Research and Development in Education
(RaDEn)

UMM

Research Article

STEM-based ecology module development for differentiated learning in agroecosystem of junior high schools

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Citation: Hariyadi, S., Prihatin, J., & Mabsutsah, N. (2024). STEM-based ecology module development for differentiated learning in agroecosystem of junior high school. *Research and Development in Education (RaDEn)*, 4(2), 1002-1016. https://doi.org/10.22219/raden.v4i2.36314

Received: 12 September 2024
Revised: 9 October 2024
Accepted: 24 October 2024
Published: 7 November 2024

Abstract: The study aims to describe the development of an integrated STEM-based ecological module to improve creative thinking skills and learning outcomes in agroecosystems in differentiated learning. The research method is developing the Thiagarajan Four-D model with a one-group pretest-posttest design. Validation data were obtained from module validation, learning design, creative thinking skills rubric, and learning outcome test. Practicality is determined based on teacher and student responses, learning implementation, and readability tests. Effectiveness is determined based on the N-gain value of creative thinking skills and learning outcomes. The results of the study were very significant: the score of module validation was 90.21, the result of all practice indicators was 92.9, the N-gain effectiveness result of creative thinking skills was 0.86, and the N-gain result of learning outcomes was 0.92. In conclusion, the STEM-based ecological module in differentiated classes is valid, practical, and effective in improving creative thinking skills and learning outcomes.
Keywords: agroecosystem region; differentiated learning; ecology module; integrated STEM

1. Introduction

Student has various characteristic, and each student is different from one another in various factors (Hidayati et al., 2024; Kubat, 2018). Teachers should recognize this condition from the beginning and prepare themselves to overcome these differences, such as differences in competence, intelligence, characteristics, and others. These students also have different learning styles and academic abilities. Some may have visual learning styles, some auditory, and others kinesthetic. Regarding academic ability, some students may easily understand what the teacher explains, some may need more time to understand the material, and others may find it challenging to understand the material on their own and need help. If these differences are not properly addressed, it can have negative consequences for students, such as marginalization of students who are considered less capable, intensifying feelings of frustration, and alienation from the educational process (Kanellopoulou & Darra, 2022).

Differentiated learning is a didactic approach that can effectively meet the needs of diverse students. Hu (2024) notes that differentiated learning is a beneficial approach to addressing students' diverse learning needs, abilities, and interests to ensure that each student has the opportunity to make academic progress. Gheyssens et al (2023) state that differentiated learning has been promoted as a model to create more inclusive classrooms by addressing individual learning needs and maximizing learning opportunities. Whilst differentiated instruction was originally interpreted as a set of teaching practices, theories now consider differentiated instruction rather a pedagogical model with philosophical and practical components than the simple act of differentiating. Dosch and Zidon (2014) reported through a self-perception survey that differentiated learning was beneficial in creating a more engaging classroom atmosphere. In addition, Suwartiningsih (2021) research concluded that differentiated learning improved students' learning outcomes in science subjects, reaching 96.55%. However, like many instructional strategies and interventions, differentiated learning has challenges. One of the challenges in implementing differentiated learning is learning media. As Ekaningtiass et al (2023) expressed, a differentiated classroom requires learning media that aligns with students' learning styles.

A suitable learning media for different learning is a module. Learning modules are essential as a learning resource for students to understand learning materials better and help teachers deliver materials (Mustadi et al., 2019). Modules can provide opportunities for students to explore and build their knowledge according to the situation and social environment of students (Bupu et al., 2018). The type of module that can be aligned with differentiated learning is a module based on Integrated STEM. Integrated STEM is an attempt to combine Science, Technology, Engineering, and Mathemathics in an everyday problem-solving context. Real-world problems are significant in integrated STEM teaching (Roehrig et al., 2021).

Everyday science problems in Indonesia are very diverse because Indonesia is an agroecosystem country with large rice fields and plantations. This sizeable agricultural area can be a learning tool for students who attend schools in agroecosystem areas (Yulyatno et al., 2019). Problems in agroecosystem areas can be used as up-to-date cases in STEM learning.

STEM learning can also be applied to environment-based subjects such as ecology (Setiawan, 2019). Ecology involves learning the various non-linear processes that occur in an ecosystem. For students to understand ecosystems' complexity and processes, interdisciplinary teaching and learning strategies are essential. Crossing the four disciplines that makeup STEM education characterizes STEM learning as an interdisciplinary approach. This study suggests incorporating STEM learning to conduct lessons on dynamic ecosystems (Khozali & Karpudewan, 2020). Sirajudin et al (2021) argued that STEM learning effectively influences students' creative thinking ability compared to traditional studies. The creativity developed through STEM learning leads students to understand the content better and improves their ability and motivation to solve problems (Conradty & Bogner, 2020; Purwadi, 2021).

Several studies have shown that STEM-based modules outperform other modules in improving motivation (Utami et al., 2023), conceptual knowledge, higher-order thinking skills, and design project activities (Martaningsih et al., 2022); motivation and creative thinking skills (Fitriana & Dewi, 2024), problem-solving, higher order thinking skills, active learning, communication, and humanitarian skills (Othman et al., 2022). However, STEM-based modules that use differentiated learning must be developed because each student has a different learning style.

Differentiated learning is integral to providing equitable and effective STEM education (Haetami, 2023). When engaging in differentiated learning, students can actively explore their abilities through STEM learning, sharpen their skills, and build confidence. However, modules containing the application of differentiated learning in integrated STEM learning at the junior high school level are still limited. Therefore, this study aims to determine integrated STEM-based modules' validity, practicality, and effectiveness on creative thinking skills and student learning outcomes.

The contribution of this study to the literature and educational development is enhancing learning engagement by making complex ecological concepts accessible and engaging through hands-on activities and real-world applications. The designed modules also cater to various learning styles, abilities, and interests, ensuring all students benefit. This study adds to the growing literature on STEM education and differentiated learning by providing empirical data and practical insights that other researchers and educators can use to explore further and implement similar educational strategies.

