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Effectiveness of Using QR Code-Based Biotechnology Practical E-Instructions for Junior High School Students to Improve Critical Thinking Skills

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Abstract

The demands of 21st century education emphasize the importance of mastering critical thinking skills for students in order to be able to compete competitively. However, the reality in the field shows that the level of students' critical thinking skills is still in the low category. The causal factors are the use of media and teaching materials that are less interesting and less interactive. This study aims to determine the effectiveness of the biotechnology practical E-Instructions product through QR Code technology to improve students' critical thinking skills in junior high schools. The method used in this study was a field trial using the One Group Pre-test Post-test design on 32 ninth grade students of SMP Negeri 5 Tuban. Data collection was carried out through the T-Paired and N-Gain tests. The results showed a significant increase (Sig. 0.000) with an N-Gain of 0.74 (high criteria), proving that QR Code-based Practical E-Instructions are effective in improving students' critical thinking skills. This innovation is expected to be a solution in more interactive biotechnology learning and encourage students' critical analysis skills.

Keywords: *E-Practical instructions; QR Code; Critical thinking*

Abstrak

Tuntutan pendidikan abad ke-21 menekankan pentingnya penguasaan keterampilan berpikir kritis bagi peserta didik agar mampu bersaing secara kompetitif. Namun, kenyataan di lapangan menunjukkan tingkat kemampuan berpikir kritis siswa masih tergolong kategori rendah. Faktor penyebabnya adalah penggunaan media dan bahan ajar yang kurang menarik serta kurang interaktif. Penelitian ini bertujuan untuk mengetahui seberapa efektivitas produk E-Petunjuk praktikum bioteknologi melalui teknologi QR Code untuk meningkatkan kemampuan berpikir kritis peserta didik di SMP. Metode yang digunakan dalam penelitian ini adalah dengan uji coba lapangan menggunakan desain One Group Pre-test Post-test pada 32 siswa kelas IX SMP Negeri 5 Tuban. Pengumpulan data dilakukan melalui uji T-Paired dan N-Gain. Hasil menunjukkan peningkatan signifikan (Sig. 0,000) dengan N-Gain 0,74 (kriteria tinggi), membuktikan bahwa E-Petunjuk Praktikum berbasis QR Code efektif digunakan dalam meningkatkan keterampilan berpikir kritis siswa. Inovasi ini diharapkan dapat menjadi solusi dalam pembelajaran bioteknologi yang lebih interaktif dan mendorong kemampuan analisis kritis siwa.

Kata Kunci: *Petunjuk praktikum; QR Code; Berpikir kritis*

1. INTRODUCTION

Education is currently developing rapidly with 21st-century competition that demands students to be able to think well (Khusna et al., 2023). In the 21st century, students are required to have critical thinking skills to be able to compete superiorly in an increasingly competitive environment (Umam, 2021). According to Elizabeth et al., (2024), critical thinking skills play a crucial role in developing the life skills that are so essential for students in today's era. These skills not only support problem-solving but also strengthen students' ability to design decisions based on rational and objective analysis of the information and situations faced. Critical thinking involves using basic cognitive abilities to assess the validity of an argument, develop in-depth interpretations, and organize ideas into a systematic line of reasoning. This process helps students build a comprehensive understanding and be able to evaluate various viewpoints reflectively to produce the right decisions (Humayroh et al., 2024). However, in reality, achieving critical thinking skills in students is not easy. Monotonous or uninteresting presentation of material can

result in a decrease in student interest and understanding (Gita, 2024). Thus, students' critical thinking skills must be adapted to current technological developments.

Based on findings from a needs analysis study conducted at SMP Negeri 5 Tuban, students' critical thinking skills were found to be relatively low. This condition indicates that some students face obstacles in meeting critical thinking indicators, such as analyzing information, drawing conclusions, and logically evaluating arguments. This low achievement in these skills is believed to be closely related to the use of learning media and materials that do not optimally stimulate students' critical thinking skills. The material presented tends to be textual and less interactive, thus failing to encourage students to think deeply, reflectively, and logically, as required by the demands of 21st-century learning. Students are also less interested in reading the learning materials, resulting in low levels of these skills. The selection of appropriate learning media and materials plays a crucial role in supporting the success of the learning process, particularly in biotechnology.

