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Research Artikel

THE DEVELOPMENT OF VIRTUAL LABORATORY EXCRETORY SYSTEM TO IMPROVE BIOLOGY LEARNING OUTCOMES FOR SENIOR HIGH SCHOOL STUDENTS

Kamilia Fadhilah Maryana^{1*}, Rusdi², Ratna Komala³

^{1,2,3} Program Studi Pendidikan Biologi, Universitas Negeri Jakarta, Indonesia

kamiliafadhilah1@gmail.com^{1*}

Abstract

Practicum is one of the activities that has become a characteristic of Biology. Students have good learning experiences and concepts through practical activities. In the Excretory System material at high school level, there are obstacles in practical activities because the research samples used are limited and require special treatment. Learning media such as virtual laboratories expected can overcome these obstacles. This research aims to: (a) develop media in the form of a virtual laboratory on Excretory System material, (b) test the product so that the product is suitable for use, and (c) analyze the application of the product in improving student learning outcomes. This development research using the ADDIE model, which consists of five stages (Analyze, Design, Development, Implementation, Evaluation) are chosen in this study. The validation from the expert uses three experts, and for the user evaluation, this study uses 50 students as the respondent. The research results show that the feasibility test by experts is included in the valid category. The results of hypothesis testing show that there is an increase in student learning outcomes before and after using virtual laboratory media. The N-gain calculation result of 0.53 is categorized in the medium category. Based on the results of product validation and application, it is concluded that the Excretory Systems Virtual Laboratory is suitable as an interactive support learning media and can improve the learning outcomes of high school students.

Keywords: Excretory system; learning outcomes; practicum; virtual laboratory.

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*Corresponding author

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INTRODUCTION

Biology learning is one of the media to improve knowledge, attitude skills and is an attitude of responsibility to the environment (Nurwahidah et al., 2019). In biology subjects, practicum in learning is the main thing. Biology learning is not only mastering in material, knowledge, concepts, principles, but also teaching the process of discovery. One of the activities that can support the value of discovery, and scientific methods is practicum activities (Ramdan & Hamidah, 2015).

Practicum activities are included in the experimental learning method which provides direct experience to students (Masruri, 2019). Practical work has become an important component and has become a characteristic in the learning process, especially in Biology lessons (Muna, 2016). Practicum activities carried out in biology learning can be carried out in the laboratory or in nature (Aswari et al., 2024). Students will have better learning experiences and concepts through media, phenomena, and teaching aids because the practicum is experimental. Students who carry out practicum activities will gain learning experiences that include cognitive, affective, and psychomotor domains (Irawati et al., 2022). Practicum activities help students to achieve learning outcomes and it is one of the factors that play an important role in supporting the success of the learning process (Sartono et al., 2025).

One of the biology materials in high school is the human excretory system, which requires more understanding because the basic concept is quite abstract and there are quite a lot of complicated mechanism processes, so this material is not easy for students to understand. According to Simorangkir et al., (2020) the material on the Excretory System is difficult for students to master it because in the learning process they are required to memorize terminology, Latin, recognition of the organs involved, the process of urine formation so that students have difficulty understanding, consider this material boring and do not want to repeat to study it which then has an impact on the low learning outcomes of students (Kharki & Berrada, 2021).

The implementation of Biology practicum activities in high schools is often not carried out due to several obstacles, including the condition of the Biology laboratory which is still combined with the Chemistry laboratory, the absence of laboratory staff, so that teachers need more time to prepare, students have difficulty understanding the practicum work procedures, limited tools and materials for practicums, especially practicums on the subtopic of urine testing or urinalysis which use urine as a sample that requires special content and treatment to avoid errors during examination. (Suryanda et al., 2017).

As time goes by, there is an integration between digital technology and science, and synergy between them occurs rapidly (Wijaya et al., 2016). The increasing role of ICT (Information and Communication Technology) in the field of education is supported by increasingly sophisticated computer capabilities. Various obstacles faced in biology learning, such as limited laboratory facilities, learning media can be overcome with computer technology capabilities (Suryanti et al., 2019).

A virtual laboratory is a media that contains simulations of activities in a real laboratory and provides a multi-sensory experience (Wibawanto, 2020). A virtual laboratory is software that contains laboratory equipment that functions like real equipment, so that it can help students to carry out experiments independently anytime and anywhere by observing the experimental steps that are already in the application (Sanova, 2017). The advantages of using virtual laboratories include being able to add experience and motivate students to conduct interactive experiments anytime and anywhere (Gunawan et al., 2017). Virtual laboratories can be repeated until students feel they understand, and can develop skill activities for experimenting, can minimize accidents and work errors during practicums, and in its application, can increase understanding so that student learning outcomes can improve (Sartono et al., 2025).