2. Materials and Methods

2.1 Types of research

The design research used in this study was the One-Group Pretest-Posttest Design. The study assessed the module's validity, practicality, and effectiveness. Two experts and two users evaluated the validity of the module. The practicality of the instructional book was determined through readability tests, teacher and student responses, and lesson implementation observations. The module's effectiveness was measured through N-Gain of creative thinking skills and cognitive learning outcomes, including pretest and posttest scores. This study followed Thiagarajan's 4-D (Four-D) development research model, which consists of four steps: Define, Design, Develop, and Disseminate (Thiagarajan et al., 1974):

2.1.1 Define

The definition stage is an activity to analyze needs consisting of (i) Front-end analysis. Data obtained from a semi-open questionnaire to determine the needs of junior high school/MTs teachers; (ii) Student analysis (learner analysis) data was obtained from a semi-open questionnaire to find out the needs of junior high school students; (iii) Task analysis involves examining the learning outcomes in the ecology chapter of the independent curriculum. This curriculum serves as a benchmark for the expected knowledge and skills, guiding the analysis of the learning tasks; (iv) Concept analysis. The material to be taught in this activity is ecological; (v) Specifying instructional objectives. The flow of learning objectives is arranged based on learning outcomes on ecological materials and indicators of creative thinking skills.

2.1.2 Design

The design stages are development planning steps, namely: (i) Preparation of tests (Constructing criterion-referenced test), tests of learning outcomes and creative thinking skills in the form of pretest and posttest, which are prepared based on learning outcomes and learning objective; 2) Media selection, the media selected is the learning module; 3) Format selection, ecological material will be presented in the form of STEM integrated modules in differentiated classrooms and equipped with creative thinking skills worksheets; 4) Initial design, the researcher designs a module design with learning materials, processes, and products, as well as designs a learning evaluation tool.

2.1.3 Develop

At this stage, there are two parts, namely: 1) Expert appraisal, expert validation data is carried out by two lecturers of the Science Education study program at the Universitas Jember and two science teachers at the test school; 2) Field Testing (Developmental testing), in the form of limited scale and classroom scale trials carried out by carrying out learning using modules that have been developed, then students are asked to work on questions of indicators of creative thinking skills and learning outcomes. Next, students complete the Rumpang test and respond to the ecology module.

2.1.4 Disseminate

The dissemination stage consists of three activities: validation testing, packaging, diffusion, and adaptation. At the validation testing stage, the product is implemented on students. At the validating testing stage, it will be disseminated to several schools in Situbondo to determine the product's effectiveness and then revised. The last activity is packaging, which is printing the Ecology module. Then, the book will be disseminated so that it can be absorbed or understood by others and used (adopted) in their class

2.2 Subjects and Objects of Research

The research was conducted in the even semester of the 2022/2023 academic year. A limited-scale trial was conducted in class VII of SMP Ibrahimy 3 Sukorejo Situbondo. The dissemination stage was carried out in three schools: SMPN 1 Banyuputih (A) and SMPN 3 Banyuputih (B) in Situbondo and MTs Almarhamah (C) in Jember, which have coastal, rice field, and forest ecosystem environments.

2.3 Types and Sources of Data

The creative thinking skills test consists of 16 questions in one chapter, with indicators based on four aspects of PE Torrence's creative thinking: fluency, flexibility, originality, and elaboration. The cognitive learning outcomes were obtained from the pretest and posttest scores of four essay questions.

2.4 Data collection techniques

The instruments used in this research include observation and documentation. Observations were conducted systematically using observation guidelines and non-systematically without using instruments. Non-systematic observations were made to observe student and teacher activities implementing intracurricular learning using STEM. The documentation study included a collection of pretest and posttest scores on ecology material.

2.5 Data Analysis Technique

Quantitative data in pretest and posttest scores were analyzed using the Normalized Gain (N-Gain) Formula 1.

$$\text{N-Gain Index (G)} = \frac{\text{Average Posttest Score} - \text{Average Pretest Score}}{100 - \text{Average Pretest Score}} \quad (1)$$

After that, the data from the calculated Gain index was converted using the score acquisition category in Table 1 and Table 2.

Table 1. Category Gain Score

Score	Category
G≥0.7	High
0.3 ≤G<0.7	Medium
G<0.3	Low

(Source: Hake, 1999)

Table 2. Criteria for learning outcomes and students' creative thinking skills

No.	Interval	Category
1	0-20	Very less
2	21-40	Not enough
3	41-60	Enough
4	61- 80	Good
5	81- 100	Very Good

2.2 Research Subjects and Objects

Research subjects are parties related to those being researched (informants or sources) to obtain information related to research data which is a sample from a study. The subjects/respondents in this research were the principal, deputy principal for curriculum and four teachers at a Muhammadiyah junior high school in East Java.

Teacher respondents were selected using purposive sampling techniques (Sugiono, 2019) representing class VII and Class VIII. Meanwhile, the research object is the problem topic to be researched which is related to the research subject, namely in the form of characteristics related to the research subject. This research has research objects, including: Syntax and methods as well as Project-based Learning (PjBL) techniques and student competencies. PjBL syntax and methods and techniques: (1) Students make decisions about a framework, (2) There are problems or challenges posed to students, (3) Students design a process to determine solutions to the problems or challenges posed. (4) Students are collaboratively responsible for accessing and managing related information and solving problems by connecting to the real world and authentic issues. (5) The evaluation process is carried out continuously, (6) Students periodically reflect on the activities they have carried out, (7) The final product of the learning activity will be evaluated qualitatively, (9) Learning is carried out as tolerant of errors as possible. Student competencies are learning achievements, namely competencies and character that are reflected in the Pancasila Student Profile. This means that what is observed is knowledge, skills, and attitudes.

2.3 Data Types and Sources

The types of data used in this research are primary data and secondary data. Primary data consists of the results of interviews with school community data sources consisting of the principal, deputy curriculum 4 subject teachers, secondary data obtained from documentation studies of lesson plans, and assessment data.

