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Development of STEM-Based E-Modules Integrated with Ethnoscience to Improve Creative Thinking Skills in Biotechnology Materials for Grade X Students

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Abstract

Creative thinking skills are part of the 21st century skills that need to be mastered and developed. Therefore, innovative teaching materials are needed that can help develop creative thinking skills. This development research aims to produce teaching materials in the form of STEM-based e-modules integrated with ethnoscience that are feasible, practical, and effective for students and teachers. The instruments used are needs analysis in the form of teacher interview guidelines and teacher and student needs questionnaires, material and media expert validation sheets, and practicality sheets. Then the effectiveness sheet in the form of pretest and post-test sheets. Based on the results of data analysis, media validation scored 99.2%, material validation results scored 88.23%, teacher response questionnaire results scored 98%, and student response questionnaire results scored 93.26%. The effectiveness assessment resulted in an average N-Gain score of 0.83 which is included in the highly criteria. Therefore, it can be concluded that this ethnoscience-integrated STEM-based e-module is feasible, practical, effective, and can facilitate the development of students' creative thinking skills.

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INTRODUCTION

In the 21st century, the world entered the digital era of the Industrial Revolution 4.0, where technology continues to develop rapidly and be updated (Saleem et al., 2024). This industrial revolution 4.0 requires human resources (HR) to have 21st century competencies in order to adapt and not be left behind. Education is the key to equipping learners with learning skills, innovation, technology utilization, and can work and survive by using life skills to survive and compete in the global world (Alhloul & Kiss, 2022). To face this challenge, learners need to be trained to have 21st century skills consisting of 4 indicators known as 4C, namely, Creative, Critical thinking, Communication, and Collaboration in order to solve complex problems (Muthmainnah et al., 2023). In facing the era of the industrial revolution 4.0, education is needed that can form creative, innovative, and competitive generations (Almazroa & Alotaibi, 2023).

One important aspect of 21st century competence is creative thinking. Guilford (1967) in his research entitled Creativity: Yesterday, today and tomorrow stated that creative thinking is a form of divergent thinking involving originality, flexibility, and fluency. It ranks above critical thinking, making it essential to be taught in schools (Nurjanah & Rifqiawati, 2023). However, creativity levels in Indonesia remain low. The Global Creativity Index by ranked Indonesia 87 out of 132 countries in aspects such as tolerance, talent, and technology in science, business, education, and health (Priyambodo et al., 2021) (Wastriani et al., 2024). This low ranking is believed to stem from an education system that prioritizes memorization and single-answer responses, limiting the development of creative thinking (Aprilina, 2024). Therefore, a learning approach is needed that can develop students' creative thinking skills so that they are better prepared to face global challenges.

One effective way to develop creative thinking is through STEM-based learning, which integrates Science, Technology, Engineering, and Mathematics to prepare students for 21st-century challenges (Barkatsas et al., 2019). found that STEM enhances creative thinking, including generating alternative solutions and designing innovative products. This approach allows students to apply knowledge to real-life problems using or creating technology (Adifta et al., 2022). According to Wang et al. (2022), a STEM learning that incorporates digital media has been shown to significantly improve student understanding. The effectiveness of this media lies in its ability to transform abstract concepts into concrete visualizations, while allowing students to conduct experiments directly.

In addition to the importance of STEM-based learning, integrating local culture into education also deserves attention. Indonesia's rich ethnic and cultural diversity is a valuable asset (Astawa, 2022). However, technological advances have led to diminishing appreciation of local culture, with the younger generation becoming more familiar with foreign cultures (Nenohai et al., 2022). Schools thus play a key role in fostering cultural appreciation, including in Biology learning. Unfortunately, cultural integration in Biology remains limited in terms of content and resources (Ihsan & Pahmi, 2022) To address this, the ethnoscience approach offers a way to connect local culture, indigenous knowledge, and modern science (Rozi et al., 2025). Based on the learning theory proposed by Vygotsky (1986)in his book Thought and Language, it is said that students first learn through their social environment, then internalize that knowledge, making it easier to understand and apply in daily life. By applying ethnoscience-based learning, students are expected to appreciate Indonesia's cultural heritage more and not forget it in the midst of advancing times.

Biotechnology material taught in class X SMA in the Merdeka curriculum emphasizes the process rather than the results, thus providing opportunities for students to explore their abilities through practicum activities (Schmidt & Müller, 2025). In addition, this material is closely related to everyday life because biotechnology products are often found around us. Therefore, a learning approach that connects indigenous knowledge with modern science can be applied in learning biotechnology (Pambudi et al., 2024).

In Biology learning, teaching materials are crucial for effectiveness. However, in one school in Medan, materials still rely heavily on printed textbooks. Many teachers use them as the sole resource, causing students to feel bored and unmotivated, which hinders learning efficiency. Research conducted by Widiantoro & Utami (2023) also showed that the use of printed books as the only source of learning tends to make students lose focus, get bored quickly, and affect their learning outcomes.

