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Innovation in Learning Biotechnology through a Virtual Laboratory Based on Islamic Values in High Schools

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ABSTRACT
Limited laboratory facilities and suboptimal practical activities are problems in biology education, particularly in biotechnology classes in high schools. To address these issues, this study aims to develop an educational medium in the form of a virtual laboratory based on Islamic values for biotechnology material in high schools. This research and development (R&D) employed the 4D development model, which consists of four stages: define, design, develop, and disseminate. Data were analyzed using descriptive qualitative and quantitative methods. The results showed that the feasibility level, as assessed by the media validation test, reached 88%, the material expert validation test reached 90%, and the Islamic values expert validation test reached 92%, each falling into the "highly valid/highly feasible" category. The practicality test by teachers scored 84%, and the practicality test by students scored 80.3%, both categorized as "practical/feasible." These findings indicate that the virtual laboratory based on Islamic values in biotechnology material at the high school level is considered practical and feasible for use in learning. It is expected that this virtual laboratory can serve as an innovative learning medium for teachers and students.

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Introduction

The rapid advancement of science and technology has brought about a paradigm shift, especially in the field of education. The influence of 21st-century technology is evident among students, who are inseparable from their use of gadgets. As professional educators, teachers are required to possess the ability to develop creative and innovative learning media (Sadriani, 2023; Fitriani et al., 2024).

A high-quality workforce, often referred to as the "golden generation," is characterized by spiritual, emotional, intellectual, and physical intelligence, as well as strong character. Such human capital can only be cultivated through a high-quality educational process, with teachers as the key determinant (Sembiring, 2022). To meet the demands of this increasingly dynamic educational landscape, teachers must act not only as facilitators but also as motivators and sources of inspiration for students.

According to data from the World Bank, Indonesia has over 50 million students and 2.6 million teachers across 250,000 schools, making its education system the third largest in Asia. This serves as a critical point for the government in planning solutions to the challenges faced by teachers and other educational stakeholders. An education system is considered superior when its policies and regulations provide a strong foundation. The presence of a high-quality teaching workforce is a determining factor in the effectiveness of educational outcomes (Sembiring, 2022). One way to overcome these challenges is through the development of innovative learning media using relevant technologies, such as virtual laboratories.

Biology, as a discipline, requires students not only to understand theoretical concepts but also to apply them through a series of scientific methods. This application is carried out through practical laboratory activities. However, only 20% of schools in Indonesia conduct practical sessions as part of their learning processes (Ahmad, 2020). The lack of practical activities is primarily due to the unavailability of laboratory facilities and infrastructure. Limited resources, such as equipment and materials, are often major obstacles in conducting laboratory-based educational activities (Waluyo, 2021). These challenges highlight the potential role of virtual laboratories.

A virtual laboratory represents a technological innovation designed to support learning. Laboratories are an integral part of practical learning, serving as a teaching method that helps students draw conclusions from experiments aligned with the learning material. Conducting these practical activities requires adequate facilities and infrastructure. As a product of

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technological advancement, virtual practical work is expected to provide a solution to the limitations of traditional laboratory work.

Virtual laboratories offer several advantages: they can be accessed anytime and anywhere, reduce the risk of laboratory accidents, and allow experiments to be repeated multiple times. This not only minimizes laboratory waste but also reduces operational costs for physical equipment and chemicals (Ahmad, 2020; Sembiring, 2022). Virtual practical sessions also provide a safe and engaging experimental experience for students (Supriyadi, 2017). The types of practical activities conducted at the high school level are diverse, with biotechnology being one example.

Biotechnology involves the use of living systems and organisms to meet human needs. Its primary goal is to modify and develop new products. The field of biotechnology is multidisciplinary, abstract, and highly applied, requiring a solid understanding of its underlying concepts. One alternative solution to address these challenges is e-learning that incorporates biotechnology concepts (Riani, 2015; Nurgas et al., 2024). The use of biotechnology includes modern applications, which, according to the Indonesian Council of Ulama (MUI) Fatwa No. 35 of 2013 on genetic engineering and its products, must be guided by Islamic values (Faridah, 2024).

Education is an effort to develop students' potential and character so they become intelligent, morally upright, and beneficial to themselves and their communities. Empirical evidence shows that the main challenges in Islamic education today are the rapid advancement of science and technology, democratization, and moral decline. The best education is one that is both excellent and holistic, enhancing not only intellectual capacity but also emotional and spiritual intelligence (Muhammad, 2022).

