



## DEVELOPMENT OF A STEM-INTEGRATED ETHNOSCIENCE E-MODULE ON BIOTECHNOLOGY TO ENHANCE JUNIOR HIGH SCHOOL STUDENTS' CRITICAL THINKING SKILLS

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### Abstract

This research aims to: (1) develop a science e-module based on STEM-integrated ethnoscience that enhances the critical thinking skills of junior high school students; (2) determine the practicality of the developed e-module; (3) assess the effectiveness of the developed e-module in enhancing the critical thinking skills of junior high school students. This study employed a Research and Development approach using the 4D model which includes Define, Design, Develop, and Disseminate. The product trial, conducted at MTsN 4 Gunungkidul, adopted a before-after design and involved Class VIII A students selected through purposive sampling. The instruments used included e-module validation sheets, student response leaflets, and pretest-posttest sheets. Data analysis techniques encompassed a 4-point scale evaluation for e-module validation, a 5-point scale evaluation of e-module practicality based on student responses, paired sample t-tests and effect size testing to gauge the effectiveness of the e-module in enhancing critical thinking skills. The research findings indicate that: (1) The developed e-module is highly suitable for use in science education; (2) The developed e-module is practical for use in science education; (3) The developed e-module effectively enhances the critical thinking skills of junior high school students.

**Keywords:** critical thinking, e-module, ethnoscience, STEM

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## INTRODUCTION

Critical thinking is one of the essential higher-order thinking skills (HOTS) that students need to develop in science education. It enables students to analyze information, evaluate evidence, solve problems, and make reasoned decisions in both academic and real-life contexts. According to Saraswati & Agustika (2020), HOTS refers to students' ability to solve problems through critical and creative thinking. Among the various components of HOTS, critical thinking plays a fundamental role in helping students interpret information, formulate logical arguments, and generate appropriate solutions to complex problems. (Widihastuti, 2015) also emphasizes that developing students' critical thinking skills is essential for preparing them to become independent learners who are capable of making informed decisions, conducting investigations, and responding to increasingly complex challenges.

High order thinking skills (HOTS) have several main goals, one of which is enhancing critical thinking skills (Saputra, 2016). According to (Juhji & Suardi, 2018), critical thinking skills are crucial for students. Through critical thinking skills, students can be rational and determine the best alternatives for themselves. Critical thinking skills become ingrained in students' character, enabling them to apply these skills in their everyday lives. Previous studies have consistently reported that junior high school students' critical thinking skills remain relatively low, particularly in science learning, where students often experience difficulties in analyzing problems, evaluating evidence, and drawing logical conclusions (Rahmawati & Atmojo, 2021). Consistent with these findings, preliminary interviews with science teachers at MTsN 4 Gunungkidul revealed that most students had difficulty solving higher-order thinking questions requiring analytical and problem-solving skills. The interviews also indicated that science instruction was still predominantly teacher-centered, causing students to participate passively during classroom activities. These conditions suggest that students' critical thinking skills have not yet developed optimally and highlight the need for innovative instructional materials that actively engage students in learning. Preliminary assessment results at MTsN 4 Gunungkidul indicated that students' critical thinking skills were still relatively low, with an average pretest score of only 44.04 out of 100. The lowest score was found in the inference aspect (32.14), followed by evaluation (40.18), interpretation (50.00), and analysis (59.82). Interviews with science teachers revealed that many students experienced difficulties in solving HOTS questions requiring analytical thinking,

reasoning, and problem-solving skills. The interviews also indicated that science learning was still predominantly teacher-centered, causing students to be passive and rely mainly on teachers' explanations. As a result, opportunities for students to develop critical thinking skills through active learning activities were limited. (Al-Tabany, 2014) states that a teacher-centered learning environment can hinder students' independent development of critical thinking, resulting in low critical thinking skills.

The enhancement of students' critical thinking abilities can be achieved through the educational journey, and one effective method for fostering this development is through STEM education which includes Science, Technology, Engineering, and Mathematics. When STEM education is incorporated into science classes, students are compelled to engage in critical thinking to address and resolve problems. (Khoiriyah et al., 2018) state that STEM education triggers critical thinking in students by demanding problem-solving, decision-making, assumption analysis, evaluation, and investigation.