According to Mardatillah (2024), biotechnology is a science subject that presents its own challenges to teach, as it requires an understanding of fundamental, applied, and abstract ideas. Biotechnology material will be difficult for junior high school students to understand if they do not yet understand the basic principles of biotechnology (Gusti et al., 2023). Therefore, the implementation of biotechnology learning at the junior high level should be carried out through a creative and innovative approach so that students not only understand the basic principles of biotechnology but also are encouraged to hone their critical thinking skills in depth. This innovative approach is essential for creating meaningful learning experiences (Tris et al., 2024). Students with critical thinking skills can not only master the subject content they are studying but also be able to apply it in their lives (Nur & Amal, 2022). These skills are crucial for students in analyzing information, evaluating, and making decisions (Rohmah et al., 2023).

The biotechnology learning process includes practical activities that play a crucial role because they provide students with the opportunity to participate directly in learning activities (Rabiudin, 2023). Through experiments, students not only hone their critical thinking skills but also gain real-world experiences that support in-depth conceptual understanding. Furthermore, in practical activities, students are not merely recipients of information but also actively involved as actors who experience, explore, and analyze the concepts being learned (Nugraini & Amelia, 2023; Nurkaenah et al., 2019). The implementation of biotechnology practicals presents unique challenges faced by teachers due to the lack of student involvement in practical activities, which should be a means of developing students' critical thinking skills (Yuni et al., 2025). However, there are still obstacles in the form of conventional text-based instructions for biotechnology practicals that are considered less engaging and less interactive, thus reducing students' thinking skills in exploring biotechnology concepts in depth (Basri et al., 2023). Based on this, it is necessary to develop innovative lab instructions in the form of QR Code-based electronic lab instructions so that students can improve their thinking skills, analyze problems, and solve them (Masithah et al., 2022).

Research by Inayati et al. (2024) states that QR Code-based electronic lab instructions can make the learning process more effective and engaging. This electronic lab instruction media is designed to provide high flexibility, allowing its use without time and place constraints. With the presence of these e-lab instructions, students are encouraged to be more active in the learning process and are also given space to hone their analytical thinking skills through directed and systematic lab activities (Fina et al., 2023). Lab instructions equipped with QR Codes make it easier for teachers and students to access electronic lab instructions independently (Fitrihidajati, 2024). Lab instructions developed with QR Code technology are an innovative learning medium that presents interactive video content containing a systematic sequence of steps for carrying out lab work. This guide also includes explanations of the material through audio narration and appropriate visual descriptions based on the learning topic, thus helping students understand the practicum procedures more easily (Selvia et al., 2023). Using electronic practicum instructions equipped with QR Codes is believed to be able to attract student interest because of its more concise, interactive display, and easy access and understanding. Based on these considerations,

this study was conducted with the aim of testing the effectiveness of the use of QR Code-based biotechnology practicum e-Instructions in supporting the improvement of students' critical thinking skills at the Junior High School (SMP) level. With this innovation, the learning process is expected to run more optimally, encourage active student involvement during the learning process, and be able to develop students' critical thinking skills.

2. METHOD

2.1. Research Design

This study aimed to determine the effectiveness of the developed e-practical instruction manual on improving students' critical thinking skills. The e-instruction product had previously undergone various stages of research and development (R&D), with expert validation results yielding a score of 91.89%. This score indicates that the product falls into the "very valid" category, meaning that the tool meets eligibility criteria and can be optimally implemented in the learning process.

The field trial was conducted using a pre-experimental design, the Pre-test and Post-test Design. This method was chosen because it can demonstrate changes in student abilities before and after receiving the learning treatment (Andini, 2025). By comparing pre-test and post-test scores, researchers were able to assess the effectiveness of the learning media in improving student abilities. Furthermore, critical thinking skills were measured using a separate instrument, allowing for more focused analysis of improvements in these skills after treatment (Devinta et al., 2025). This design provided researchers with the opportunity to evaluate changes in student learning outcomes before and after treatment or intervention. A more detailed explanation of the structure and implementation flow of the trial design can be seen in Table 1 below.

Table 1. Research Design The One Group Pre-Test Post-Test Design

O1	X	O2
Pre-test	Treatment	Post-test

(Sugiyono, 2017)

2.2. Population and Sample

Researchers conducted a field trial. This trial involved a group of 32 ninth-grade junior high school students, with a total population of 32. The study was conducted over four meetings.

2.3. Research Prosedure

Research procedure was conducted through several systematic stages to evaluate the effectiveness of the QR Code-based e-practical instructions in improving students' critical thinking skills. The stages are described as follows:

2.3.1. Preparation Stage: At this stage, the researcher prepared all research needs, including the development of QR Code-based e-practical instructions, preparation of research instruments (pre-test and post-test questions), validation of instruments by experts, and coordination with the school regarding the research implementation schedule.

