UNIVERSITAS SEBELAS MARET
BIOEDUKASI: JURNAL PENDIDIKAN BIOLOGI
https://jurnal.uns.ac.id/bioedukasi
1693-265X (Print) | 2549-0605 (Online)

Enhancing Scientific Creativity Through STEM-Based Flipbooks: A Study on Environmental Changes

Desylva Nikita Jasmine [1], Indri Yani [2], Desti Herawati [3]*
Biology Education Study Program, FKIP, Universitas Pakuan, Bogor, Indonesia
[1] nikitajasmine15@gmail.com; [2] indri@unpak.ac.id; [3]desti.herawati@unpak.ac.id
* Corresponding author: desti.herawati@unpak.ac.id

Submission	: 10/02/2025
Revision	: 29/04/2025
Accepted	: 31/07/2025

ABSTRACT

This study investigates the development and effectiveness of a STEM-based flipbook designed to enhance students' scientific creativity in biology, specifically focusing on environmental change topics. Scientific creativity is increasingly vital in addressing technological and societal challenges, prompting the integration of STEM elements into educational materials. The flipbook was developed using the ADDIE model, encompassing five stages: analysis, design, development, implementation, and evaluation. During the design stage, STEM components—science, technology, engineering, and mathematics—were embedded to support student engagement and understanding. The research involved 31 Grade X students and utilized pre-test and post-test assessments to measure the impact on scientific creativity skills. Data analysis was conducted using quantitative descriptive methods and SPSS software for statistical testing. Expert validation indicated excellent content and media quality (95% and 97.5%, respectively), affirming the flipbook's educational relevance. Results showed a significant improvement in students' scientific creativity, with average scores rising from 71.4 to 90.4 and an N-Gain of 0.44, categorized as moderate. The Wilcoxon test yielded a p-value of 0.001, indicating statistically significant improvement. Teacher and student responses were highly positive, with 100% and 85% satisfaction ratings, respectively. These findings suggest that STEM-based flipbooks can effectively enhance students' creative thinking and problem-solving skills in biology. The study concludes that interactive STEM-integrated materials are valuable tools for fostering 21st-century skills and recommends broader implementation in science education to improve learning outcomes and student engagement.

Keywords: Scientific, Creativity, STEM, Environmental changes

Introduction

In the 21st century, education is crucial in preparing high school students for the challenges and opportunities they will face in a rapidly evolving world. The educational landscape has shifted towards emphasizing the acquisition of 21st-century skills essential for students to thrive in the modern workforce. These skills encompass critical thinking, communication, collaboration, creativity, and technological literacy (Komari, 2024). Research indicates that STEM education, focusing on science, technology, engineering, and mathematics, is a valuable avenue for cultivating these skills among students (Xu & Zhou, 2022). STEM-based teaching materials have gained popularity due to their effectiveness in enhancing students' logical reasoning, problem-solving abilities, and collaborative skills, integral components of 21st-century learning (Nilyani et al., 2023), including scientific creative thinking.

The issue of scientific creative thinking in Indonesia, particularly within science education, has become a critical concern that requires attention and significant improvement. Scientific creativity, defined as the ability to express oneself innovatively, plays a vital role in shaping students' problem-solving abilities, especially when combined with the rapidly advancing world of technology. This relationship can profoundly affect academic performance and the development of essential skills in students (Park et al., 2020). Scientific creativity is also a key dimension of creative thinking, scientific knowledge, and the skills necessary for scientific research (Nursiwan & Hanri, 2023). However, various studies have highlighted challenges Indonesian students face in nurturing their creative thinking skills within scientific disciplines. For instance, Sumarni et al. (2020) found that 7th-grade students struggled significantly with creative thinking, stressing the importance of intervention strategies to enhance these skills. Similarly, Astawan (2023) explored how STEM-based learning can boost critical and creative thinking, indicating that innovative teaching methods are necessary to foster creativity. The 2013 curriculum, which aims to promote higher-order thinking skills, further reflects the systemic effort to improve critical and creative thinking in education (Utami et al., 2019). Despite these efforts, research conducted at a private high school in Bekasi City revealed that scientific creativity skills are still low and remain underdeveloped. According to teacher interviews, students show limited engagement in the learning process, with many perceiving environmental change topics as challenging to understand. The school still relies heavily on traditional, printed textbooks, which are often limited to basic biology content without stimulating students' creativity (Pujawan et al., 2022). Statistical data supports this concern, with a study by Daryanto (2021) revealing that over 60% of students in Indonesian high schools' struggle with integrating creative thinking into scientific learning, primarily due to outdated teaching materials and a lack of interactive learning strategies.