STEM-based E-modules have been developed by many previous researchers, but STEM-based E-modules integrated with Ethnoscience were only developed in Environmental Chemistry material, namely in research by (Al Idrus &

Rahmawati, 2024), Solution Material, namely in research by Fikrina et al. (2023), Substance and Change material in research by Wulandari et al. (2023), but no one has developed a STEM-based e-module Integrated with Ethnoscience on Biotechnology material. Previous research only developed STEM-integrated E-modules for biotechnology material, namely in research conducted by Muninggar & Ramli (2023).

Based on the analysis of the Biotechnology textbook used in one of the schools in Medan, several shortcomings were found that could affect the effectiveness of learning. For example, shallow explanation of key concepts like conventional vs. modern biotechnology, lack of contextualization with students' surroundings, and unengaging illustrations. Some QR codes were also inaccessible. Questionnaire and interview data show that available learning media are inadequate, and the dominant lecture method makes students passive and disengaged. Teachers observed low creative thinking abilities, evident from exam answers that tend to be rote-based and lack idea development.

To address these issues, the use of innovative learning media is essential. Media plays a vital role in enhancing student efficiency and comprehension (Melinda & Saputra, 2021). Effective media makes learning more engaging and easier to grasp. One such solution is the E-module, which improves Biotechnology learning through interactive features that boost motivation and understanding with appealing visualizations (Riza & Djunaidi, 2021)(Permana & Al., 2021).

Based on these problems, research on the development of STEAM-based E-modules on Biotechnology material is very relevant. This e-module is expected to be an interesting, interactive teaching material, and able to support students' creative thinking skills.

METHOD

The development method in this study uses a Research and Development (R&D) based approach developed by Thiagarajan et al. (1974) in his book entitled Instructional Development for Training Teachers of Exceptional Children. This approach is widely recognized in the field of instructional design for its systematic and structured procedures. The development model employed in this research is the 4-D model, which stands for Define, Design, Develop, and Disseminate. Each stage in the model plays a critical role in ensuring that the product developed in this case, a STEM-based e-module integrated with ethnoscience is valid, practical, and effective for use in learning activities. The Define stage involves identifying and analyzing needs and problems in the learning process. The Design stage focuses on planning and structuring the e-module content and layout. The Develop stage is used to create and refine the module through expert validation and trials. Finally, the Disseminate stage involves the broader implementation and distribution of the module. The detailed flow of the e-module development process based on this 4-D model is illustrated in Figure 1.

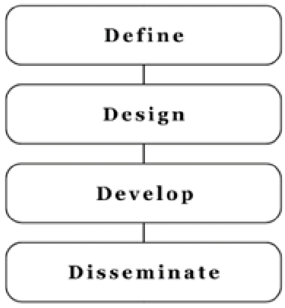


Figure 1. 4-D Model Design (Irmaningrum et al., 2023)

At the Define stage, researchers prepare data related to the research conducted, including making observations about learning activities at their school, analyzing the curriculum, characteristics of students, materials and objectives. Furthermore, at the Design stage, researchers compile and select media, in the form of selecting forms and simulating the presentation of material according to the media. The next stage is Development or development, at this stage the researcher has begun to develop the media that was previously designed, then validated by material experts and media material experts. Furthermore, at the last stage Disseminate, at this stage the researcher disseminates the media that has been previously validated and has been revised to a wider group so that it can be tested more broadly also regarding its effectiveness and practicality in improving the creative thinking skills of these students.

The subjects in this study were students of MA Laboratorium UINSU class X MIPA totaling 33 students who were taken randomly from each of the 3 classes. The data acquisition instrument of this research uses qualitative and quantitative data acquisition techniques. Qualitative data acquisition was carried out by means of interviews, as well as criticism and suggestions from validators. While the acquisition of quantitative data is obtained from the validator's questionnaire score from the validator, teacher and student response questionnaires, as well as pretest and posttest scores obtained from students to test the level of creative thinking skills of students. All data obtained previously will be analyzed and processed qualitatively and quantitatively. The score results of module validity and module practicality were analyzed using Formula 1.

$$\text{Percentage } (100\%) = \frac{Score\ obtained}{Maximum\ score} \times 100\%$$

Furthermore, the results of data analysis were interpreted with reference to the criteria listed in Table 1. and Table 2.

Table 1. Criteria for Validation Assessment Results

Percentage (%)	Assessment Criteria
80.00-100.00	Very Valid
60.00-79.99	Valid
50.00-59.99	Fairly Valid
00.00-49.99	Invalid

(Riduwan & Akdon, 2010)

To be considered valid, the developed educational module must achieve at least 60% validity according to expert ratings. Modules scoring within the 60.00–79.99% range are classified as Valid, while 80.00–100.00% represent Very Valid. These thresholds are supported by content validation literature, which emphasizes that a Content Validity Index (CVI) of around 0.60 (60%) or higher generally indicates acceptable content validity. Lower values (e.g., below 0.50 or 50%) are considered insufficient and require significant revision. This classification ensures that the module content accurately reflects its intended domain before further implementation.