2.4 Data collection technique

The instruments in this research include in-depth interviews, observation and documentation studies. Observations are carried out systematically using observation guidelines and non-systematic without using instruments. Non-systematic observation to observe student and teacher activities in implementing intracurricular learning using PjBL. The observation guide is used as a record of things that occur during the activity process, and then the results of the observation are interpreted

2.5 Data Analysis Techniques Data Analysis Techniques

The data that has been collected is then analyzed. Data analysis was carried out descriptively. The steps taken to analyze and interpret qualitative research data are, 1) preparing and organizing the data; 2) exploring and coding the database; 3) describing findings and forming themes; 4) representing and reporting findings; 5) interpreting the meaning of the findings; and 6) evaluate the accuracy of the findings.

3. Results

The Integrated STEM module product using Differentiated Learning can be seen in Figure 1.

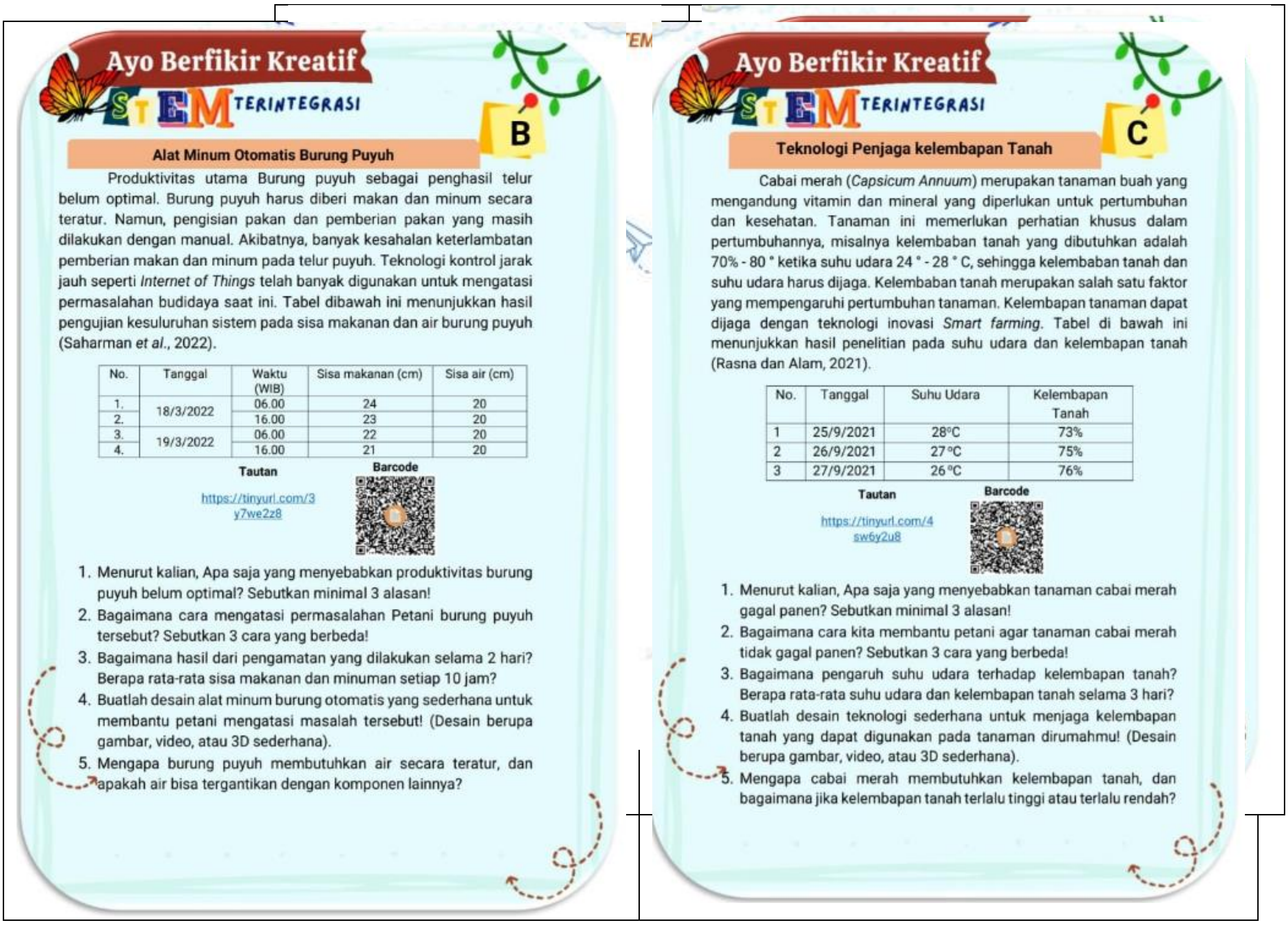

Figure 1. Integrated STEM Features using Content Differentiated Learning

The research results are presented in three sections, namely validation results, practicality test results, and effectiveness test results.

3.1 Validation Results

Validation was carried out by two expert lecturers, namely a Master of Science Education lecturer and an undergraduate lecturer in Biology Education, as well as two teachers. The validation results in data from various aspects by expert validators can be seen in Figure 2.

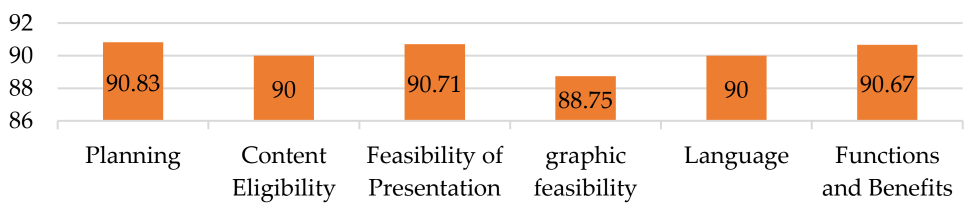

Figure 2. Ecology Module Validation Results

The average validation result for the differentiated STEM-based ecology module is 90.21, categorized as highly valid. Based on Figure 2, the module validation results from various aspects show that the graphic aspect has the lowest score compared to other aspects. Differentiated STEM modules are considered highly valid if revised according to the validator's suggestions. The validators' suggestions included clarifying image resolution, improving links, and barcoding. The highly valid criteria indicated that the module could be used in the experimental phase.