The enhancement of students' critical thinking skills is one of the primary goals of science education because critical thinking enables students to analyze information, solve problems, and make informed decisions (Sari et al., 2021). One effective approach for fostering these skills is STEM education, which integrates Science, Technology, Engineering, and Mathematics into meaningful learning experiences. Through STEM-based learning activities, students are encouraged to investigate problems, evaluate evidence, design solutions, and apply scientific concepts in real-world contexts (Laili et al., 2019). Furthermore, Khoiriyah et al., (2018) stated that STEM education promotes critical thinking by engaging students in problem-solving, decision-making, assumption analysis, evaluation, and investigation processes.

STEM education can be integrated with ethnoscience, a teaching approach that combines learning materials with the local environment and culture (Rahmawati & Atmojo, 2021). Through this combination, science education becomes more relatable and meaningful to students because it is contextualized in their everyday lives. This supports Sanjaya's claim that by applying the content to actual circumstances, contextual learning helps students better understand the subject matter. (Sanjaya, 2011). Students can also apply the acquired knowledge in real-life situations, making the learning experience meaningful. According to Shidiq (2016), ethnoscience motivates educators to incorporate science into local traditions, wisdom, or social concerns. This helps students comprehend science

more easily and uses it to solve problems in the real world, giving science instruction in the classroom a deeper meaning. Teaching with ethnoscience is a learning strategy that creates an integrated learning environment by integrating culture and designing students' learning experiences. Ethnoscience learning is done by selecting local culture or wisdom and integrating it into school learning with appropriate teaching materials (Fahrozy et al., 2022). One form of local wisdom practiced by communities around MTsN 4 Gunungkidul is the traditional processing of cassava into fermented food products, such as tape, gatot, growol, and peuyeum. This traditional knowledge has been passed down through generations and reflects the community's understanding of natural fermentation processes. In addition to its cultural value, these traditional practices contain scientific concepts related to biotechnology, making them highly relevant for integration into science learning through an ethnoscience approach. Cassava is also one of the most important agricultural commodities in Gunungkidul Regency and is symbolized by a cassava leaf in the regency's official emblem, representing its significance to the local community Department of Agriculture and Food Security of Gunungkidul Regency, 2023).

Cassava can be processed into various foods involving scientific concepts related to fermentation, which falls under biotechnology studies. Some of these cassava-based foods include cassava tape, peuyeum, gatot, and growol. By integrating ethnoscience with biotechnological studies related to cassava-based fermented foods commonly found in daily life, students can better understand and apply the scientific principles, adding meaning to their science education.

Additionally, integrating ethnoscience with STEM education can enhance students' critical thinking skills by helping them identify problems, explain phenomena scientifically, and draw conclusions about abstract knowledge embedded in the local wisdom involved. This aligns with the theory that through ethnoscience-integrated learning, students can discover and optimize their knowledge, tailored to their respective backgrounds. Ethnoscience-integrated learning can foster critical thinking skills, connect science learning with community culture, and reinforce students' knowledge (Sari et al., 2021). The integration of STEM and ethnoscience approaches becomes more meaningful when learning is contextualized through local wisdom, such as traditional cassava fermentation practices in Gunungkidul. Students can explore scientific concepts related to fermentation processes (Science), examine traditional methods and tools used in cassava processing (Technology), design or

evaluate fermentation procedures (Engineering), and analyze measurements such as fermentation time and ingredient proportions (Mathematics). By engaging in these interdisciplinary activities, students are encouraged to analyze information, evaluate evidence, solve problems, and draw conclusions, thereby enhancing their critical thinking skills.

Creating an interactive classroom environment is essential for teachers to enhance students' critical thinking skills. Besides being a source of information and instructor, teachers must also act as facilitators and motivators, encouraging students to actively seek information from various sources (Nuryanti et al., 2018). Using the right teaching resources is essential to enhancing the learning process, enhance student potential, and facilitating comprehension of the information being taught. (Novita et al., 2021; Prastowo, 2015).