Based on the problems outlined above, this research was conducted to develop a virtual laboratory based on Islamic values for biotechnology material in high schools. This initiative is expected to be beneficial in learning activities and holds significant potential to improve the quality of education in line with modern demands while adhering to Islamic principles. The purpose of this study is to develop a virtual laboratory grounded in Islamic values for teaching biotechnology material in high schools. This tool aims to overcome the limitations of laboratory facilities and provide a practical product that can be used in teaching biotechnology.

Methods

This study employed a Research and Development (R&D) approach using the 4D development model (Define, Design, Develop, Disseminate) proposed by Thiagarajan. The participants included Grade 10 students at SMA Negeri 1 Pabedilan, as well as validators consisting of a subject matter expert, a media expert, and an Islamic values expert. The practicality test involved one biology teacher and 27 students.

Research Stages

Define

Front-end analysis: Interviews and observations revealed that the school laboratory was underutilized, biology learning relied heavily on textbooks, and biotechnology practical work was rarely conducted.

Learner analysis: Students struggled to understand biotechnology concepts and demonstrated low learning enthusiasm, indicating the need for more engaging media.

Task analysis: Competency indicators were aligned with the Merdeka Curriculum, focusing on biotechnology.

Concept analysis: The material emphasized DNA isolation as an example of modern biotechnology.

Specifying instructional objectives: The objectives included enabling students to (1) identify various biotechnology innovations, (2) understand their significance, and (3) apply them in accordance with Islamic values.

Design

Development of evaluation instruments: Validation sheets (content, media, Islamic values) and response questionnaires (teachers and students).

Media selection: Articulate Storyline and Canva software.

Format design: The application included the title, learning outcomes, biotechnology content, integration of Islamic values, case studies, practical objectives, procedures, a DNA isolation simulation, and evaluation.

Initial design: Prototyping aligned with student needs and instructional objectives.

Develop

An Android application (.apk) was developed based on the design. The menus and layout of the product are shown in Figure 1. The application included features such as biotechnology content, integration of Islamic values, a DNA isolation practical simulation, and evaluation items.

Figure 1. Menu of the Virtual Laboratory Application

Disseminate

The final product was distributed on a limited basis to teachers and students via WhatsApp, Telegram, and Bluetooth for trial use.

Instruments and Data Analysis

Instruments: validation sheets (Likert-scale) and teacher/student questionnaires.

Data analysis: Scores were converted into percentages using the formula:

$$P = \frac{\sum x}{\sum Xi} x\ 100\%$$

Interpretation criteria: 81–100% = very valid/practical; 61–80% = valid/practical; 41–60% = fairly valid/practical.

Information/Key:

P: Percentage

X: The number of responses from respondents for a single item.

Xi: The ideal number/value for a single item.

Results and Discussions

The final product was a Virtual Laboratory Application for Biotechnology (DNA Isolation) integrating Islamic values.

Validation Results

Expert validation was carried out by three experts: content, media, and Islamic values. The results are presented in Figure 2.

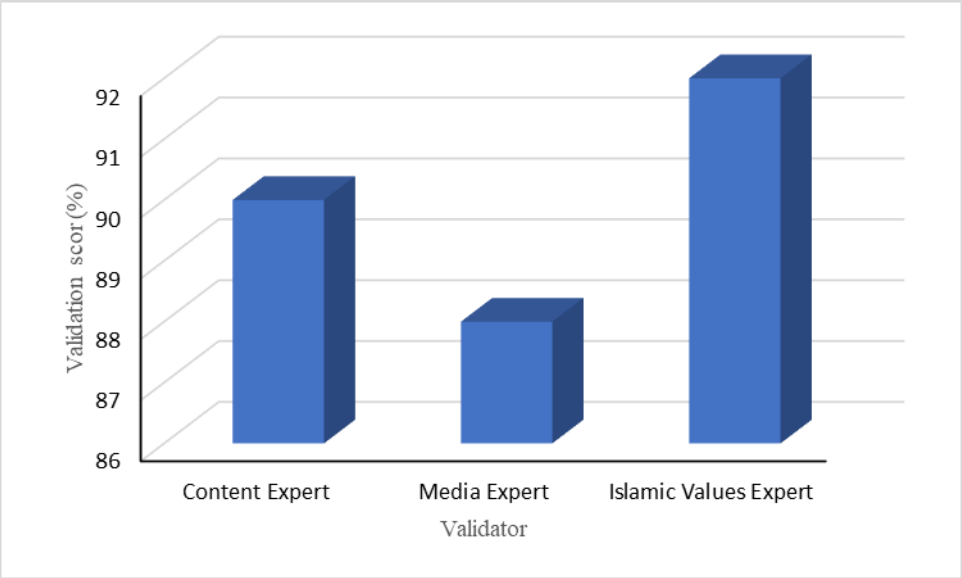

Figure 2. Expert appraisal results

These results confirm that the product met the validity standards across all aspects. The high content score shows the material aligned with learning objectives (Nieveen, 1999). The strong Islamic values score indicates successful integration of spiritual principles (Al-Qarni, 2025). The media score, while high, suggests some areas for visual and design improvements (Nurjanah et al., 2025).