Virtual laboratories are more widely used at the high school level to improve student learning outcomes because they have been adjusted to the goals, needs and psychological development aspects of high school students (Hao et al., 2021).

Excretory System material in high school, in its subtopics, is more related to experiments, so it requires a virtual laboratory so that the Excretory System material is well visualized, both from the structure of the excretory organs and the excretory mechanism so that students understand better, active, collaborative and creative in learning (Radhamani, 2021). Virtual laboratories can improve student learning outcomes because they provide variation in the learning process, are interactive in their use, and can display experimental results quickly, directly and accurately, because there are guidelines that direct students to work in a structured manner (Azizah & Aloysius, 2021).

Findings from several studies have shown that virtual laboratories help students understand experimental design and are easier to use than real laboratories (Irawati et al., 2022). The positive impact of using virtual laboratories is due to various activities that interest students. Motivation in learning is important because the presence of motivation can increase activity and initiative so that it can maintain student perseverance in learning activities (Fitria & Ristanto, 2023).

Based on the exposure above, this research realizes that developing of virtual laboratory is necessary as an interactive support learning media to be used in the learning process especially for senior high school in 11th grades for Excretory Systems material. The virtual laboratory developed based on the syllabus concerned at school. This virtual laboratory is expected to be able as a support media for biology subject (Veza et al., 2022).

METHOD

This research is a research and development study using the ADDIE model. The ADDIE development model consists of five stages, namely (1) analysis, (2) design, (3) development, (4) implementation, (5) evaluation. The ADDIE model was chosen because it has an effective and systematic sequence of steps in various educational product developments (Sukenti, 2021). The ADDIE model can be collaborated with technology and has advantages, namely having good and structured design quality because there is formative

evaluation at each stage, clear learning objectives, student activities can be relevant to learning outcomes, can be used to see learning outcomes that have been achieved, is cost-effective and saves time (Sadiki et al., 2020).

Analysis

The first stage begins with analysis. In the analysis stage, an analysis of the needs of students and teachers at school is carried out with the aim of finding problems in learning, especially in the Excretory System material in senior high school (Fitria & Ristanto, 2023).

Design

The design made at this stage is a product design in the form of a storyboard that is useful as an initial product framework. In it there is a detailed product design that will be developed. The results of the design stage are evaluated by improving the arrangement of materials and practicum results that are adjusted to the suggestions of the lecturer.

Development

The development stage is an activity where all designs that have been made on the storyboard are realized into a product. The finished virtual laboratory product is validated by experts and tested on small and large groups. The results of the product assessment carried out by experts, teachers, and students related to the virtual laboratory, then the quality value can be determined as an overall average or calculated using the following formula:

$$value = \frac{Obtained\ Score}{number\ of\ questions}$$

The results obtained from the quality value, then the feasibility of the product can be known by interpreting the feasibility test scores of Ratumanan and Laurens (2011). The interpretation of the scores can be seen in Table 1.

Table 1. Interpretation of Virtual Laboratory Validity Test Scores

Interval Score	Category
$3.25 > x < 4.00$	Very Valid
$2.50 > x < 3.25$	Valid
$1.75 > x < 2.50$	Less Valid
$1.00 > x < 1.75$	Not Valid

(Suwarna & Zulfiani, 2024)

A Normalized Gain test was conducted to determine the learning outcomes of students after the product was implemented, then calculated using N-Gain (Normalized gain value (N)), namely with the formula from (Hake, 1999).

$$N - \text{gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}}$$

The improvement of students' learning outcomes is divided into three categories, based on the results of the normalized gain values, categories in Table 2.

Tabel 2. Normalized Gain Interpretation

N-Gain	Category
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

(Hake, 1999)

RESULTS AND DISCUSSIONS

Analysis

The needs analysis that has been carried out obtained results in the form of information related to the opinions of 11th grader students of SMA Negeri 16 Jakarta regarding what materials are considered difficult, learning media that have been used during learning, regarding practicums that have been carried out at school, The information that has been obtained is used as a reference for the next stage.