Based on interviews with science teachers at MTsN 4 Gunungkidul, teachers frequently relied on textbooks as the primary instructional materials used in science learning. However, these teaching materials had not effectively supported the development of students' critical thinking skills. This finding is supported by preliminary assessment results showing that students' average critical thinking score was only 44.04. The interviews also revealed that students rarely asked questions during classroom learning and experienced difficulties in answering HOTS questions requiring analytical thinking and problem-solving skills.

One instructional material that can help students understand concepts and actively participate in learning activities is the use of e-modules. E-modules contain a complete learning module, methods, limitations, and evaluations designed according to the curriculum. These modules are non-print teaching materials displayed on electronic devices like computers or smartphones (Laili et al., 2019).

Unlike previous studies that mainly focused on STEM-based learning, ethnoscience-based learning, or digital modules separately, this study develops a STEM-integrated ethnoscience e-module on biotechnology that incorporates traditional cassava fermentation practices from Gunungkidul as a local wisdom context. This integration is expected to provide meaningful science learning experiences and enhance junior high school students' critical thinking skills.

## **METHOD**

### **Development Model**

This research utilizes the Research and Development method for creating electronic modules, a research approach specifically designed

to develop a product and assess its efficacy (Sugiyono, 2020). The development model used in creating electronic modules is the 4-D model by (Thiagarajan., & Sivasailam, 1974) which includes Define, Design, Develop, and Disseminate.

### Development Procedure

The development process employed in this study is a modified version of the 4-D model steps proposed by (Thiagarajan., & Sivasailam, 1974). These stages include Definition (defining), Design (designing), Development (developing), and Dissemination (distribution). The Define stage involves initial studies of urgency and needs analysis conducted through interviews, as well as task analysis and concept analysis based on the 2013 Junior High School Science curriculum. The Design stage includes the preparation of instruments, format development, and the initial design (draft I of the e-module).

The Develop stage involved several activities to refine and evaluate the developed e-module. First, draft I of the e-module was reviewed by supervising lecturers to obtain suggestions and improvements, resulting in draft II. Subsequently, draft II was validated by two experts, namely a subject matter expert and a media expert, to evaluate the content accuracy, language appropriateness, presentation, graphical design, and technical quality of the e-module. Revisions based on the validators' recommendations were then made to produce draft III. After the validation process, a limited trial was conducted involving junior high school students to evaluate the practicality and effectiveness of the developed e-module. Practicality was assessed through student response questionnaires, while effectiveness was measured using pretest and posttest assessments of students' critical thinking skills.

The final stage was Disseminate. At this stage, the validated and revised e-module was disseminated on a limited scale to science teachers at MTsN 4 Gunungkidul. The dissemination process aimed to introduce the developed e-module as an alternative learning resource for biotechnology learning and to provide teachers with information regarding its implementation in science learning activities.

### Location and Time of the Study

The research and development activities were carried out at MTsN 4 Gunungkidul, situated on Jl. Kyai Legi, RT.07/RW.04, Bansari, Kepek, Wonosari, Gunungkidul Regency, Special Region of Yogyakarta. The study took place in May, within the second semester of the academic year 2022/2023.

### Subjects and Trial Objects

The subjects for testing this developed product were 28 students from class VIII A at MTsN 4 Gunungkidul, selected using purposive sampling technique. The object of the study was the science e-module based on STEM integrated ethnosience used as a teaching material to enhance the critical thinking skills of students at MTsN 4 Gunungkidul.

### Trial Design

The product trial was conducted on a limited scale using a before-after experimental design with the following trial design.

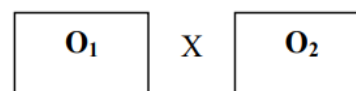


Figure 1. Experimental design (before-after) (Sugiyono, 2013: 303)

The limited trial employed a one-group pretest-posttest design (before-after design). In this design, students were given a pretest (O<sub>1</sub>) to measure their initial critical thinking skills before using the STEM-integrated ethnosience e-module. Subsequently, the students participated in learning activities using the developed e-module as the treatment (X). After the implementation, a posttest (O<sub>2</sub>) was administered to measure changes in students' critical thinking skills. The difference between pretest and posttest scores was used to determine the effectiveness of the developed e-module in enhancing students' critical thinking skills.