Developmental Testing

Practicality testing was conducted with teachers and students. The results are presented in Figure 3.

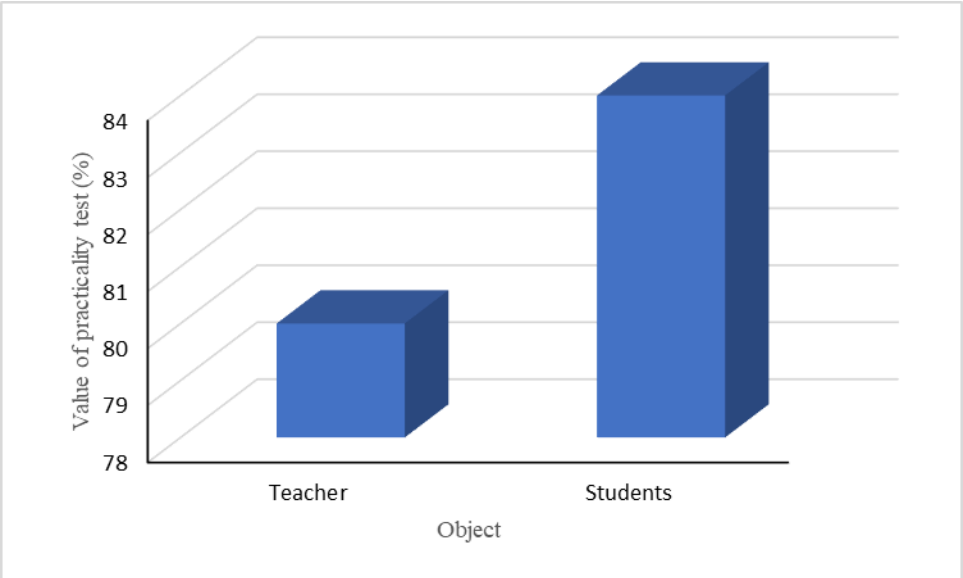

Figure 3. Developmental testing results (Practicality Test)

These findings indicate that the product is generally easy to use and effective. The higher score from teachers shows that the application integrates well into classroom practices, while the student score reflects usability and engagement. According to Tessmer & Richey (1997), practicality refers to products being easy to operate and efficient in real educational contexts.

The findings demonstrate that the developed virtual laboratory for biotechnology, integrated with Islamic values, is both highly valid and practical. The strong validation scores across content, media, and values confirm that the product aligns with curricular standards, technological requirements, and religious principles. This aligns with Nieveen (1999), who

emphasizes that high content validity reflects the degree to which a product's material corresponds to the intended competencies. The integration of Islamic values further strengthens the moral and spiritual dimension of learning, supporting Al-Qarni (2025), who argues that value-based learning should not only provide knowledge but also embed ethical and normative principles.

The practicality results, showing positive responses from both teachers and students, indicate that the product is feasible for classroom use. Teachers' relatively higher practicality rating (84%) suggests that the application aligns with instructional goals and is manageable within existing teaching workflows. Students' slightly lower score (80.3%) reflects that while the product is easy to operate, further improvements in design and interactivity could enhance their learning experience. This echoes Tessmer and Richey (1997), who note that practicality is determined by simplicity, usability, and relevance in authentic learning environment

Compared to previous studies on virtual laboratories, this product presents a unique contribution. Supriyadi (2017) highlighted that virtual laboratories improve students' scientific attitudes, while Waluyo et al. (2021) found that software-based labs enhance learning outcomes in STEM contexts. However, both studies primarily focused on cognitive and technical outcomes. The current study extends this literature by embedding Islamic values, offering a dual advantage: addressing laboratory infrastructure limitations while simultaneously cultivating ethical and spiritual awareness. This makes the product particularly relevant in Islamic education contexts, where the integration of faith and science is a pedagogical priority. Nonetheless, the study has limitations. The dissemination stage was conducted only in one school, restricting the generalizability of the findings. Future research could expand the testing to multiple schools, incorporate larger and more diverse student samples, and refine the application's design features to maximize engagement.

Conclusions

The Virtual Laboratory for Biotechnology (DNA Isolation) based on Islamic values is highly valid (88–92%) and practical (80–84%). It can serve as an innovative alternative to overcome laboratory limitations while promoting value-based education in high schools.

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