Table 2. Criteria for Practicality Assessment

Percentage (%)	Assessment Criteria
81-100	Very Practical
61-80	Practical
41-60	Practical enough
21-40	Not Practical

(Riduwan & Akdon, 2010)

Referring to Table 2, an e-module is considered practical if it achieves a minimum score of 61%. Therefore, this threshold serves as the minimum standard for an e-module to be categorized as practically feasible for use in the learning process. Any score below this, particularly within the 41–60% range, would only classify the e-module as “practical enough,” indicating a need for improvement before effective implementation. The effectiveness of the critical thinking skills-based learning module was obtained using the N-Gain calculation in Formula 2.

$$\text{N} - \text{Gain} = \frac{Postest\ score - Pretest\ Score}{Maximum\ score - \text{Pretest}\ score} \times 100\%$$

The interpretation of the N Gain calculation results refers to Table 3.

Table 3. Criteria for N-Gain Results

N-Gain	Assessment Criteria
$g > 0.7$	High
$0.3 < g < 0.7$	Medium
$g < 0.3$	Low

(Nasution & Rasyidah, 2022)

Based on the N-Gain interpretation criteria proposed in Table 3., the effectiveness of an e-module in improving student learning outcomes is measured through the normalized gain (N-Gain) score. As shown in Table 3, the N-Gain score is categorized into three levels: high ($g > 0.7$), medium ($0.3 < g < 0.7$), and low ($g < 0.3$). To be considered effective, an e-module must result in a minimum N-Gain score greater than 0.3, which corresponds to the medium category. This threshold indicates that students experienced a meaningful improvement in their understanding as a result of using the e-module. Therefore, any N-Gain score above 0.3 can be interpreted as evidence of the e-module’s educational effectiveness.

RESULT AND DISCUSSION

In this development research, a biotechnology e-module based on STEM Integrated Ethnoscience was produced which can be accessed using various electronic devices, such as smartphones, computers and laptops. This e-module was developed using the 4D development model which consists of 4 stages, including define, design, develop, and disseminate.

1. Define

The define stage is carried out by conducting five main stages, including front end analysis, student analysis, concept analysis, task analysis, and learning objectives analysis. This stage aims to recognize and define the needs during teaching and learning activities.

a. Front end analysis

At the front end stage, this analysis is carried out to analyze the background of the development research being carried out. At this stage, observations were made of the learning process in biology subjects at MA Laboratorium. This analysis was carried out using interview sheets and questionnaires to analyze the needs of teachers and students. In the observation results, it was found that at MA Laboratorium students are allowed to bring smartphones for learning purposes only. In addition, the curriculum used in class X is the independent curriculum, while in classes XI and XII still use the k13 curriculum. The teaching method applied by the teacher in class still uses the lecture method and the teaching materials at school still use textbooks. Furthermore, the teacher mentioned that students need to be accustomed to using digital teaching materials, such as e-modules.

b. Student analysis

Student analysis aims to understand the characteristics of students. The results of the student needs analysis questionnaire showed that students liked learning biology that was directly related to real-world experiences. In addition, students stated that they felt more bored with the learning methods that had been used by their teachers. The students also agreed that they needed interactive digital teaching materials such as e-modules to support their learning activities.

c. Concept analysis

Concept analysis aims to identify, define, and organize systematically the material to be developed in the STEM-based digital module Integrated Ethnoscience in biology learning. This analysis aims to compile learning objectives and important things that must be learned and prepare relevant material based on Learning Outcomes (CP). After the analysis, the material developed in the STEM-based e-module Integrated Ethnoscience is class X biotechnology material. The biotechnology material developed must be in accordance with CP (Learning Outcomes) 10.3, namely students have the ability to create solutions to problems of local, national or global issues related to understanding biological technology innovation, with Learning Objectives (TP), namely 1) Analyze the principles of conventional and modern biotechnology; 2) Analyze the processes that occur in conventional and modern biotechnology; 3) Analyze the role of biotechnology in various fields; 4) Predict the positive and negative impacts of biotechnology; 5) Analyze the concepts and processes that occur in tissue culture.

d. Task analysis

This analysis aims to see the appropriate activities to be carried out by students to achieve the Learning Objectives (TP) of the Learning Outcomes (CP) developed. This analysis is carried out by making questions that are in accordance with Learning Outcome (CP) 10.3, namely creating solutions to problems based on local, national or global issues related to understanding biological technology innovation. This task analysis was carried out by means of interviews which aimed to identify the main skills to be assessed and analyze them into additional skill sets. This analysis ensures a thorough review of the tasks in the learning materials. Based on the results of this task analysis, an overview of the tasks required in learning is obtained and in accordance with the standard of Learning Outcomes (CP) and Learning Objectives (TP).

e. Learning Objective Analysis

Analysis of learning objectives is carried out to change the results of task analysis and concept analysis into learning objectives. The results of determining learning objectives will be the basis for preparing materials, and evaluation questions on e-modules based on STEM Integrated ethnoscience biotechnology material. In this analysis, the learning objectives that will be achieved in the STEM-based e-module integrated with ethnoscience to improve students' creative thinking skills will be developed.