Based on the results of the analysis of the needs of students and teachers, it was found that the material that was considered difficult by students was one of the Excretory System materials with a percentage of 38.9%. In the Excretory System material, practicums have never been carried out at school, so 97.2% of students answered that they felt

the need to be given additional learning media related to the Excretory System material. Biology teachers are of the opinion that media development needs to be carried out and agree that additional learning media such as virtual laboratories are one of the media that are interesting for students and their use is expected to improve understanding and learning outcomes in students.

Design

The next step is to create a storyboard or design plan for creating a virtual laboratory application product according to the results of the material analysis and the needs of learning media. The storyboard is compiled in the Microsoft Word application and the Canva application. The storyboard contains a visual display along with the layout of the virtual laboratory to be created, the practical activities to be carried out (urine tests on the kidneys, tests on the lungs, skin, and liver), display of tools and materials, work steps, display of results from each practical test of the Excretory System.

Development

The development stage is an activity where all designs that have been made on the storyboard are realized into a product. The finished virtual laboratory product is validated by experts and tested on small and large groups. At the beginning of the development, image assets were created using the Corel Draw X7 application, followed by adding audio, sound and effects using the Audacity application. All assets that have been created are entered into the Unity 3D application and continued by arranging objects in the scene on the Unity 3D page. The next step is to create animations in Unity 3D and patterns are adjusted to the designs that have been designed, then continued by creating a coding script with the help of the Visual Studio 2017 application. After the Excretion System virtual laboratory application has been developed in HTML5/WEBGL form, the application is uploaded to the website.

Practicum activities in the virtual laboratory that will be developed consist of ten test activities, including seven tests on the kidney organ, including physical tests on urine (urine color test, urine pH, urine specific gravity), chloride test in

urine, albumin test in urine, glucose test in urine, bile test in urine. In the lungs there will be a test that proves the results of excretion from respiration (H_2O and CO_2), in the skin organ there will be a test

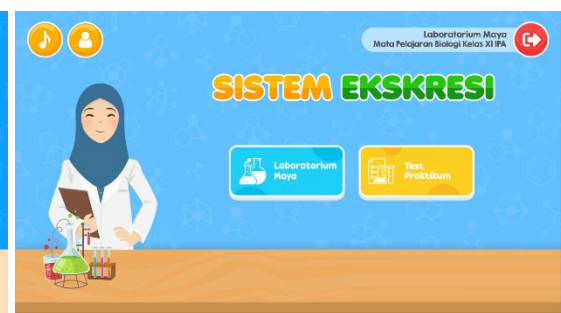
that proves the results of skin excretion (sweat), in the liver organ there will be a test that proves the presence of bilirubin components in the results of liver excretion.



(a) Main Menu Page



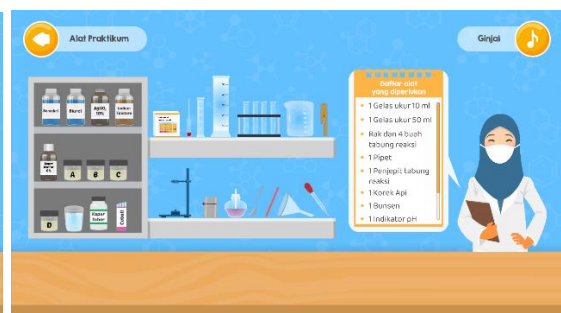
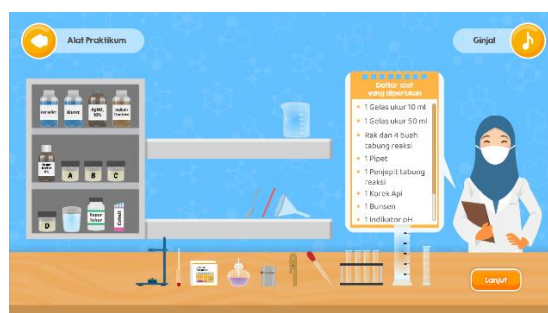
(b) Display of identity filling



(c) View of the contents of the virtual laboratory



(d) Display of selected organs to be tested



(e) Display of tools and materials to be used

Figure 1. Virtual Laboratory of Excretory System

After the product has been developed, there are three expert judgments which consist of content, media, and language aspects. Validation from content experts includes aspects of material coverage, material accuracy, and aspects of currency and contextuality. Validation from media experts includes aspects of text, picture and animation, background, and ease of operating applications. Validation from language experts includes aspects of developmental suitability students, aspects of readability, ability to motivate, straightforwardness, aspects of writing rules. The validation results can be seen in Table 3.