3.2 Practicality Test Results

The practicality test can be assessed based on teacher and student responses, observation of the implementation of the final instructional meeting, and readability test (Table 3).

Table 3. Classroom Scale Practicality Test

Practicality Test Variables	N	Value	Category
Teacher Response	5	96	Very practical
Student Response	32	92.6	Very practical
Implementation of learning last meeting		90.76	Very practical
Readability Test	32	91	Very practical
Average		92.59	Very practical

Thus, the ecology module is efficient and very easy to understand.

3.3 Effectiveness Test Results

The results of the effectiveness test of the STEM-based ecology module on student learning outcomes in four instructional meetings can be observed in Figure 3.

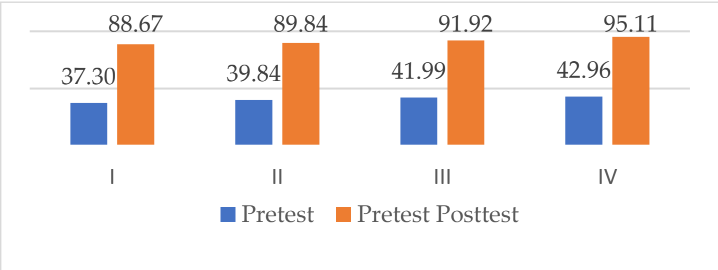

Figure 3. Pretest and Posttest Results of Student Learning Outcomes for Each Meeting

The results of the ecology module effectiveness test can be seen in Figure 3, which shows an increase in learning outcomes at each meeting. The N-gain results for each meeting were 0.81, 0.83, 0.86, and 0.92, categorized as high. The ecology module is very effective in improving learning outcomes. The results of the effectiveness test of creative thinking skills in each meeting are presented in Figure 4.

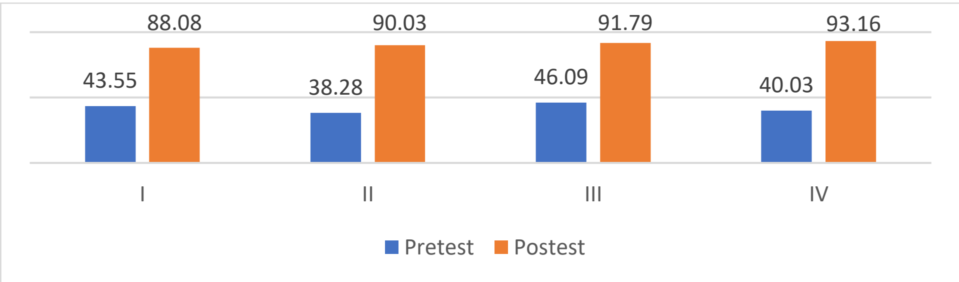

Figure 4. Results of pretest-posttest of creative thinking skills for each meeting

The results of the ecology module effectiveness test can be seen in Figure 4, showing an increase in the value of creative thinking skills in each meeting. The N-gain results for each meeting were 0.78, 0.83, 0.84, and 0.87, categorized as high. It can be concluded that the ecology module is very effective in improving students' creative thinking skills. The results of creative thinking skills for each indicator can be seen in Figure 5.

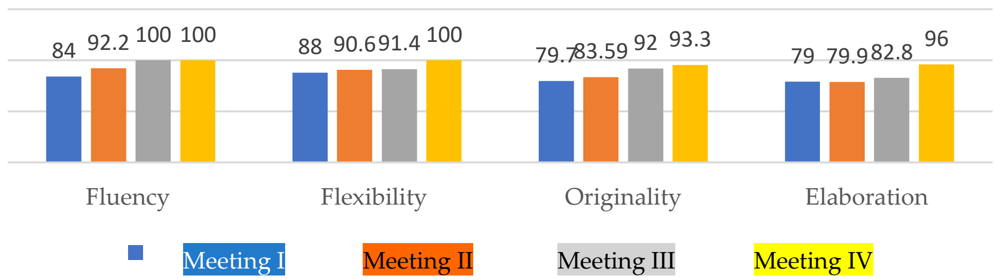

Figure 5. Results of Creative Thinking Skills Indicator

Based on Figure 5, it can be observed that each indicator of creative thinking ability has shown improvement in each meeting. Each indicator has increased more than or equal to 80. This indicates that the STEM-based ecology module in differentiated classes is effective and can be continued in the classroom scale trial.

3.4 Four-D Stage Result

3.4.1 Define

Based on the results of the define stage, data showed that 93.3% of teachers still use textbooks from the Ministry of Education and Culture, and the rest use modules. All respondents admitted that they had never used the STEM integrated module, and 88.9% had not used the differentiated module. As many as 40% of respondents stated that the learning outcomes of the ecology material were quite good, and 46.7% of students' creative thinking skills were categorized as sufficient in the ecology material.

3.4.2 Design

The module design is adjusted to 2 module principles, 4 STEM component components, and the principle of differentiating processes, content, and products. Images and text show a differentiated learning process to read the material's content, links, and barcodes to view video materials and activities such as exploring, making water cycles, and making plastic recycling. Differentiated content is short, regular, and enrichment reading materials. Differentiated products are making videos, images, and simple 3D media.

3.4.3 Develop

Validation was conducted by two experts, lecturers of Master of Science Education and Biology Education, and two teachers. The validation results in data by expert validators are as in Table 4.