The limited implementation of STEM-PjBL (Project-Based Learning) in schools, which is only occasionally applied in projects like the growth of green bean seeds, further exacerbates the issue, leaving a gap in the development of students' scientific creativity skills (Mulyono, 2020). To address these challenges, researchers have proposed integrating modern teaching tools, such as STEM-based flipbooks, which have effectively enhanced student engagement and fostered creativity in the learning process (Tariq & Ali, 2022). The flipbook format, enriched with STEM features, offers an innovative approach allowing students to explore complex concepts like environmental changes interactively, promoting creativity and more profound understanding (Susanto et al., 2021). As such, there is a pressing need for educational reform to incorporate these digital, interactive resources into the learning environment better to support the development of scientific creativity in Indonesian students.

Methods

The method used in this study is the research and development method (Research and Development) using the ADDIE development model. This model consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation. In the first stage (Analysis), the researcher analyzes the learning process, learning media, methods, models, learning approaches,

assessment of biology learning outcomes, understanding of environmental change material, and students' creative thinking skills through observation, interviews, and surveys. In the second stage (Design), the researcher determines the flipbook design theme, designs the material's content according to learning outcomes, and determines the learning objectives in the environmental change material through discussions and literature studies. Furthermore, the researcher designs the material's content using Canva and Flipbook applications. In the third stage (Development), the product is continued to the validation stage by a team of experts to measure the feasibility level and provide suggestions and input from the validators of the material, media, and essay question instruments.

The validation process of the STEM-based flipbook involved two experts: one specializing in material validation and the other in media validation. These experts assessed the flipbook based on specific criteria, ensuring its educational quality and usability. The material validation expert focused on several key aspects: content feasibility, which assessed whether the educational content was accurate, relevant, and aligned with learning objectives; language feasibility, ensuring that the language used in the flipbook was clear, appropriate, and easily understood by students; and the presentation aspect, which evaluated how effectively the material was organized and presented to facilitate student comprehension. Furthermore, the expert also evaluated the aspect of independent learning, which examined how well the flipbook encouraged self-directed learning among students. On the other hand, the media validation expert evaluated aspects such as the aesthetic quality of the flipbook, its interactivity, and the usability of digital elements like animations and links. These experts used a Likert-scale instrument for scoring each aspect, where scores above 85% were considered highly valid, ensuring the reliability and relevance of the flipbook for educational use.

In the fourth stage, the flipbook was implemented in a class of 31 Grade X students in one of the private high schools in Bekasi City, over three meetings. The learning process utilized the STEM-based flipbook and the Project-Based Learning (PjBL) model, which was designed to foster active student engagement and creativity. An essay question instrument was developed to measure students' creativity, which consists of 7 questions according to the indicators of scientific creative thinking skills. The indicators of creative thinking skills measured include problem finding, product improvement, science imagination, science problem solving, and innovative product design. Data analysis techniques used in this study include quantitative descriptive analysis and statistical testing using SPSS software version 29.

The fifth stage involved distributing questionnaires to teachers and students to evaluate the effectiveness of the flipbook. The teacher questionnaire consisted of 10 items focusing on the efficacy of the flipbook in enhancing student engagement, its contribution to fostering scientific creativity, and its alignment with the curriculum. The student questionnaire, comprising 10 items, assessed their perceptions of the flipbook's ability to aid their understanding, its user-friendliness, and its impact on fostering independent learning and creativity. Additionally, essay questions were used to assess students' scientific creativity, with specific indicators such as problem-solving abilities, creative concept generation, and applying learned concepts to real-world scenarios.