Table 3. Expert Validation Result

No.	Experts	Score
1.	Content	3.5
2.	Media	3.4
3.	Language	3.9
Average		3.6

The formula above shows that the average experts' validation about virtual laboratory excretory system is 3.6. Here is the indicate that the product has the "Very Valid" criteria. The experts also provided suggestions to make this product more feasible to use.

Implementation & Evaluation

The implementation stage includes a product feasibility trial in a small group involving 10 students and a large group involving 30 high school students in grade 12. This test was conducted to obtain data on the views of students as users. Product implementation was carried out by researchers sending a link to the virtual laboratory of the excretory system that had been revised according to expert advice. After students used the virtual laboratory of the excretory system, they were given a questionnaire of 10 questions related to the product using *Google Form*. The average value for each aspect can be seen in the Table 4.

Table 4. Expert Validation Result

No.	Experts	Score
1.	Small Group (10 person)	3.6
2.	Large Group (30 person)	3.8
3.	Biology Teacher	3.9
Average		3.8

The results of the trial obtained results with an average value of 3.8 and were categorized as valid. Biology students and teachers have assessed that the Excretory System virtual laboratory has a good appearance, has attractive features both in terms of color and images, and is easy to drag and drop when conducting experiments, presentation according to age, according to the material and can increase curiosity. A series of assessments produced an average value that was categorized as good, so the product was declared very valid.

The practicality test which contains with pretest and posttest results of students were tested to determine the learning outcomes of the application of the virtual laboratory application of the excretion system carried out on 50 class XII students at SMA Negeri 16 Jakarta and measured through pretest and posttest activities given to students which included 33 questions. The pretest results with an average value of 59.05 and an average posttest value of 81.16. From these results, there is a difference in the average value between the pretest and posttest. The difference in results shows an increase in student learning outcomes after using the virtual laboratory of the excretion system as additional learning media.

The results of the N-Gain calculation obtained a result of 0.53 and the increase in learning outcomes of students' excretory system using supporting learning media in the form of virtual laboratories was categorized as medium level. Some material in biology cannot be visualized directly so it is difficult for students to understand the material, especially if it is practicum-based learning processes, one of which is the Excretory System material. The existence of this virtual laboratory facilitates these limitations so that the learning process will be better and learning outcomes will increase because in using the virtual laboratory students will be able to find themselves and carry out investigations. Helping

students become active, collaborative and creative in their learning activities.

Another thing that makes this laboratory effective is the attractive visuals, tools and materials and conditions created like real conditions in the laboratory. Accuracy and the opportunity to experiment repeatedly so that students are not afraid to try because it contains detailed instructions for use. There are pop up questions from the results of the experiments carried out so that students gain new knowledge. This virtual laboratory is also equipped with practical tests, where students will also be tested on their psychomotor knowledge and skills so that the knowledge and experience gained can be more effective.

At the analysis stage is carried out to determine needs, conditions, and problems of students and teachers at SMA Negeri 16 Jakarta. At this stage needs analysis questionnaire was administered via Google form. Analysis of student needs uses a 12-item questionnaire which was given to 36 students who had studied the System Excretion. The results of this analysis were 52.8% of students stated the material The Excretory System is one of the materials that is considered difficult to understand. Regarding the use of media in the form of videos, students have already been taught with this media, but for the use of virtual laboratory media on Excretory System material, students have never used it. 97.2% of students expect media development in the form of a virtual laboratory because this is related to the potential it has virtual laboratory as a supporting medium to increase understanding Excretory System material and as an alternative to not carrying out practicum excretory system at school. Based on the results of a series of questions and statement to students, it can be seen that the development of supporting media in the form of a virtual laboratory for the excretion system needs to be carried out.

Based on the results of the biology teacher's analysis, the teacher gave an opinion that the Excretory System material is quite difficult material and it takes quite a long time for students to understand. Teacher biology expects learning media that is more interesting, easy to access, easy to understand and learn, and does not bore students.

Teacher stated that he agreed if media development was carried out in the form of a laboratory virtual media as a learning support media to improve students learning outcomes.

The results of this study are that the development stage of a virtual laboratory of the excretion system is valid and can be used as a supporting learning media for grade 11 students in high school with validation data by media, material, and language experts obtained a score of 3.6. The implementation score from students who are members of small and large groups, teachers was also obtained at 3.8.