2. Design

In the design stage, an ethnoscience-integrated STEM-based e-module was designed. This stage aims to prepare teaching materials consisting of several components, including cover, preface, table of contents, Learning Outcomes (CP) and Learning Objectives (TP), concept map, material, STEM activities, exercise questions, answer keys, bibliography, glossary, and author biography. After that, at the next stage, the design of research tools in the form of expert validation sheets to assess the feasibility aspects of e-modules based on STEM integrated ethnoscience, designing teacher and student response instruments to determine the practicality of e-modules based on STEM integrated ethnoscience. At this stage, designing or planning the appearance of the e-module based on integrated STEM integrated ethnoscience is also carried out in the form of color combinations, image and video layouts, interesting info, and title frames using the Canva application. The next stage is to provide hyperlinks to each command button that has been determined. After everything has been completed, the next stage is to share the e-module link that has been designed in display mode and the ethnoscience integrated STEM-based e-module can be used and accessed online by students using various smart devices, such as smartphones, laptops, tablets, and PCs.

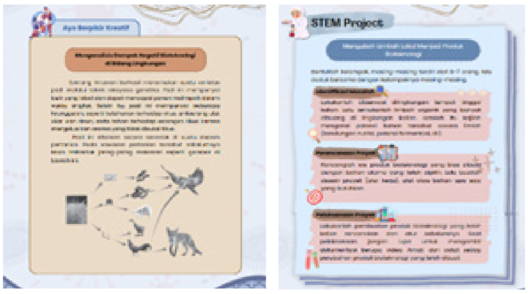
3. Development

This development stage aims to produce teaching material products that are being developed. The product content is compiled based on the results of the previously conducted define stage (Table 4.).

Table 4. Media Validation Results

No	Assessment Aspect	Score	Max Score	(%)	Criteria
1	View	25	25	100%	Very Valid
2	Ease of Use	20	20	100%	Very Valid
3	Module Aspects	79	80	98.75%	Very Valid
Total		124	125	99.2%	Very Valid

The e-module product developed is accompanied by relevant implementation examples in everyday life to provide in-depth understanding to students (Figure 2.).

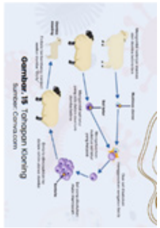
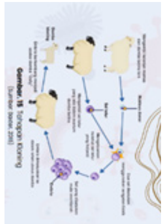


(a) (b)

Figure 2. Example of Implementation in the form of (a) discussion, (b) STEM project

At this stage, the validity of the e-module teaching materials being developed is carried out to media experts, material experts, and question experts. After that, a practicality trial was conducted by looking at student responses and teacher responses to the e-modules developed. This validation assessment is carried out to determine whether the e-modules developed are suitable for use or not. The results of media and material validation carried out can be seen in Tables 5 and Table 7.

Table 5. Revision Notes from Media Expert

Advice	Before	After
On the cover, the use of font variations cannot be more than 3 types.		
Try to use images that are high-resolution or not blurry		
Include an evaluation in each Activity (Chapter) of the module.		
Images related to the concept should use credible sources such as from books.		

In addition to the validation scores, qualitative feedback from media experts was also collected to improve the quality and effectiveness of the developed e-module. These suggestions were used to revise specific aspects of the e-module's content and presentation.

Table 6. Material Validation Results

No	Assessment Aspect	Score	Max Score	(%)	Criteria
1	Completeness of Material	8	10	80%	Very Valid
2	Appropriateness of Learning Objectives	4	5	80%	Very Valid
3	Breadth of Material	14	15	93.3%	Very Valid
4	Accuracy of Material	9	10	90%	Very Valid
5	Relevant Materials and Media	14	15	93.3%	Very Valid
6	Use of Language Rules	10	10	100%	Very Valid
7	The attractiveness of the packaged material	8	10	80%	Very Valid
8	Appropriateness of Material with Illustrations	8	10	80%	Very Valid
Total		75	85	88.23%	Very Valid

Table 7 outlines the feedback given by media experts, detailing the issues identified in the initial product and the corresponding improvements made after revision.