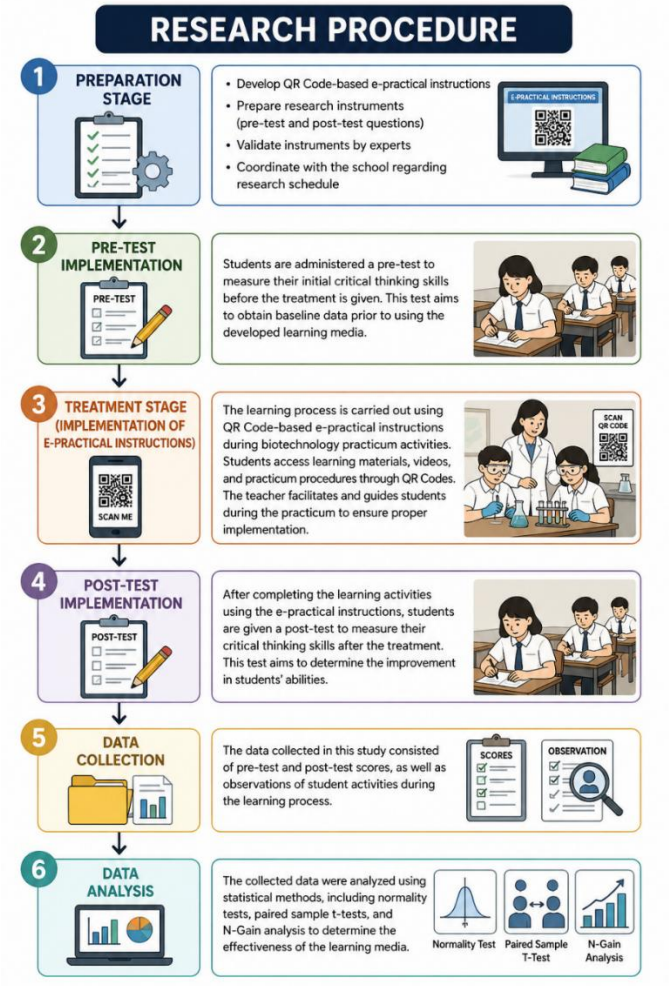
2.3.2. Pre-test Implementation: Before the treatment was given, students were administered a pre-test to measure their initial critical thinking skills. This test aimed to obtain baseline data prior to the use of the developed learning media.

2.3.3. Treatment Stage (Implementation of E-Practical Instructions): The learning process was carried out using QR Code-based e-practical instructions during biotechnology practicum activities. Students accessed learning materials, videos, and practicum procedures through QR Codes. The teacher facilitated and guided students during the practicum to ensure proper implementation.

2.3.4. Post-test Implementation: After completing the learning activities using the e-practical instructions, students were given a post-test to measure their critical thinking skills after the treatment. This test aimed to determine the improvement in students' abilities.

2.3.5. Data Collection: The data collected in this study consisted of pre-test and post-test scores, as well as observations of student activities during the learning process.

2.3.6. Data Analysis: The collected data were analyzed using statistical methods, including normality tests, paired sample t-tests, and N-Gain analysis to determine the effectiveness of the learning media."



2.4. Instrument Research

The practicum activity began with a pre-test given to students to assess their initial abilities. After completing the practicum session with the aid of the designed e-practicum instructional media, students were given a post-test as a form of evaluation to assess the extent of their improvement. To determine whether there was a significant difference between the pre-test and post-test results, the collected data were analyzed quantitatively using a paired sample t-test (Dewi et al., 2024).

2.5. Data Analysis

The research instrument will be validated by a research instrument expert using the following index formula:

Index Formula % = (total score) / Y X 100

Prior to conducting the analysis, a normality test was performed to examine the distribution of the data. Since the sample size was fewer than 50 participants, the Shapiro–Wilk test was applied in line with standard statistical procedures. To evaluate the effectiveness of the developed e-practicum instructions in enhancing students' critical thinking skills, the Normalized Gain (N-Gain) analysis was utilized. As stated by Sujanem et al. (2022), a learning process is considered

effective when it yields a high N-Gain score. Moreover, based on the classification proposed by Yulani et al. (2024), specific criteria are used to interpret students' N-Gain scores as indicators of improvements in their critical thinking abilities. The classification or categories of N-gain values are presented in Table 2 as follows:

Table 2. N-gain value classification

<g> value	Criteria
(<g>) ≥ 0,7	High
0,7 > (<g>) ≥ 0,3	Medium
(<g>) < 0,3	Low

3. RESULT AND DISCUSSION

The complete results of the normality test for the data obtained in this study using SPSS version 23 can be seen in Table 3 below.