Table 4. The validation results

Substance	Validator	Score	Criteria
Design	Validator 1	93.58	Very Valid
Content Feasibility	Validator 2	77.69	Valid
Presentation Feasibility	Practitioner 1	95.97	Very Valid
Graphic Feasibility	Practitioner 2	93.61	Very Valid
Language Feasibility			
Feasibility of Function and Benefits			
Average		90.21	Very Valid

3.4.4 Dissemination

The dissemination stage was carried out in 3 schools to know the practicality and effectiveness of the ecology module when applied to students with different cognitive abilities and environments (Figure 6).

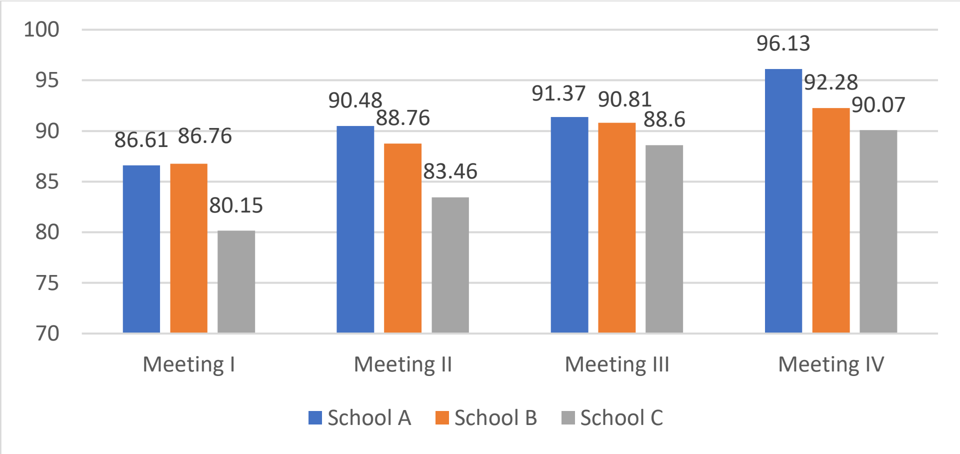

Figure 6. Student Learning Outcomes at 3 Different Schools

Based on Figure 6, the learning outcomes in the three schools were effective, as evidenced by the last fourth meeting in School A, School B, and School C, which were 96.13, 92.28, and 90.07, respectively. This indicates that the ecology module is highly effective in improving learning outcomes in the three deployment schools. Based on Figure 7, the creative thinking skills at the last meetings in Schools A, B, and C were 95.54, 93.38, and 91.54, respectively. This shows that the module is effective in various environments and different student cognitive.

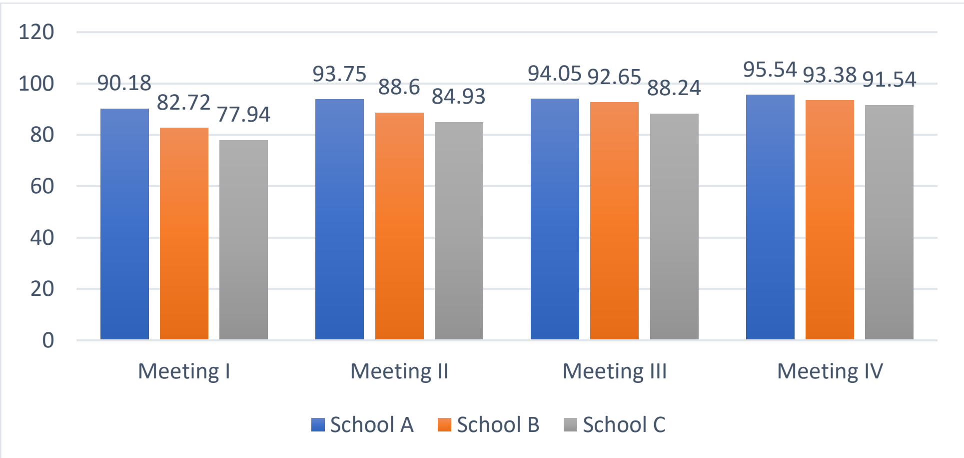

Figure 7. Students' Creative Thinking Skills in 3 Different Schools

4. Discussion

The learning outcomes assessment results were measured using N-gain to evaluate the effectiveness of the ecology module in improving learning outcomes. At each meeting, there was an increase from good to very good criteria in the limited scale test, class scale, and distribution of N-gain values. This is evidenced by the same N-gain value on a limited scale and class scale, which is 0.9 with high criteria. This shows that the ecology module effectively improves student learning outcomes in understanding ecological concepts.

The effectiveness of this module is attributed to its features that are aligned with students' learning styles, interests, talents, and abilities in the process and content of the module. This is in line with the opinion of Cromley and Chen (2024) that the importance of visual displays in instructional media, noting that well-designed visuals can improve comprehension and learning outcomes by making abstract concepts more concrete.. This is because it can make students enjoy reading books and increase motivation and enthusiasm for learning, allowing the material to be accepted and remembered by the student's brain for a long time.

All student needs in the module are met through different processes, such as the "Link and barcode" feature for students with audiovisual learning styles, allowing them to view and listen to the material through videos. The "activity" feature is for students with kinesthetic learning styles, allowing them to move their bodies to try out ecological concepts. The presence of pictures and readings in the module makes students with visual learning styles enjoy reading and seeing pictures of ecological concepts. The different process features make students happy because their needs are met. This happiness increases students' motivation, and the ecological material is more easily absorbed into their long-term memory, resulting in better learning outcomes. This finding aligns with AM's research (2023), which states that differentiated learning significantly improves student learning outcomes across various subjects, including science. The study highlights that differentiated instruction effectively creates inclusive and student-centered learning experiences. Differentiated learning integrated into modules improves learning outcomes, which showed that modules based on differentiated learning can improve student learning outcomes.

Another factor contributing to improved learning outcomes is the influence of motivation and interest in learning due to learners' freedom to choose how they usually learn. According to Kanellopoulou and Darra (2022), teachers' adaptation to students' learning styles, interests, and prior knowledge results in fulfilling all students' needs, leading to improved learning outcomes. Learning style becomes an essential aspect of student learning success as it relates to how students concentrate, process, internalize, and remember new academic information (Haryulinda et al., 2020).