Table 7. Revision Notes from Media Experts

Advice	Before	After
Add activities to train students' creative thinking skills	The creative thinking activities in the developed product initially contained only 2 of them.	The creative thinking activities in the developed product have been added to a total of 5 activities
Try not to let in one page there is nothing that does not have illustrations	There are some pages with no illustrations at all.	Each page in the developed e-module has illustrations that match concept on page.

After being declared valid by both media experts and material experts, a small-scale trial was conducted by distributing questionnaires containing teacher and student responses to the ethnoscience-integrated STEM-based e-module teaching materials being developed. The results of the teacher and student response questionnaire to the ethnoscience-integrated STEM-based e-modules being developed can be seen in Table 8. and Table 9.

Table 8. Teacher Response Questionnaire Results

No	Assessment Aspect	Score	Max Score	(%)	Criteria
1	Interest	20	20	100%	Very Effective
2	Material	16	16	100%	Very Effective
3	Language	11	12	91.6%	Very Effective
Total		47	48	98%	Very Effective

The results from the teacher response questionnaire ini Table 8. indicate that the developed e-module was perceived as very effective across all assessed aspects. In terms of interest, the module received a perfect score, suggesting that it successfully captured teachers' attention and engagement. The material component also achieved the maximum score, indicating that the content was considered relevant, accurate, and suitable for the targeted curriculum. The language aspect, with a score of 91.6%, was also rated as very effective, showing that the language used in the module was clear and appropriate, although with slight room for improvement. Overall, the total percentage score of 98% confirms that the e-module is highly practical and usable from the teachers' perspective.

Table 9. Results of Student Response Questionnaire

No	Assessment Aspect	Score	Max Score	(%)	Criteria
1	Contents	966	1080	89.44%	Very Effective
2	Linguistics	679	720	94.3%	Very Effective
3	Graphics	929	960	96.77%	Very Effective
Total		2574	2760	93.26%	Very Effective

The analysis of student responses in Table 9. also reveals a highly positive evaluation of the e-module. The content aspect obtained a score of 89.44%, indicating that students found the material clear, informative, and engaging. The linguistics component received 94.3%, showing that the language used in the module was comprehensible and accessible to students. Meanwhile, the graphics aspect achieved the highest score of 96.77%, highlighting the effectiveness of visual elements in enhancing student understanding and interest. The overall percentage score of 93.26% reflects that the e-module is perceived by students as very effective in supporting their learning process.

The developed ethnoscience-integrated STEM-based e-module looks feasible to be used by students during the learning activity process while helping students in carrying out learning in the digital era. The high practicality of this module comes from various factors, including this ethnoscience-integrated STEM-based e-module is easy to access and use by teachers and students in the process of learning activities. This is in line with research conducted by Hamadi et al. (2022) which states that the practicality of teaching materials or learning media is seen in how easily teachers and students can use them in the learning process.

4. Disseminate

The product can be disseminated after making revisions to aspects of teaching materials, as well as making and testing teaching materials on a small scale. This product was previously tested at Madrasah Aliyah Laboratorium UINSU, precisely in class X IPA 2. This trial was conducted to evaluate its effectiveness.

Table 10. Effectiveness Test Data for N-Gain Results

Pretest	Posttest	N-Gain	Percentage	Criteria
36.66	89.83	0.83	83%	High

The results of the effectiveness test of this ethnoscience-integrated STEM-based e-module in Table 10 are proven through pretest-posttest analysis to measure students' creative thinking skills before and after product application. The results of the N-Gain calculation show that students' pretest scores are lower than their posttest scores, with an average N-Gain value of 0.83 with a high category. This proves that the STEM-based e-module integrated with ethnoscience has an influence on students' creative thinking skills. By using this ethnoscience-integrated STEM-based e-module, students can develop students' creative thinking skills. This finding is consistent with previous studies that emphasize the effectiveness of STEM-based learning combined with ethnoscience in enhancing students' creative thinking. Research conducted by Shim & Yoon (2024) highlights that integrating local cultural contexts into STEM learning not only enriches scientific understanding but also stimulates students' ability to generate innovative ideas and problem-solving strategies. Similarly, Kwon & Lee (2025) demonstrated that ethnoscience-based e-modules on science topics could significantly support the development of higher-order thinking skills, including creativity. The alignment between these studies and the current research reinforces the conclusion that embedding ethnoscience into STEM-oriented instructional materials is a pedagogically sound approach to foster creativity among learners, particularly in biology education.

The STEM syntax contained in this e-module can encourage students to learn actively, work in teams to solve real problems collaboratively and systematically, and can build creative thinking skills (Sari et al., 2022). With practicum activities to solve environmental problems that occur around, it can encourage students to make observations, formulate problems that occur, analyze findings, so that they can design prototypes or simple practicum models that can be done to produce solutions to problems that occur in the environment and by considering cultural values and local wisdom. This whole process equips students to develop collaborative skills, problem solving, and critical and creative thinking that are very relevant to the demands of 21st century learning (Hallström et al., 2023).