### Data Collection Instrument

The research instrument used to obtain a science e-module based on STEM integrated ethnosience as appropriate teaching material to enhance students' critical thinking skills is the e-module validation sheet instrument used to obtain e-module feasibility value data from material experts and media experts, sheet student response questionnaires used to determine student responses to e-module products, as well as critical thinking ability test questions (pretest and posttest) to obtain data on students' critical thinking abilities before and after using e-modules so that their effectiveness in enhancing abilities can be determined. students' critical thinking.

### Data analysis technique

Using the quantitative analysis approach, media and real estate specialists examine the quantitative data from the e-module validation form, and the results are adjusted according to the following scale.

**Table 1.** Conversion of four-point scale scores

Score Interval	Category
$(\bar{X}_i + 1.5 S_{bi}) < X \leq (\bar{X}_i + 3S_{bi})$	Highly feasible
$(\bar{X}_i) - < X \leq (\bar{X}_i + 1.5 S_{bi})$	Feasible
$(\bar{X}_i - 1.5 S_{bi}) < X \leq (\bar{X}_i)$	Moderately feasible
$(\bar{X}_i - 3 S_{bi}) < X \leq (\bar{X}_i + 1.5 S_{bi})$	Less feasible

Data obtained from the student response questionnaires were used to evaluate the practicality of the developed e-module because students were the primary users of the product. The questionnaire assessed several practicality indicators, including ease of use, readability, attractiveness, accessibility, and usefulness in supporting learning activities. Through direct experience in using the e-module during the limited trial, students were able to provide valid feedback regarding the practicality of the product.

**Table 2.** Conversion of five-point scale scores

Score Interval	Category
$X > (\bar{X}_i + 1.80 S_{bi})$	Highly practical
$(\bar{X}_i + 0.60 S_{bi}) < X \leq (\bar{X}_i + 1.80 S_{bi})$	Practical
$(\bar{X}_i - 0.60 S_{bi}) < X \leq (\bar{X}_i + 0.60 S_{bi})$	Moderately practical
$(\bar{X}_i - 1.80 S_{bi}) < X \leq (\bar{X}_i + 0.60 S_{bi})$	Not practical

The data obtained from the pretest and posttest critical thinking tests were analyzed using the following statistical procedures: normality test, paired sample t-test, and effect size analysis. A normality test is used to determine whether the data obtained in a study is normal or not. This test is done using SPSS software and Shapiro-Wilk test. In research analysis, data is considered as valid if it is based on a pattern and a center. According to (Rosana, 2016), the data is considered normal if the level of significance or Sig. value (2-tailed)  $\geq \frac{1}{2} \alpha$  (0.05) and considered not normal if Sig. value (2-tailed)  $< \frac{1}{2} \alpha$  (0.05), the value of  $\alpha$  is 0.05.

The paired sample t-test is used to test samples that receive the same treatment, and compare the proportions of these samples before and after treatment (Nuryadi et al., 2017). In this study, a paired t-test was conducted to determine the comparison of critical thinking skills before and after using the e-module. A paired sample t-test was conducted using IBM SPSS Statistics Version 25 to determine whether there was a significant difference in students' critical thinking skills before and after the implementation of the STEM-integrated ethnoscience e-module. The hypotheses tested were as follows:

H<sub>0</sub>: There is no significant difference between students' critical thinking scores before and after using the STEM-integrated ethnoscience e-module.

H<sub>1</sub>: There is a significant difference between students' critical thinking scores before and after using the STEM-integrated ethnoscience e-module.

The decision criteria were as follows: if the significance value (Sig. 2-tailed) was greater than or equal to 0.05, H<sub>0</sub> was accepted; if the significance value (Sig. 2-tailed) was less than 0.05, H<sub>0</sub> was rejected.

An effect size test is performed to determine the magnitude of the effect of the independent variable on the dependent variable. In this study, it is used to determine the effect of e-module integrated science STEM ethnoscience based on students' thinking skills. According to (Cohen et al., 2007), effect sizes can be calculated using this method.

$$d = \sqrt{\frac{(X1 - X2)}{Sp}}$$

Where:

- d : Effect size
- X1 : Mean score of the experimental group
- X2 : Mean score of the control group
- Sp : Pooled standard deviation

The results of the analysis are then converted into qualitative data using the following effect size criteria.