The reliability and validity of the instruments were tested to ensure scientific rigor. For the questionnaires, reliability was assessed using Cronbach's alpha, with a threshold of 0.7 indicating acceptable reliability. The validity of the instruments was confirmed through expert reviews and a pilot test conducted with a small group of students and teachers before the main data collection. The expert validation and pilot testing results indicated that both the teacher and student questionnaires were valid and reliable for measuring the desired aspects of learning effectiveness. The essay tests were also validated through expert review, ensuring that the questions accurately measured the indicators of scientific creativity. This rigorous validation process guaranteed that the instruments used in the study were scientifically sound and capable of capturing meaningful data on the effectiveness of the

STEM-based flipbook in enhancing students' scientific creativity.

Results and Discussion

This research is a developmental research on STEM-based environmental change material in the form of a flipbook. The development of this flipbook aims to train and develop the creative thinking skills of grade X high school students. The development of a STEM-based flipbook goes through 5 stages, where the results are as follows: In the first stage (analysis), the results of interviews, observations, and surveys showed that students' scientific creativity skills were not trained enough by teachers during the learning process, teachers had not applied the STEM approach in biology learning so that students still had difficulty in developing ideas or concepts in real form. Another finding is that teachers and students generally use printed books provided by the school and learning methods often used conventionally with media in the form of visualization and audio-visual. In the second stage (design), environmental change material was developed by inserting 4 STEM (Science, Technology, Engineering, and Mathematics) features through the Canva application. Teaching materials are equipped with text, image visualizations, and video animations. Then, the digital book (e-book) design was converted using Heyzine software to look like a flipbook (Figure 1). Furthermore, the researcher developed a learning plan in the form of a teaching module and an evaluation instrument in the form of a pre-test and a post-test in the form of an essay to measure students' scientific creativity.

(a)

(b)

(c)

(d)

(e)

(f)

(g) (h) (i)

Figure 1. Sections in a STEM-based Flipbook on environmental change material (a) opening cover (b) closing cover (c) material content (d) bio-science features (e) bio- technology features (f) bio-engineering features (g) bio-mathematic features (h) student worksheets (i) STEM project sheets

In the third stage (development), the flipbook teaching media was validated by two experts, including a material validation expert and a media validation expert. The aspects used in this validation are the aspects of content feasibility, language feasibility, presentation, and independent learning. The results obtained from various validators were that the material validator scored 95% and the media validator 97.5%. This follows Arikunto (2020), who stated that a product or media can be suitable for use in learning if the percentage figure obtained from the results of respondents is a minimum of 61%. The following compares the percentage results of scores from several validators calculated using a Likert scale presented in Figure 2.