Table 3. Descriptive Analysis

Test	Shapiro-Wilk		
	Statistic	df	.Sig
Pre-test	.955	32	.184
Post-test	.940	32	.070

Referring to the analysis results presented in Table 3, the significance value for the pre-test was 0.184 and the post-test was 0.070. Both values exceeded the significance threshold of 0.05, indicating that the data from both the pre-test and post-test met the assumption of normality. This finding aligns with the results of research conducted by Aina & Hariyono (2023), which showed that the data measured through their pre-test and post-test were normally distributed, with a pre-test value of 0.144 and a post-test value of 0.116. Once these requirements are met, further statistical analysis can be conducted using the paired sample t-test. The paired sample t-test is used as a statistical analysis tool to determine the significance of differences between student learning outcomes before and after participating in learning activities with specific treatments.

Figure 1. Field Data Collection Process

Furthermore, analysis of the pre-test and post-test data using a paired sample t-test indicated a significant difference after students used the developed e-practicum instructional media. This finding indicates that the use of the developed innovative product has a significant contribution to improving student learning outcomes. Specifically, this product has proven effective in honing students' critical thinking skills. All stages of the statistical analysis were conducted using SPSS version 23, and detailed calculation results can be seen in Table 4 below.

Table 4. Paired T-Test Analysis Results

Test	Mean	Std. Deviatition	Std. Error Meam	t	df	Sig (2-tailed)
Pretest-Posttest	-48.751	.67203	.11880	-410.362	32	.000

The analysis using a paired sample t-test on the pre-test and post-test data yielded a significance value (2-tailed) of .000. This value is well below the 0.05 significance level, indicating a statistically significant difference between student learning outcomes before and after participating in the practicum using the developed e-practicum instruction product. These results

reinforce the evidence that the use of QR Code-based e-practicum instruction media has a positive impact on improving student learning outcomes after treatment through interactive practicum activities. This is further supported by the results of research by Christianto (2022), which demonstrated that the application of practical guidance in learning can improve student cognitive and learning outcomes with a percentage increase of 74%, categorized as high.

The critical thinking skills focused on in this trial consist of five main indicators: 1) the ability to identify a problem; 2) understanding the relationships between existing problems; 3) collecting and organizing relevant information; 4) evaluating data and assessing the validity of statements; and 5) drawing logical conclusions based on the information obtained (Wayudi et al., 2020). Analysis of these indicators indicates that the use of e-practicum instruction can support the development of students' critical thinking skills comprehensively. The assessment results from the practicum activities show that the average student score in these critical thinking indicators ranges from 3, 4, to 5. This score indicates that their critical thinking skills have been able to connect two or more pieces of information logically in a certain context. In line with the statement by Mulia & Murni (2022) who stated that practicum activities can strengthen students' analytical skills in solving problems that involve critical and logical thinking. The results of the N-gain calculations for the students' pre-test and post-test can be seen in Table 5 below.

Table 5. Results of N-gain Calculation of Pre-test and Post-test Scores

Average Pre-test Score	Average Post-test Score	N-gain	Criteria
52,46	87,53	0,74	High

Based on the analysis of the N-gain calculations presented in the table above, it can be concluded that student learning outcomes have improved significantly. This study yielded an N-gain score of 0.74, which falls into the high category based on standard interpretation. This achievement is consistent with findings by Aina & Hariyono (2023), who also demonstrated a significant improvement in learning outcomes through the implementation of innovative learning media, with a score increase of 0.718, which falls into the high category. The N-gain test results conducted by Frelin et al. (2024) also showed a high average N-gain score of 0.87, indicating that students' critical thinking skills are in the very good category. This improvement demonstrates that the implementation of QR Code-based e-practical instructions has had a positive and tangible impact on students' critical thinking skills in the classroom learning process.

The effectiveness of the developed e-practical instructions is reflected in students' improved ability to understand, analyze, and draw conclusions after participating in learning activities using the e-practical instructions. Thus, it can be said that the QR Code-based e-practical instructions are effective in not only facilitating access to information, but also encouraging the optimal development of critical thinking skills in the context of science learning or practical work.

4. CONCLUSION

The implementation of QR Code-based e-practical instructions significantly improves students' critical thinking skills. Statistical analysis showed normally distributed data (Shapiro-Wilk > 0.05), allowing further testing. The paired sample t-test ($p < 0.05$) confirmed a significant improvement in learning outcomes, supported by a high N-Gain score (0.74). These results indicate that the e-practical instructions are effective and suitable for learning, promoting active engagement, analytical thinking, and problem-solving. Therefore, this approach is a promising innovative tool for enhancing 21st-century skills, especially in practice-based learning.

5. ACKNOWLEDGMENT

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