**Table 3.** Effect size criteria

Score Interval	Category
$> 1$	Strong
0.51 – 1.00	Moderate
0.21 - 0.50	Modest
0 - 0.20	Weak

## RESULTS AND DISCUSSION

### Product Development Result

The results of the product development research aim to determine the feasibility and effectiveness of the science e-module based on STEM integrated ethnoscience product for enhancing critical thinking skills, which is loaded on a website and accessed online through AnyFlip. The content developed in this product includes material for grade 9 on Competency Standards (KD) 3.7 and 4.7 about biotechnology, integrated with ethnoscience in the production of fermented cassava-based foods such as cassava tape, peuyeum, gatot, and growol. The science e-module based on STEM integrated ethnoscience format consists of cover pages, introductions, tables of contents, introductions, usage instructions, concept maps, analyses, STEM-related learning activities supported with images and YouTube links to help students understand the material. It includes worksheets with live worksheet links, allowing

students to work directly on the platform without the need for printed materials. The e-module also provides information related to ethnoscience about cassava-based fermented foods, such as cassava tape, peuyeum, gatot, and growol. Finally, the e-module concludes with summaries, evaluations containing HOTS multiple-choice questions to practice critical thinking abilities, and a list of references.

### Feasibility of Science e-Module Based on STEM Integrated Ethnoscience

The science e-module based on STEM integrated ethnoscience was evaluated for feasibility by validators, Drs. Allesius Maryanto, M.Pd., and Asri Widowati, M.Pd., who assessed the media and content. The content assessment included indicators such as material relevance, language usage, and presentation, adapted and synthesized from various sources. The validation results for the content of the e-module based on STEM integrated ethnoscience can be seen in Figure 2.

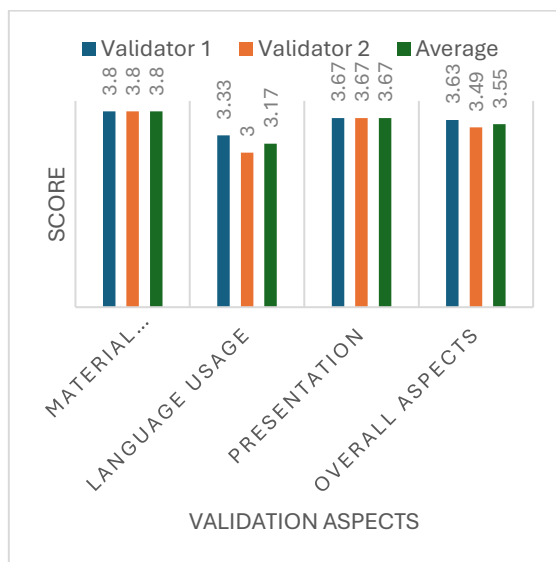


Figure 2. Validation results diagram of science e-module based on STEM integrated ethnoscience by subject matter expert

Based on the converted score scale of four, the content and presentation aspects were found to be very feasible, and the language aspect was feasible. Overall, the content of the science e-module can be categorized as highly feasible.

The assessment of the feasibility of the science e-module's media included aspects such as software, instructional design, and visual communication. The validation results for the science e-module based on STEM integrated ethnoscience can be seen in Figure 3.

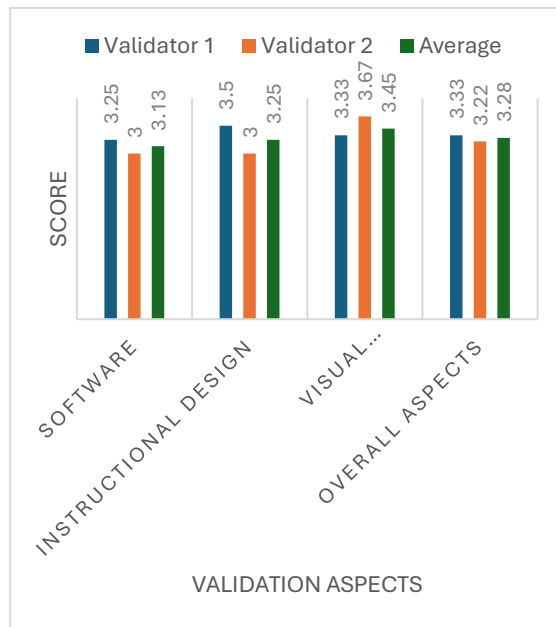
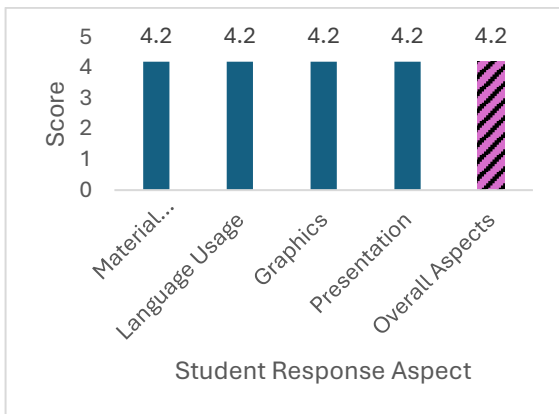


