process skills of students in biology. *IIJRR: Nternational Journal of Research & Review*, *6*(6), 64–74. https://www.ijrrjournal.com/IJRR_Vol.6_Issue.6_June2019/Abstract_IJRR0012.html

Widayanti, W., Yuberti, Y., Irwandani, I., & Hamid, A. (2018). Pengembangan lembar kerja praktikum percobaan melde berbasis project based learning. *Jurnal Pendidikan Sains Indonesia*, *6*(1), 24–31. https://doi.org/10.24815/jpsi.v6i1.10908

Zaturrahmi, Z., Festiyed, F., & Ellizar, E. (2020). The utilization of virtual laboratory in learning: A meta-analysis. *Indonesian Journal of Science and Mathematics Education*, *3*(2), 228–236. https://doi.org/10.24042/ijsme.v3i2.6474