The next stage of formative evaluation is carried out by improving the product from the results of expert assessments. The evaluation aims to assess the quality of the product and the learning process both before and after implementation (Munthe & Nina, 2024). In this study, a product practicality test was also conducted by calculating the product's n-gain on student learning outcomes. The results of the n-gain calculation produced a score of 0.53 with a moderate category. This interpretation is based on the gain score in the range of $0.30 \leq g < 0.70$. This indicates an increase in student learning outcomes with a medium category (Byukusenge & Tarmo, 2022). According to Listyawati, (2012) which states that if the n-gain results are in the medium to high category, then the product developed is feasible and effective for use in learning.

This study is in line with research conducted by Suryanda et al., (2017) which states that interactive multimedia learning media based on websites is feasible and effective for use in learning, and can be used to improve mastery of concepts and learning outcomes in students. According to Wijaya et al., (2016) with the existence of learning media there are several things that can improve student learning outcomes, including (1) the teaching and learning process becomes easier and more interesting, (2) student learning efficiency can increase, (3) helping student learning concentration, (4) increasing student learning motivation, (5) providing a comprehensive experience in learning, (6) students are involved in the learning process. The product that has been developed makes it easier for students

and teachers to use. Students can more focus because they immediately carry out their own practicum according to the stages listed on their respective screens, can be done anywhere and can be repeated at any time (Wulandari et al., 2018). Students get varied learning experiences so that students are more interested and motivated because the visuals of this laboratory application are attractive, this is strengthened by expert validation (Sadiki et al., 2020).

The developed virtual laboratory media successfully improved student learning outcomes with an N-gain value of 0.53, which is categorized as moderate. This indicates the effectiveness of the media in supporting students' understanding of the Excretory System material. This finding is in line with the Constructivism theory Piaget Vygotsky, where students build their knowledge through direct experience and active involvement in learning (Sukenti, 2021). The virtual laboratory provides space for students to explore, try, and repeat the practicum process independently, which supports the active learning and experiential learning processes (Suwarna & Zulfiani, 2024). Virtual lab activities significantly support students in inquiry-based learning by allowing them to visualize and investigate complex or abstract concepts (Aswari et al., 2024). In addition, from the perspective of Multimedia Learning Theory by Lisa et al., (2022) the virtual lab allows the integration of text, images, animations, and audio that synergize to strengthen cognitive processing. This combination of visual and verbal elements contributes to strengthening working memory and long-term retention (Schweppe & Rummer, 2014).

Compared to conventional media such as printed modules or learning videos, virtual laboratories have significant advantages in terms of interactivity and flexibility. Printed modules are only one-way and passive, while videos, although visual, still do not give students full control over their learning process. In a virtual lab, students can repeatedly simulate experiments, make decisions in practicum procedures, and receive direct feedback from the system through pop-up question features or test result simulations. However, unlike real practicums in physical laboratories, virtual labs have limitations in presenting a complete

multisensory experience. For example, students cannot physically smell, touch, or actually feel the tools and materials. In this context, a combination of virtual labs and real practicums (blended practicum) may be ideal in Biology learning (Sukenti, 2021).

Some limitations of this study that need to be considered, there is no control or comparison group, so it cannot be concluded that virtual laboratory is superior to other methods. The number of samples is limited (50 students from one school), so the generalization of the results is limited to the local context. No long-term effectiveness tests were conducted, such as delayed post-tests that can measure learning retention after several weeks or months. Validation was only carried out by three experts without triangulation of data from classroom observations, in-depth interviews, or documentation of student learning activities (Munthe & Nina, 2024).

This study has important implications, including, for teachers, virtual laboratories can be used as alternative or complementary media for practicum-based learning, especially if the school laboratory is inadequate. For principals and policymakers, it is necessary to consider integrating this media in the curriculum and teacher training, so that its utilization is optimal. For media developers, these results open up opportunities to create interdisciplinary and cross-material virtual labs, not only limited to the excretory system. For students, this media can be a bridge to building a more active, creative, and enjoyable technology-based learning experience (Bykusenge & Tarmo, 2022). According to research by Azizah & Aloysius, (2021) learning media provides opportunities for students to learn more independently, repeat after evaluation, and enrich their understanding by further exploring the material studied. This causes the application of biology learning media to improve student learning outcomes because when developing this learning media, it has also been adapted to the needs of students.

CONCLUSION

The virtual laboratory media was developed using the ADDIE model consisting of five stages, namely Analyze, Design, Development, Implementation, Evaluation. In the product feasibility test, the virtual laboratory of the excretion system that has been developed has a very valid category and can be used based on the assessment of the validator, the assessment of students and biology teachers and is effective in improving student learning outcomes.

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