Figure 3. Validation results diagram of science e-module based on STEM integrated ethnoscience by media expert

Based on the reference for converting scores on a four-point scale, it can be noted that the aspects of software and instructional design are categorized as feasible, while the visual communication aspect is categorized as very feasible. Overall, the media in the science e-module based on STEM integrated ethnoscience can be categorized as highly feasible. The validators also provided suggestions and input used as the basis for product development to make it more suitable for use in learning. The science e-module based on STEM integrated ethnoscience that was developed also adheres to the criteria for good teaching materials according to (Magdalena et al., 2020), stating that good teaching materials have several criteria, namely being relevant to competency standards and basic competencies, having knowledge aspects, containing skill materials, motivating students to learn further, relating to previous material, beneficial for students, practical, and in line with the times.

### Practicality of Science e-Module Based on STEM Integrated Ethnoscience

The practicality of the e-module based on STEM integrated ethnoscience was assessed through a questionnaire measuring student responses. Students provided feedback on several aspects, including material relevance, language use, presentation, and graphics. The results of the students' responses to the e-module are presented in the Figure 4.

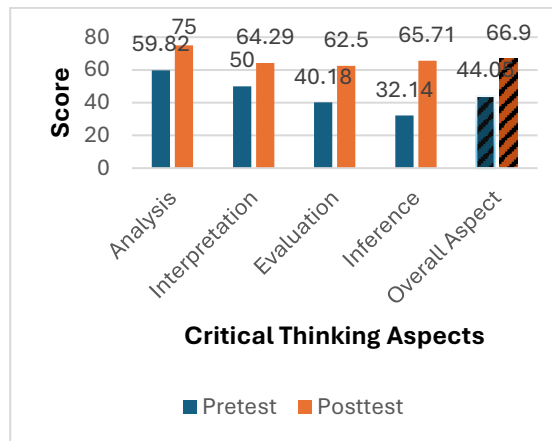


**Figure 4.** Student responses to science e-module based on STEM integrated ethnoscience

The average scores of students' responses were then converted based on the assessment criteria using a 5-point scale, as shown in Table 2. The overall student response score was 4.2, indicating that the developed e-module falls within the practical category.

#### Effectiveness of Science e-Module Based on STEM Integrated Ethnoscience

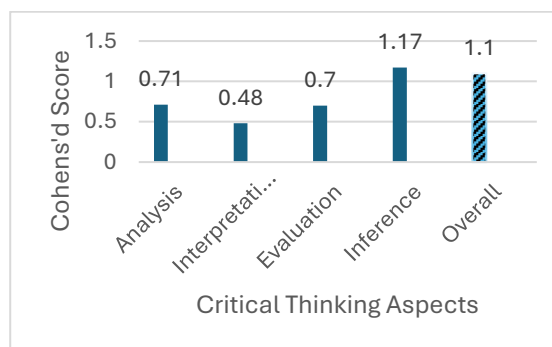
Critical thinking ability is one of the High-Order Thinking Skills (HOTS) necessary for developing 21st-century skills (Rahardhian, 2022). Critical thinking involves skills such as skepticism, problem identification, analysis, decision-making, and scientific research (Syahrul et al., 2021). The effectiveness of the e-module based on STEM integrated ethnoscience in enhancing critical thinking skills was determined through the analysis of pretest and posttest scores. The pretest and posttest questions, totaling 15 multiple-choice questions, were adapted to assess critical thinking abilities, including aspects such as analysis, interpretation, evaluation, and inference, as per (A Facione, 2015). The results of students' pretest and posttest scores for each aspect of critical thinking can be seen in Figure 5.