The effectiveness shown from the pretest and posttest results or before and after the application of the ethnoscience integrated STEM-based e-module shows that this product can be a means of learning in the classroom because using ethnoscience integrated STEM-based e-modules makes students more active, improves creative thinking skills and indirectly also improves collaboration skills between students as well as in solving a problem and creating solutions to the problem. In addition, by connecting learning with local culture, it can make it easier for students to understand learning because it is connected to their daily lives, and can instill a sense of love for local culture. This is in line with research by Widowati & Wakid (2024) which reveals that by linking STEM with ethnoscience, it can encourage students to design simple technological solutions inspired by traditional practices, or conduct experiments based on local materials. So that this combination can strengthen concept understanding, hone creative thinking skills, and foster appreciation for local culture. However, this teaching material still has limitations, such as the limitations of learning activities contained in e-modules that still require third-party applications in each activity such as youtube to watch videos, gform to access evaluations, and wordwall for quizzes, besides that this ethnoscience-integrated STEM-based e-module is also limited to biotechnology material only, so the researcher's suggestion for further research can expand the scope of other biology materials in the development of this ethnoscience-integrated STEM-based e-module.

Considering the promising results of this study, it is recommended that future research explore the development of STEM-based e-modules integrated with ethnoscience for other biology topics beyond biotechnology, such as genetics, ecology, or human physiology. Expanding the scope of materials would provide a broader understanding of the e-module's applicability and effectiveness across diverse scientific content. Furthermore, future studies could involve larger and more varied student populations to examine the module's impact on different learner characteristics and educational settings. Researchers are also encouraged to incorporate longitudinal approaches to investigate the sustained effects of the e-module on students' creative thinking skills and cultural awareness over time. Integrating additional digital features, such as augmented reality or interactive simulations, may further enhance student engagement and deepen conceptual understanding in future module iterations.

CONCLUSION

The development of STEM-based e-modules integrated with ethnoscience on biotechnology material for class X students produces teaching materials called electronic modules that combine STEM and ethnoscience methods that can be accessed using various electronic devices such as smartphones, tablets, laptops, and PCs with various search applications. Before this teaching material is disseminated, a validity test process must be carried out, and a practicality test. The results of media validation obtained a score of 99.2% with very valid criteria. The material validation results obtained a score of 88.23% with very valid criteria. In the practicality test, the results of the teacher response questionnaire were 98% which was included in the very practical category, while the results of the student response questionnaire from 30 students obtained a score of 93.26% which was included in the very practical criteria. After the validity and practicality tests were carried out, it was continued with the N-Gain test which was seen from the results of the pretest and post-test conducted by students. The results of the N-Gain findings obtained a score of 0.83 which is included in the highly effective category. So that overall it can be concluded that the developed ethnoscience-integrated STEM-based e-module is feasible to use and has the potential to improve students' creative thinking skills.

REFERENCES

Adifta, E. D., Murni, A., & Roza, Y. (2022). Desain Perangkat Pembelajaran Daring Menggunakan Model Problem Based Learning Dengan Pendekatan STEAM Pada Materi Barisan Dan Deret. *PRISMA, Prosiding Seminar Nasional Matematika*, 5, 98–105. https://journal.unnes.ac.id/sju/prisma/article/view/54346

Al Idrus, S. W., & Rahmawati, R. (2024). Efektivitas E-Modul Kimia Lingkungan Berbasis Etnosains Terintegrasi Stem Untuk Meningkatkan Keterampilan Berpikir Kritis Dan Literasi Lingkungan. *Jurnal Pendidikan, Sains, Geologi, Dan Geofisika (Geoscienceed Journal)*, 5(4), 1039–1044. https://doi.org/10.29303/goescienceed.v5i4.637

Alhloul, A., & Kiss, E. (2022). Industry 4.0 as a challenge for the skills and competencies of the labor force: A bibliometric review and a survey. *Sci*, 4(3), 34. https://doi.org/10.3390/sci4030034

Almazroa, H., & Alotaibi, W. (2023). Teaching 21st century skills: Understanding the depth and width of the challenges to shape proactive teacher education programmes. *Sustainability*, 15(9), 7365. https://doi.org/10.3390/su15097365

Aprilina, F. N. A. (2024). Pengaruh Model Pembelajaran Project Based Learning Terhadap Keterampilan Berpikir Kreatif Peserta Didik. *Jurnal Pembelajaran, Bimbingan, Dan Pengelolaan Pendidikan*, 4(5), 4. https://doi.org/10.17977/um065.v4.i5.2024.4

Astawa, I. N. T. (2022). Keragaman budaya lokal dalam pembangunan karakter bangsa. *Pangkaja*. https://doi.org/10.25078/pjah.v25i1.985

Atmojo, S. E., Anggriani, M. D., Rahmawati, R. D., Skotnicka, M., Wardana, A. K., & Anindya, A. P. (2025). Bridging STEM and Culture: The Role of Ethnoscience in Developing Critical Thinking and Cultural Literacy. *Jurnal Pendidikan IPA Indonesia*, 14(2). https://doi.org/10.15294/jpii.v14i2.23505

Barkatsas, T., Carr, N., & Cooper, G. (2019). *STEM Education: An Emerging Field of Inquiry.* Brill Sense.