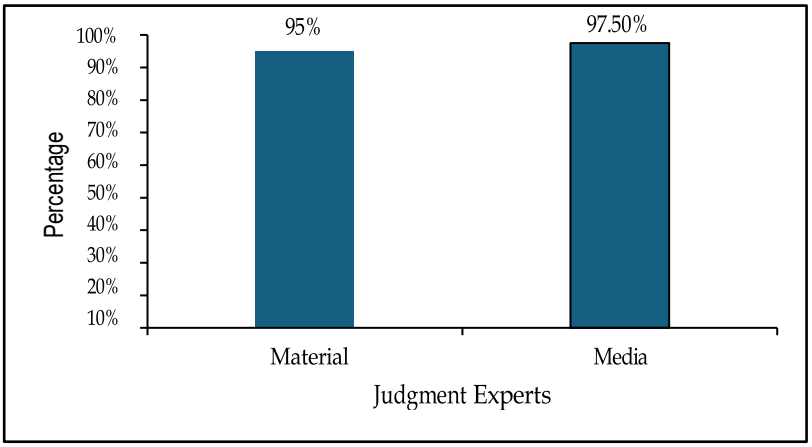

Figure 2. Tabulation of validation results

The bar chart from Figure 2 underscores the effectiveness of the flipbook in both content and media design. The high percentages (95% for material and 97.5% for media) from judgment experts suggest that the flipbook is a well-rounded educational tool capable of enhancing students' scientific creativity and understanding of environmental changes through the integrated use of STEM principles. The nature of teaching materials can be divided into four categories: skills, principles, concepts and facts seen from the content aspects such as the suitability of learning objectives, the suitability of the material with the indicators used, the clarity of the material description, the clarity of the material description, the accuracy of the animation displayed, the accuracy of the sequence of the material, examples of questions, and exercises do not confuse students.

In the fourth stage (implementation), STEM-based flipbooks were used in biology learning on Environmental Change material for three meetings with the Project-Based Learning model. This product trial was tested to determine how much influence the flipbook

media had on student learning, including student thinking skills, attractiveness, effectiveness, and efficiency in student learning. Before being given treatment in learning to measure scientific creativity skills, students carried out a pre-test activity. After being given treatment at the end of the meeting by carrying out the post-test activity, the results were calculated and accumulated using a statistical test, namely the first stage of the N-Gain calculation. The results of the N-Gain calculation in the pre-test and post-test of scientific creativity skills are as follows:

Table 1. N-Gain calculation results

Students Total	Average Score	N-Gain Score	Description
	Pre-test	Post-test	
31	71,4	90,4	0,44

Table 1 shows that STEM-based flipbooks significantly improved student performance (scientific creativity skills), with pre-test scores averaging 71.4 and post-test scores averaging 90.4. The N-Gain score of 0.44, categorized as medium, indicates that the intervention had a positive impact, but with room for improvement. While this score demonstrates a significant improvement in students' performance—confirmed by a Wilcoxon test with a p-value of 0.001, indicating statistical significance—it also signals that the flipbook's effectiveness may not be maximized. A moderate N-Gain suggests that the flipbook, while beneficial, could be further refined to achieve higher learning outcomes.

The moderate score could indicate several areas for improvement. Despite the positive feedback from both teachers and students, the flipbook's content and design might require additional interactive or engaging elements to stimulate student creativity further. Previous research by Astawan (2023) and Sari et al. (2020) has highlighted the potential for integrated STEM tools to foster higher-level critical and creative thinking when appropriately designed. Therefore, future iterations of the flipbook could explore incorporating more real-world applications, case studies, or deeper problem-solving activities to challenge students' creative thinking abilities further. Additionally, more frequent or extended use of the flipbook in classroom settings could boost the N-Gain score.

In this STEM-based flipbook, there are various features related to STEM (Science, Technology, Engineering, and Mathematics) to support students in practicing scientific creativity skills on environmental change material. The STEM feature presents case studies on the sub-materials contained in the flipbook. The first feature, namely the science feature, is conceptualized to invite students to use scientific knowledge in understanding the natural world and the ability to participate in making decisions in solving problems. Regarding its implementation, students are asked to analyze issues related to the loss of environmental balance. Mastery of the concept of science can provide students with a meaningful learning experience because it helps them achieve high-level thinking and solve ecological problems (Darmaji et al., 2019). Then, students are asked to share ideas/concepts in the feature containing questions. The second feature, technology, is conceptualized to invite students to develop a simple device that refers to current technology to solve water pollution and household waste. This feature instructs students to determine what simple devices will be developed to operate the project. Quality learning environments are pivotal in nurturing students' problem-solving abilities and fostering inquisitiveness and open-mindedness (Keinänen & Kairisto-Mertanen, 2019). By providing students with the freedom to think, inspiring learning spaces, and leveraging technology effectively, educational institutions can effectively cultivate innovation and creativity among students (Istiqomah, 2023).