**Figure 5.** Pretest and posttest results of critical thinking skills

The test data were first analyzed for normality using the Shapiro-Wilk test (Sugiyono, 2020). The significance values for the pretest and posttest scores were 0.203 and 0.073, respectively. These values were greater than  $\frac{1}{2} \alpha$ , where  $\alpha$  is 0.05, indicating that the pretest and posttest scores for critical thinking skills were normally distributed. After confirming the normal distribution, a paired sample t-test was conducted to compare students' critical thinking skills before and after using the Science e-Module based on STEM Integrated Ethnoscience (Rosana, 2016). The paired sample t-test result showed Asymp.Sig (2-tailed) of 0.000, which is less than  $\frac{1}{2} \alpha$ , with  $\alpha = 0.05$ . Thus,  $H_0$  was rejected, indicating a significant difference between pretest and posttest scores, supporting Nuryadi's explanation that a rejection of  $H_0$  indicates a difference between scores before and after treatment (Nuryadi et al., 2017).

An effect size analysis was carried out to evaluate the impact of the science e-Module based on STEM integrated ethnoscience on students' critical thinking abilities after it was established that there was a difference in the critical thinking abilities of the students before and after using the module. The following graph displays the effect size analysis results.



**Figure 6.** Effect size analysis diagram

Referring to the diagram and interpretation, it is clear that the impact ranges from strongest to weakest in the following sequence: inference, evaluation, analysis, and interpretation. Inference is the ability to deduce and conclude temporarily using logic based on acquired data (Rifqi Zahro & Faninda Novika Pertiwi, 2021). A Facione (2015) also explains that inference is the ability to identify elements needed to formulate hypotheses by considering relevant information and drawing conclusions. According to the diagram in Figure 21, the inference aspect received the highest effect size score, which is 1.17. This indicates that the use of science e-module based on STEM integrated ethnosience strongly influences the enhancement of students' ability to draw conclusions based on hypotheses derived from relevant information. This aligns with the research framework, emphasizing that the inference aspect has the most significant impact compared to other aspects. Activities in the e-Module, such as observation and automatic data collection, encourage students to infer the data they obtain and draw conclusions. This finding is supported by the study conducted by Ritonga & Zulkarnain (2021), which states that STEM facilitates students in making accurate and relevant conclusions while explaining the reasons for their conclusions.

The effect size score for the analysis aspect is 0.71. Analysis, according to A Facione (2015), is the ability to identify statements, concepts based on reasons, experiences, beliefs, decisions, information, and opinions. Following the criteria for effect size in Table 3, the score of 0.71 falls into the moderate category. Thus, it can be said that the use of science e-module based on STEM integrated ethnosience moderately affects students' ability to identify statements and concepts based on reasons, experiences, beliefs, decisions, information, and opinions. This is consistent with the research conducted by Sartika et al. (2022), which demonstrates that ethno-STEM-based science education, integrating local wisdom and STEM, effectively trains analytical thinking skills.

The effect size score for the evaluation aspect is 0.70. Evaluation is the ability to assess the accuracy of statements described regarding perceptions, experiences, and beliefs, using the true strength of logic (A Facione, 2015). The effect size value of 0.70 indicates that the use of science e-module based on STEM integrated ethnosience moderately influences students' ability to evaluate the accuracy of statements regarding perceptions, experiences, and beliefs. This aligns with the findings of Ritonga & Zulkarnain (2021), which state that through STEM, students can verify the truth of a statement by connecting whether the

context of the problem situation is appropriate or not.

The interpretation aspect got the lowest enhancement score with a score of 0.48. According to (A Facione, 2015), interpretation is the ability to comprehend and communicate the meaning of experiences, circumstances, facts, events, judgements, procedures, or criteria. Based on the test results diagrams, the average post-test scores of students in this aspect are not much different from the other aspects. The low effect size score on this aspect is due to the ethnosience principle as well as the STEM characteristics have the least influence on the critical thinking aspects of the pupils, as seen in the research thinking framework.