Fikrina, Q. A., Sudarmin, S., Sumarni, W., & Sumarti, S. S. (2023). Pengambangan E-Modul Kimia Larutan Terintegrasi Etno-STEAM Bahan Kajian Batik Pekalongan. *Chemistry In Education*, 12(1), 17–24. https://doi.org/10.15294/chemined.v12i1.59507

Guilford, J. P. (1967). Creativity: Yesterday, today and tomorrow. *The Journal of Creative Behavior*, 1(1), 3–14. https://doi.org/10.1002/j.2162-6057.1967.tb00002.x

Hallström, J., Norström, P., & Schönborn, K. J. (2023). Authentic STEM education through modelling: an international Delphi study. *International Journal of STEM Education*, 10(1). https://doi.org/10.1186/s40594-023-00453-4

Hamadi, M., El-Den, J., Azam, S., & Sriratanaviriyakul, N. (2022). Integrating social media as cooperative learning tool in higher education classrooms: An empirical study. *Journal of King Saud University-Computer and Information Sciences*, 34(6), 3722–3731. https://doi.org/10.1016/j.jksuci.2020.12.007

Ihsan, M. S., & Pahmi, M. Z. (2022). Development Of Etnoscience Based Interactive Science Module To Improve Student's Critical Thinking Ability. *Jurnal Inovasi Pendidikan Dan Sains*, 3(3), 83–88. https://doi.org/10.51673/jips.v3i3.1151

Irmaningrum, R. N., Zativalen, O., & MZ, A. S. A. (2023). The development of e-comics media based on the vark model to measure the understanding of elementary school students. *EduHumaniora | Jurnal Pendidikan Dasar Kampus Cibiru*, 15(1), 85–96. https://doi.org/10.17509/eh.v15i1.51780

Kwon, H., & Lee, Y. (2025). A meta-analysis of STEM project-based learning on creativity. *STEM Education*, 5(2), 275–290. https://doi.org/10.3934/steme.2025014

Listiyani, L. R., Wilujeng, I., Suyanto, S., & Pratama, D. H. (2025). EthnoSTEM-based Learning Tools: Connecting Cultural Heritage with STEM Education. International Electronic

Journal of Elementary Education, 17(4), 593–609. https://iejee.com/index.php/IEJEE/article/view/2428

Melinda, T., & Saputra, E. R. (2021). Canva sebagai media pembelajaran ipa materi perpindahan kalor di sekolah dasar. *JIPD (Jurnal Inovasi Pendidikan Dasar*), 5(2), 96–101. http://jurnal.unikastpaulus.ac.id/index.php/jipd/issue/view/84

Muninggar, S., & Ramli, M. (2023). The Effectiveness of Learning Progression-based Biotechnology STEM Module to Improve Metacognitive Skills. *Journal of Education Research and Evaluation*, 7(4), 684–691. https://doi.org/10.23887/jere.v7i4.67502

Muthmainnah, A., Pertiwi, A. D., & Rustini, T. (2023). Peran Guru Dalam Mengembangkan Keterampilan Abad 21 Siswa Sekolah Dasar. *Jurnal Ilmiah Wahana Pendidikan*, 9(4), 41–48. https://doi.org/10.5281/zenodo.7677116

Nasution, D. F., & Rasyidah, R. (2022). Development of problem based learning student worksheets on human digestive system materials to increase students learning outcome. *BIO-INOVED : Jurnal Biologi-Inovasi Pendidikan*, 4(2), 207–215. https://doi.org/10.20527/bino.v4i2.13489

Nenohai, J. A., Rahayu, S., & Dasna, I. W. (2022). Validity And Effectiveness Of Chemical Practicum E-Modules Of Various Applications With Ethnoscience Approach In Chemical Learning: Analysis Review. *Jurnal Pendidikan Kimia*, 14(2), 70–78.