The third feature, namely the engineering feature, is conceptualized with the aim that students can implement the device through the engineering or design process regarding the project to be created, as shown in Figure 9. This feature instructs students to design the project to be created using the help of predetermined device materials. Understanding engineering involves applying technology to solve problems and increase student creativity. The last stage is the mathematics feature, which is conceptualized with the aim of students analyzing,

formulating, and communicating solutions or efforts by connecting numeracy between numbers and numbers. Integrated STEM learning based on Project Based Learning (PjBL) adds evidence that design activities in learning can produce various innovative experimental designs. This study found that Project-based STEM can be an effective method for fostering creativity in students because students are encouraged to think critically and creatively when designing and carrying out a project (Sari et al., 2020). This further supports the idea that integrated learning by STEM based on PjBL can positively impact students' scientific creativity.

The fifth evaluation stage is the last stage of the ADDIE development model. At this stage, the teacher and student response questionnaires are filled out. Based on the results of the teacher response questionnaire containing statements regarding aspects of product use, learning content, and flipbook components, the student response questionnaire contains statements regarding aspects of learning content, design aspects, language aspects, independent learning aspects, and aspects of flipbook use. This shows that the teacher's response was 100%, so it is included in the outstanding category. Meanwhile, the student response showed a result of 85% and was included in the positive and excellent categories. The high percentage obtained stated that students agreed this flipbook could train scientific creativity skills. This can be proven by Astawan et al. (2023), who found that STEM-based flipbooks positively impact students' critical and creative thinking skills. The education process in the current information and communication technology era helps optimize learning by developing STEM-based digital teaching materials, especially on environmental change materials.

The STEM-based flipbook developed in this study, focusing on environmental changes, offers a valuable model that can be adapted for other biology topics or even interdisciplinary content. To expand its applicability, the flipbook format can be tailored to various biological themes such as human anatomy, ecosystems, genetics, or biodiversity, integrating STEM principles into each topic to foster scientific creativity and critical thinking. The interactive and multimedia elements embedded in the flipbook (animations, images, and video) can further enrich these adaptations, making abstract concepts more accessible and engaging. Teachers can customize the content to suit the curriculum of different biology topics or cross-disciplinary subjects, ensuring that learning is comprehensive and engaging. This flexibility in adapting the STEM-based flipbook model to various content areas suggests that it can be potent in fostering scientific creativity across various educational contexts, making learning more interactive, dynamic, and connected to real-world challenges.

Conclusion

Developing and applying the STEM-based flipbook on environmental change material significantly improved students' scientific creativity skills, as evidenced by the moderate N-Gain score of 0.44. This indicates that while the intervention showed promising results in enhancing students' creativity, there is still room for further refinement to achieve greater gains. The flipbook received high validation scores from both material and media experts, with ratings of 95% and 97.5%, respectively, confirming its high quality and educational value. Statistical tests, including the Wilcoxon test, also supported the significant impact of the flipbook on students' creativity, highlighting the effectiveness of the learning tool. Positive feedback from teachers (100%) and students (85%) further underscores the tool's ability to engage students and foster creative thinking.

For future research, it is recommended to explore the integration of additional STEM-based features or multimedia elements further to enhance the interactivity and engagement of the flipbook. Expanding the sample size and testing the flipbook in different educational contexts would provide more robust data on its effectiveness. Additionally, incorporating longer-term follow-up studies could help assess the sustainability of the improvements in scientific creativity over time. Furthermore, investigating the potential of flipbook-based learning in other scientific topics beyond environmental change would provide insights into

this educational tool's versatility and broader application. Ultimately, the continued development and refinement of STEM-based learning materials like flipbooks could play a crucial role in fostering the critical thinking and creative problem-solving skills necessary for students to thrive in the 21st century.

References

Arikunto, S. (2020). *Prosedur penelitian suatu pendekatan praktik*. Rineka Cipta.