This study grouped students based on similar interests and learning styles. Thus, they can achieve learning objectives through the same learning process. This is in line with the opinion of Kieu et al (2023), who stated that students with similar learning styles and potentials are grouped together to achieve learning objectives according to their learning styles and abilities. Students choose themes and products in the "let us think creatively, STEM integration" feature based on their experiences, backgrounds, and talents, improving students' cognitive abilities. In line with Moallemi (2024) opinion, learners' cognitive abilities also increase due to students' emotional and experiential involvement. Students are involved in selecting content, processes, and products that attract their attention. As a result, students are interested and motivated to exert every effort to improve their potential.

The integration of STEM into learning activities and learning material content also influences the improvement in learning outcomes. In STEM activities, students are required to think at a higher level to familiarize themselves with answering cognitive level questions 4, 5, and 6. Student learning outcomes are influenced by internal factors, such as when students think at a high level when given a problem, then analyze the problem, find ideas to solve the problem, design tools, make technology, and then test the tools. This is in line with the statement of Han et al (2021) that external factors, such as social and internal factors, such as motivation, can influence student outcomes in STEM learning. (Wahono et al., 2020) support that internal and external factors influence student learning outcomes in STEM learning. According to Dökme et al (2022), the increase in student knowledge is due to learning motivation resulting from practical STEM practice activities in the classroom. The second factor is the influence of the father's education level, receiving knowledge about STEM, and having role models working in STEM fields. Another factor in improving learning outcomes is the presence of learning media. According to Nuriyah et al (2020), the presence of STEM-based media can encourage and help students to think and innovate to solve everyday problems.

Research on creative thinking skills was measured using N-gain to assess the effectiveness of the ecology module in improving creative thinking skills. In limited scale and class scale testing, the N-gain value at each meeting increased from good to excellent. This is evidenced by the N-gain value at the first meeting, averaging 0.6 to 0.7 and then to 0.9 at the last meeting. This increase was due to the activities in the "Let us think creatively, STEM integration" feature in the module. STEM integration allows students to identify scientific problems in ecology, solve problems with techniques, design tools to solve problems, and calculate some measurements in ecological science. After students repeatedly engaged in these activities for four meetings, they became accustomed to creative thinking due to STEM integration. The findings of this study are consistent with the study of Han et al (2022), which stated that STEM-integrated modules can enhance individual and group student creativity. Group work and individual work did not differ significantly in the final designs produced regarding novelty, usability, and overall creativity.

Students can improve their creative thinking skills because of the four indicators underlying the STEM integrated worksheet: fluency, flexibility, originality, and elaboration. The fluency indicator asks students to mention several ecological problems fluently based on the problems in the "let us think creatively" feature. This is in line with Suherman and Vidákovich (2022) opinion that fluency refers to how individuals produce many responses to questions. In the Flexibility indicator, students were asked to mention several techniques to solve the problem differently. This is in line with Erdoğan and Yıldız (2021) statement that flexibility becomes a basic skill when comparing different perspectives and considering many ways or ideas to solve problems. It becomes an intermediate skill when individuals think about various meanings before deciding what makes more sense.

In the Elaboration indicator, students are asked to deepen the reasons accompanied by concepts in answering ecological problems. Meanwhile, students are asked to design tools to solve ecological problems in the Originality indicator. This is in line with Suherman and Vidákovich (2022) opinion that elaboration becomes an intermediate skill when individuals can provide more detailed explanations and then becomes an advanced skill when individuals carefully plan how to control variables. The elaboration score is also influenced by the father's parenting style and the cultural factors of the individual's home environment. On the other hand, originality refers to how individuals generate new, unusual, and distinctive ideas in a group and then create those ideas.

Creativity increased because the "Let us think creatively - Integrated STEM" feature effectively encouraged students to use their whole-brain skills to think at a higher level in solving problems. This aligns with Han et al (2022) that educators can emphasize the importance of creativity in their assessment rubrics by integrating STEM to give more weight to creative design activities, such as ideation and evaluation. According to Othman et al (2022), STEM elements and creative thinking skills need to work together to form new ideas. According to Duval et al (2023), creativity is also influenced by pedagogy in schools; children who experience modern teaching methods (not just lectures) have higher creativity than children influenced by traditional pedagogy. Children's creativity increases due to the formation of discussion groups and exploration in problem-solving.

STEM, combined with differentiated learning, such as asking students to create products to design tools in the form of drawings, simple 3D models, and videos on student worksheet instruments, can also improve students' creative thinking ability based on their talents, interests, and profiles. According to the research results, students prefer to create simple 3D products rather than drawings and videos. Making drawings requires techniques and talent that not all students can do. On the other hand, students who prefer to work without talking and express themselves when faced with difficulties in creating products are more likely to do so when creating videos. In each meeting, students did not use the same learning styles and products monotonously when creating STEM products. This is in line with the opinion of Balgan et al (2022) that one student can have more than one intelligence ability. Therefore, the different learning developed with the product learning outcomes allows students to achieve a common goal, regardless of the different processes to achieve that goal. Furthermore, according to Kamarulzaman et al (2022), differentiation in activities or practical activities can ensure that all groups of students from different backgrounds can maximize their potential by relying on their existing skills and talents. It also ensures that they all reach their full potential with creative ideas.

Implications of this study include improved learning outcomes as students tend to develop stronger problem-solving skills, critical thinking, and a deeper understanding of ecological concepts. This approach can lead to improved academic performance and greater interest in ecology. Moreover, differentiated learning ensures that educational content is accessible to students with diverse learning needs and abilities. This inclusivity can help reduce educational disparities and help all students reach their full potential. The development of this STEM-based ecology module can also serve as a model for curriculum innovation in other subjects and levels of education. It shows how interdisciplinary approaches can be effectively integrated into traditional subjects to enhance learning. The findings of this study can also inform educational policies and practices that encourage the implementation of STEM and differentiated learning strategies in other schools. The research result can lead to systemic changes that improve the overall quality of education.