Nurjanah, L. S., & Rifqiawati, I. (2023). Peran Komunitas Gerakan Mengajar Desa Terhadap Pendidikan Kecakapan Hidup Pada Sekolah Dasar Di Provinsi Banten. *Prosiding Seminar Nasional Pendidikan Non Formal,* 1. https://ejournal.untirta.ac.id/SNPNF/issue/view/1

Pambudi, E. S., Parno, Marsuki, M. F., Fardhani, I., Fitriyah, I. J., & Silfiyah, E. (2024). Improving creative thinking skill on biotechnology material through the effectiveness of project-based learning-STEM e-module provided with formative assessment. *International Conference on Current Issues in Education (ICCIE 2023),* 15(3), 246–252. https://doi.org/10.2991/978-2-38476-245-3_36

Permana, D. F., & Al., E. (2021). Development Of E-Module Of Teacher Professional Ethics Based On Team-Based Project With Onenote Office 365. *Dinamika Pendidikan*, 16(2). https://doi.org/10.15294/dp.v16i2.33017

Priyambodo, M., Probosari, R. M., & Indriyanti, N. Y. (2021). Hubungan Kepercayaan Diri Dan Adversity Quotient Dengan Keterampilan Berpikir Kreatif Siswa Kelas VIII Pada Materi Gerak Dan Gaya. *Phenomenon: Jurnal Pendidikan BuPA*, 11(2), 231–244. https://doi.org/10.21580/phen.2021.11.2.9544

Riduwan, & Akdon. (2010). *Rumus dan Data dalam Analisis Statistika*. CV. Alfabeta.

Riza, F., & Djunaidi. (2021). Pengembangan Modul Kimia Berbasis Kearifan Lokal Kota Semarang Pada Materi Larutan Asam Dan Basa. *JIPVA Jurnal Pendidik. IPA Veteran*, 4(1).

Rozi, F., Prawijaya, S., & Manurung, I. F. U. (2025). Development of science learning teaching materials based on ethnoscience. *Proceedings of the 6th International Conference on Innovation in Education, Science, and Culture (ICIESC 2024)*, 1–6. https://doi.org/10.4108/eai.17-9-2024.2352852

Saleem, S., Dhuey, E., White, L., & Perlman, M. (2024). Understanding 21st century skills needed in response to Industry 4.0: Exploring scholarly insights using bibliometric analysis. *Telematics and Informatics Reports*, 13, 100124. https://doi.org/10.1016/j.teler.2024.100124

Sari, M., Andra, D., Distrik, I. W., & Aleksandervic, K. S. (2022). Problem-based e-module integrated with stem and assisted by lms to foster creative thinking ability. *Indonesian Journal of Science and Mathematics Education,* 5(2), 224–237. https://doi.org/10.24042/ijsme.v5i2.13087

Schmidt, M., & Müller, J. (2025). Educational approaches to bioprocess engineering using DIY bioreactors for scientific literacy. *Education Sciences*, 15(3), 323. https://doi.org/10.3390/educsci15030323

Shim, J., & Yoon, S. A. (2024). Improving STEM education through resource activation: A study of culturally relevant teaching for critical data literacy in a high school science classroom. *Journal of Research in Science, Mathematics and Technology Education*, 7(SI). https://doi.org/10.31756/jrsmte.311SI

Sudirman, S., Sutikno, S., Indriyanti, D. R., Sumarni, W., & Rahayuningsi, M. (2025). Integration of Ethnoscience in Natural Science learning: Literacy Study. *Jurnal Penelitian Pendidikan IPA*, 11(6), 68–77. https://doi.org/10.29303/jppipa.v11i6.9980

Thiagarajan, S., Semmel, D. S., & Semmel, M. I. (1974). *Instructional Development for Training Teachers of Exceptional Children: A Sourcebook*. Indiana University.

Vygotsky, L. S. (1986). *Thought and language.* MIT Press.

Wang, L. H., Chen, B., & Hwang, G. J. (2022). Effects of digital game-based STEM education on students' learning achievement: A meta-analysis. *International Journal of STEM Education*, 9, 26. https://doi.org/10.1186/s40594-022-00344-0

Wastriani, E., Bhakti, Y. B., & Fatahillah, F. (2024). Pengaruh Model Pembelajaran Berbasis Proyek Terhadap Hasil Belajar Fisika Siswa. *Science: Jurnal Inovasi Pendidikan Matematika Dan Ipa,* 4(2), 147–153. https://doi.org/10.51878/science.v4i2.3021

Widiantoro, B., & Utami, M. P. (2023). Effectiveness of using digital media as a learning support media in elementary school. *Proceedings of the Fifth International Conference on Arts and Design Education (ICADE 2022)*, 75–80. https://doi.

org/10.2991/978-2-38476-100-5_14
Widowati, A., & Wakid, M. (2024). Integrating ethnoscience: Enhancing culture, technology, and sustainable economic development through design and education. *SHS Web of Conferences*, 197, 1003. https://doi.org/10.1051/shsconf/202419701003
Wulandari, S. I., Pamelasari, S. D., & Hardianti, R. D. (2023). Penggunaan E-Modul Berbasis Etnosains Materi Zat Dan Perubahannya Dalam Usaha Meningkatkan Kemampuan Berpikir Kritis Siswa Smp. *Proceeding Seminar Nasional IPA*. https://proceeding.unnes.ac.id/snipa/article/view/2294/1777