Astawan, I. G. (2023). STEM-based scientific learning and its impact on students' critical and creative thinking skills: an empirical study. *Jurnal Pendidikan IPA Indonesia*, *12*(3), 482–492. https://doi.org/10.15294/jpii.v12i3.46882

Darmaji, D., Agus Kurniawan, D., & Irdianti, I. (2019). Physics education students' science process skills. *International Journal of Evaluation and Research in Education (IJERE)*, *8*(2), 293–298. https://doi.org/10.11591/ijere.v8i2.28646

Daryanto, M. (2021). The impact of teaching materials on creative thinking skills of indonesian students in high school. *Jurnal Pendidikan Indonesia*, *4*(2), 123-135.

Hee Park, S., Urn Choe, S., & Jong Kim, C. (n.d.). Elementary students' creativity appear in small group interactions during model-based classrooms on terraforming. *Journal of the Korean Association for Science Education Journal Homepage: www.Koreascience.org Journal of the Korean Association for Science Education*, *40*(6), 2020. https://doi.org/10.14697/jkase.2020.40.6.611

Istiqomah, N. (2023). Carving superior achievements through innovative strategies in implementing students' creativity. *Indonesian Journal of Educational Management, 5*(1), 12-25. DOI: https://doi.org/10.52627/managere.v5i1.287 .

Keinänen, M. M., & Kairisto-Mertanen, L. (2019). Researching learning environments and students' innovation competences. *Education and Training*, *61*(1), 17–30. https://doi.org/10.1108/ET-03-2018-0064

Komari, A. (2024). Differences in the implementation of physical education (Pe) planning containing 21st-century skills based on period of work and gender. *Retos*, *57*, 697–706. https://doi.org/10.47197/retos.v57.105895

Mulyono, A. (2020). The implementation of project-based learning in indonesian secondary schools. *Indonesian Journal of Education and Learning*, 8(1), 34-40

Nilyani, K., Asrizal, A., & Usmeldi, U. (2023). Effect of STEM integrated science learning on scientific literacy and critical thinking skills of students: A meta-analysis. *Jurnal Penelitian Pendidikan Ipa*, *9*(6), 65–72. https://doi.org/10.29303/jppipa.v9i6.2614

Nursiwan, W. A., & Hanri, C. (2023). Relationship between level of scientific creativity and scientific attitudes among prospective chemistry teachers. *International Journal of Evaluation and Research in Education (Ijere)*, *12*(1), 174. https://doi.org/10.11591/ijere.v12i1.22852

Pujawan, I. G. N., Rediani, N. N., Antara, I. G. W. S., Putri, N. N. C. A., & Bayu, G. W. (2022). Revised bloom taxonomy-oriented learning activities to develop scientific literacy and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 47–60. https://doi.org/10.15294/jpii.v11i1.34628

Sari, U., Duygu, E., Sen, O. F., Kirindi, T. (2020). The effects of STEM education on scientific process skills and STEM awareness in simulation-based inquiry learning environment. *Journal of Turkish Science Education*, *17*(3), 387-405. https://doi.org/10.36681/tused.2020.34

Sumarni, E., Setiandi, A. E., & Sunandar, A. (2020). Profile of conceptual photosynthesis and creative thinking: Study of 7th-grade students. *Biosfer*, *13*(2), 250–265. https://doi.org/10.21009/biosferjpb.v13n2.250-265

Susanto, H., Putra, E. F., & Yuliana, E. (2021). Enhancing students' creativity through flipbook learning media in science education. *Journal of Educational Innovation*, *12*(2), 44-55. https://doi.org/10.17509/jsl.v2i2.13271

Tariq, R., & Ali, M. (2022). Integrating STEM education with flipbook teaching materials for interactive learning. *International Journal of Educational Technology*, *8*(3), 232-239.

Utami, F. D., Nurkamto, J., & Marmanto, S. (2019). Higher-order thinking skills on test items designed by english teachers: A content analysis. *International Journal of Educational Research Review*, *4*, 756–765. https://doi.org/10.24331/ijere.629581

Xu, S.-R., & Zhou, S. (2022). The effect of students' attitude towards science, technology, engineering, and mathematics on 21st century learning skills: A structural equation model. *Journal of Baltic Science Education*, *21*(4), 706–719. https://doi.org/10.33225/jbse/22.21.706