5. Conclusion

The STEM ecology-based module for creative thinking skills and learning outcomes of junior high school students in the Merdeka curriculum was declared very valid, practical, and effective. STEM integration can improve students' creative thinking skills as they learn to solve ecological problems, explore various technologies to solve problems, design technologies, and integrate their ideas according to the concept. In addition, learning outcomes increase because the learning process is adjusted to each student's learning style, and the creation of integrated STEM products aligns with each student's talents or potential. Therefore, the integrated STEM-based ecology module is suitable for improving students' creative thinking skills and learning outcomes.

Authors Contribution: S. H.: the idea of research, methodology, check of data analysis, and final revision. J. P.: check of data analysis and revision. N. M.: conducting the research, field data collection, data analysis, and writing a draft article.

Conflict of Interest: The research was conducted independently, and the authors declare no conflict of interest in relation to the findings presented.

Acknowledgments: This journal article was written based on research results funded by the Direktorat Riset, Teknologi, dan Pengabdian Kepada Masyarakat (DRPTM) with Master Contract Number 127/E5/PG.02.00.PL/2023 dated 19 June 2023, and Derivative Contract Number 5455/UN25 .3.1/LT/2023 dated 20 June 2023.

6. References

Balgan, A., Renchin, T., & Ojgoosh, K. (2022). An experiment in applying differentiated instruction in STEAM disciplines. *Eurasian Journal of Educational Research.* https://doi.org/10.14689/ejer.2022.98.02.

Bupu, S., Rukayah, R., & Subiyantoro, S. (2018). Influence of writing poetry module using in contextual learning to writing poetry learning result of elementary student. *International Journal of Multicultural and Multireligious Understanding, 5*(2), 9. https://ijmmu.com/index.php/ijmmu/article/view/229.

Conradty, C., & Bogner, F. X. (2020). STEAM teaching professional development works: Effects on students' creativity and motivation. *Smart Learning Environments, 7*(1), 26. https://doi.org/10.1186/s40561-020-00132-9.

Cromley, J., & Chen, R. (2024). Instructional support for visual displays: An updated literature review. *Tech Know Learn 29,* 1191–1205. https://doi.org/10.1007/s10758-023-09699-x.

Dökme, İ., Açıksöz, A., & Koyunlu Ünlü, Z. (2022). Investigation of STEM fields motivation among female students in science education colleges. International *Journal of STEM Education, 9*(1), 8. https://doi.org/10.1186/s40594-022-00326-2.

Dosch, M., & Zidon, M. (2014). "The Course Fit Us": Differentiated instruction in the college classroom. *International Journal of STEM Education*, *9*(1), 1-14. https://files.eric.ed.gov/fulltext/EJ1060829.pdf.

Duval, P. E., Fornari, E., Décaillet, M., Ledoux, J., Beaty, R. E., & Denervaud, S. (2023). Creative thinking and brain network development in schoolchildren. *Developmental Science, 26*(6), e13389. https://doi.org/10.1111/desc.13389.

Ekaningtiass, P., Fitriani, H., Nurudin, M. N., & Akhodiyah, S. (2023). Pengembangan media pembelajaran berdiferensiasi berbasis teknologi pada materi teks prosedur untuk siswa kelas VII SMP. *Journal on Education, 6*(1), 841–847. https://doi.org/10.31004/joe.v6i1.3000.

Erdoğan, F., & Yıldız, F. (2021). Investigation of pre-service mathematics teachers' creative thinking tendencies. *International Online Journal of Education and Teaching (IOJET), 8*(4). 2297-2316. https://files.eric.ed.gov/fulltext/EJ1318733.pdf.

Fitriana, W. N. F. & Novi Ratna Dewi. (2024). The influence of e-module with the stem approach on students' motivation and creativity in SMP Negeri 10 Tegal. *PSEJ (Pancasakti Science Education Journal), 8*(2), 1–10. https://doi.org/10.24905/psej.v8i2.197.

Gheyssens, E., Griful-Freixent, J., & Struyven, K. (2023). Differentiated instruction as an approach to establish effective teaching in inclusive classrooms. In: Maulana, R., Helms-Lorenz, M., Klassen, R.M. (eds) Effective Teaching Around the World . Springer, Cham. https://doi.org/10.1007/978-3-031-31678-4_30.

Haetami, H. (2023). Effect of STEM-based differentiated learning to improve students' critical thinking skills: a meta-analysis study. *Jurnal Penelitian Pendidikan IPA, 9*(9), 655–663. https://doi.org/10.29303/jppipa.v9i9.5084.

Hake, R. R. (1999). Analyzing Change/Gain Scores. American Educational Research Association's Division D. https://web.physics.indiana.edu/sdi/AnalyzingChange-Gain.pdf..

Han, J., Kelley, T., & Knowles, J. G. (2021). Factors influencing student STEM learning: Self-efficacy and outcome expectancy, 21st century skills, and career awareness. *Journal for STEM Education Research, 4*(2), 117–137. https://doi.org/10.1007/s41979-021-00053-3.

Han, J., Park, D., Hua, M., & Childs, P. R. N. (2022). Is group work beneficial for producing creative designs in STEM design education? *International Journal of Technology and Design Education, 32*(5), 2801–2826. https://doi.org/10.1007/s10798-021-09709-y.

Haryulinda, A. Z., Prihatin, J., & Fikri, K. (2020). Development of brain-based learning model based on problem-based learning (BBL-PBL) to improve critical thinking and learning outcomes. *Bioedukasi: Jurnal Biologi dan Pembelajarannya, 18*(2), 69-79. DOI: 10.19184/bioedu.v18i2.17174.

Hidayati, S. A., Hariyadi, S., & Putra, P. D. A. (2024). Development of STEM-Based educational games as differentiated learning media to improve students' creative thinking skills. *Jurnal Paedagogy, 11*(1), 1. https://doi.org/10.33394/jp.v11i1.9589.