The initial abilities of the pupils are also higher than the other aspects, thus causing their influence to appear weaker. However, the scores obtained still show that the use of e-module IPA based on STEM integrated ethnosience has an influence on the interpretation ability of the students. Based on the effect size criteria in table 3, this value of 0.48 is in the category sufficient, so it can be said that use of the e-module IPA base STEM based integrated ethnosience is quite influential in enhancing the ability of students to comprehend and communicate the meaning of experiences, circumstances, facts, events, judgements, procedures, or criteria. This result is consistent with study by Ritonga & Zulkarnain (2021), which shows that students can offer additional explanations on meaning based on activities or experiments carried out through STEM-based learning.

The overall effect size analysis across all aspects yielded a value of 1.1. According to the criteria in Table 3, the use of science e-module based on STEM integrated ethnosience strongly influences the enhancement of students' critical thinking skills. Based on the collected data and analysis conducted, the science e-module based on STEM integrated ethnosience stands as a suitable, practical, and effective teaching material for enhancing students' critical thinking skills. The STEM aspects incorporated into the e-Module can enhance students' critical thinking abilities. This aligns with (Khoiriyah et al., 2018), findings that learning using the STEM approach, integrating its four components – Science, Technology, Engineering, and Mathematics – can generate mental activities that trigger students to think critically by demanding problem-solving, decision-making, analyzing assumptions, evaluating, and conducting investigations.

The integration of ethnosciences into the e-Module also helps train students' critical thinking skills. During the learning process, students ask questions related to ethnosciences under study,

encouraging other students to use their abilities to analyze, interpret, evaluate, and infer. This is consistent with (Sari et al., 2021) assertion that integrating ethnosciences into education can develop critical thinking skills, link science learning with community culture, and summarize knowledge information obtained.

The STEM and ethnosciences approaches mutually support each other to enhance students' critical thinking skills. STEM and ethnosciences are closely related to students' daily life issues, encouraging students to actively learn and train their critical thinking skills. This corresponds to Dwita & Susanah's (2020) explanation of STEM as an approach to solve real-life problems by involving creative thinking, critical thinking, and collaboration skills, creating students with 21st-century skills. It also aligns with Dinissjah et al., (2019) that ethnosciences-based learning can train critical thinking skills by linking learning to students' daily life experiences, encouraging students to actively participate in the learning process.

The overall effect size of 1.1 obtained in this study indicates a strong effect on students' critical thinking skills. Similar results have been reported in previous studies examining STEM-based learning (Khoiriyah et al., 2018) and ethnoscience-based learning (Sari et al., 2021). However, unlike previous studies, the present research integrates STEM and ethnoscience within a biotechnology context using local cassava fermentation practices as a learning resource. This contextual integration may explain the substantial improvement in students' critical thinking skills observed in this study.

## CONCLUSION AND SUGGESTION

### Conclusion

Based on the analysis of data and the discussions in this research, the following conclusions can be drawn: (1) The science e-module based on STEM integrated ethnoscience is highly feasible for use in science education, with a feasibility rating of 3.55 for the content and 3.28 for the media; (2) The science e-module based on STEM integrated ethnoscience is practical for use in science education, receiving a practicality rating of 4.2. (3) The STEM-integrated ethnoscience science e-module was effective in enhancing junior high school students' critical thinking skills. The average critical thinking score increased from 44.04 in the pretest to 66.90 in the posttest. The paired sample t-test showed a significance value of 0.000 ( $p < 0.05$ ), indicating a statistically significant difference between students' critical thinking scores before and after using the e-module. Furthermore, the effect size value of 1.1

indicated a strong effect of the developed e-module on students' critical thinking skills.

### Suggestion

Based on the conducted research, the following recommendations can be made by the researcher: (1) If smartphones are limited within the classroom, the use of computer laboratories or group-based learning can be considered as an alternative when using e-modules; (2) The development of a science e-module based on STEM integrated ethnoscience is encouraged because both the STEM components and ethnoscience are closely related to everyday life. They can motivate students to engage in various critical thinking processes when solving real-world problems.

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