Hu, L. (2024). Utilization of differentiated instruction in K-12 classrooms: A systematic literature review (2000–2022). *Asia Pacific Educ, Rev 25,* 507–525. https://doi.org/10.1007/s12564-024-09931-y.

Kamarulzaman, M. H., Kamarudin, M. F., Sharif, M. S. A. M., Esrati, M. Z., Esrati, M. Z., & Yusof, R. (2022). Impact of differentiated instruction on the mathematical thinking processes of gifted and talented students. *Journal of Education and E-Learning Research, 9*(4), 269–277. https://doi.org/10.20448/jeelr.v9i4.425.

Kanellopoulou, E.-M., & Darra, M. (2022). Pedagogical differentiation in primary education: conceptual determinants and definitions. *International Education Studies, 15*(2), 138. https://doi.org/10.5539/ies.v15n2p138.

Khozali, N. B., & Karpudewan, M. (2020). An interdisciplinary facebook incorporated STEM education strategy in teaching and learning of dynamic ecosystems. *Eurasia Journal of Mathematics, Science and Technology Education, 16*(11), em1902. https://doi.org/10.29333/ejmste/8704.

Kieu, P.-T., Nguyen, C.-T., & Huy, D. T. N. (2023). Self-directed learning capacity by differentiated teaching – A case study of high school students. *Scholars Journal of Physics, Mathematics and Statistics, 10*(03), 87–96. https://doi.org/10.36347/sjpms.2023.v10i03.001.

Kubat, U. (2018). Identifying the individual differences among students during learning and teaching process by science teachers. *International Journal of Research in Education and Science,* 30–68. https://doi.org/10.21890/ijres.369746.

Martaningsih, S. T., Maryani, I., Prasetya, D. S., Prwanti, S., Sayekti, I. C., Aziz, N. A. A., & Siwayanan, P. (2022). STEM problem-based learning module: A solution to overcome elementary students' poor problem-solving skills. P*egem Jurnal Pendidikan dan Pengajaran, Vol. 12, No. 4* , 340-348. https://doi.org/10.47750/pegegog.12.04.35.

Moallemi, R. (2024). The relationship between differentiated instruction and learner levels of engagement at university. *Journal of Research in Innovative Teaching & Learning, 17*(1), 21–46. https://doi.org/10.1108/JRIT-07-2022-0041.

Mustadi, A., Murtiningsih, M., Lestari, D. P., & Amalia, E. (2019). Sociocultural based descriptive writing skill learning module for elementary school students. KnE Social Sciences. https://doi.org/10.18502/kss.v3i17.4646.

Nuriyah, D., Sutarto, & Prihatin, J. (2020). The development of environmental change textbook based on STEM-Cp to improve problem-solving skills in high school biology learning. Journal of Physics: Conference Series, 1563(1), 012054. https://doi.org/10.1088/1742-6596/1563/1/012054.

Othman, O., Iksan, Z. H., & Yasin, R. M. (2022). Creative teaching STEM module: High school students' perception. *European Journal of Educational Research, 11*(4), 2127–2137. https://doi.org/10.12973/eu-jer.11.4.2127.

Purwadi, P. (2021). Students' statistical literacy through lab school car model in STEM activity. *Journal of Physics: Conference Series. Journal of Physics: Conference Series,* 1957 012019. https://doi.org/doi:10.1088/1742-6596/1957/1/012019.

Roehrig, G. H., Dare, E. A., Ring-Whalen, E., & Wieselmann, J. R. (2021). Understanding coherence and integration in integrated STEM curriculum. *International Journal of STEM Education, 8*(1), 2. https://doi.org/10.1186/s40594-020-00259-8.

Setiawan, A. R. (2019). Assessment for ecological learning with scientific literacy oriented. *Assimilation: Indonesian Journal of Biology Education*, 2(2), 42-46. https://ejournal.upi.edu/index.php/asimilasi/article/view/19250/10212.

Sirajudin, N., Suratno, J., & Pamuti. (2021). Developing creativity through STEM education. *Journal of Physics: Conference Series, 1806*(1), 012211. https://doi.org/10.1088/1742-6596/1806/1/012211.

Sugiono, S. (2017). Metode Penelitian dan Pengembangan. Alfabeta.

Suherman, S., & Vidákovich, T. (2022). Assessment of mathematical creative thinking: A systematic review. *Thinking Skills and Creativity, 44,* 101019. 1-11. https://doi.org/10.1016/j.tsc.2022.101019

Suwartiningsih, S. (2021). Penerapan pembelajaran berdiferensiasi untuk meningkatkan hasil belajar siswa pada mata pelajaran IPA pokok bahasan tanah dan keberlangsungan kehidupan di kelas IXB semester genap SMPN 4 Monta Tahun Pelajaran 2020/2021. *Jurnal Pendidikan dan Pembelajaran Indonesia (JPPI), 1*(2), 80–94. https://doi.org/10.53299/jppi.v1i2.39.

Thiagarajan, S., Semmel, D., & Semmel, M. (1974). Instructional development for training teachers of exceptional children: A sourcebook. Bloomington, IN: Center for Innovation in Teaching the Handicapped, Indiana University.

Utami, A., Astuti, D. P., & Sandi, A. P. (2023). Outline, validity, readability, and response toward the layout, content, and utility aspects of a STEM-based Module. *Journal of Science Education Research*, 7(1), 55-67. DOI: 10.21831/jser.v7i1.51371.

Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. International Journal of STEM Education, 7(1), 36. https://doi.org/10.1186/s40594-020-00236-1.

Yulyatno, N. S., Prihatin, J., Fikri, K., & Kalimantan, J. (2019). Pengembangan model pembelajaran kolaboratif *send a-problem* berbasis BBL untuk pembelajaran IPA SMP di wilayah Agroekosistem. S*aintifika, 21*(1), 23-38. https://jurnal.unej.ac.id/index.php/STF/article/view/9787.