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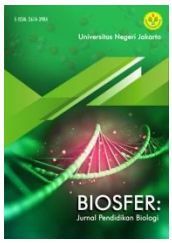

Developing an SSI-based module on biotechnology to improve students' problem-solving and creative thinking skills

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ABSTRACT

In the 21st century, education demands students to master essential skills like problem-solving and creative thinking. However, some studies show that Indonesian students, especially in biotechnology, still struggle with these skills. This highlights the need for effective teaching materials, such as SSI-based modules to help students improve their skills. This study aimed to develop a feasible module-based SSI on biotechnology, improve problem-solving and creative thinking skills, and evaluate students' responses to the module-based SSI on biotechnology. The module was developed using the 4D model (Define, Design, Develop, and Disseminate). The sample for this study was 60 students in 11th Grade Science Class from MAN Pematangsiantar. The research findings were as follows: 1) The module feasibility categorized as "excellent" in both media design and language, while model content categorized as "good" 2) The result of N-gain for problem-solving was 0.61 (medium) and creative thinking was 0.73 (high). 3) Students' responses to the module categorized as "excellent". Based on these results, the module based-SSI on biotechnology is considered highly feasible and can be used as a learning material that enhances problem-solving and creative thinking skills.

INTRODUCTION

The 21st century has been marked by significant transformations in numerous aspects of life, including education. In this era, education is not only focused on academic knowledge but also requires students to develop the necessary skills to face complex challenges. According to Care et al. (2017), problem-solving and creative thinking are essential for navigating the complexities of modern life, making these skills crucial for success. Creative thinking, as emphasized by the Organization for Economic Cooperation and Development (OECD), is one of the most important skills young adults should acquire in 21st-century societies (Bouckaert, 2023). Equally important, problem-solving is recognized as a core 21st-century skill, requiring students to work in novel environments (Csapó & Funke, 2017). Together, these skills prepare individuals to adapt and thrive in the face of rapid changes in 21st century.

Creative thinking refers to the skill of producing unique ideas and develop innovative solutions (Vincent-Lancrin et al., 2019). It encourages individuals to examine issues from multiple perspective, promoting flexibility and adaptability. In addition, problem-solving skills are crucial in addressing the various challenges of this century, which are often complex (Luthfi et al., 2019). These two skills are closely interrelated, as creative thinking provides the foundation for developing unique approaches to solving problems, helping individuals navigate uncertainties and ambiguities effectively. These skills are not only essential in academic life but also in making informed and systematic decisions in everyday life (Novitasari et al., 2015). By promoting creative problem-solving, individuals can better contribute to both professional environments and personal growth, addressing modern challenges with innovation and resourcefulness.

The importance of creative thinking and problem-solving skills in Indonesia remains a significant challenge, particularly in the context of biology education. Research conducted Sari et al. (2023) revealed that the creative thinking skills of students in grades X, XI, and XII at Senior High School 2 Lambandia in biology are still lacking. Fatmawati (2016) found that students exposed to traditional teaching methods demonstrated low levels of creativity in biotechnology topics. Students' creative thinking skills in learning biology were still low across all indicators of creative thinking and categorized as uncreative, particularly in detailing, producing innovations, and troubleshooting problems using various approaches (Handayani et al., 2021). This issue extends to problem-solving skills as well. Problem-solving abilities in biology among students at SMAN Surakarta, Indonesia, are categorized as low, while in nine Senior High Schools in Sleman, these skills are at a medium level (Cahaya et al., 2018; Ayunda et al., 2024). These findings emphasize the need for innovative teaching strategies that can enhance both creative thinking and problem-solving skills in biology education.

Improving creative thinking and problem-solving skills requires relevant teaching strategies that meet 21st-century needs. One approach that has proven effective is Socio-Scientific Issues (SSI). This method encourages students to examine and discuss real-world scientific issues, fostering the enhancement of critical and creative thinking skills (Sadler, Romine, et al., 2016). SSI-based modules also offer opportunities for students to practice collaboration, communication, and problem-solving skills (Susilawati et al., 2021). SSI helps students engage with real-world scientific issues, enhancing their comprehension of scientific concepts (Sadler et al., 2016). Research shows that SSI-integrated materials foster critical thinking and problem-solving skills (Hastuti et al., 2013; Sa'adah et al., 2022). SSI topics integrated into modules must be contemporary, controversial, and relevant to students, related to scientific content, and promote open discussion (Hancock et al., 2019). Biotechnology is one subject that easily incorporates SSI, especially in topics like genetic engineering, GMOs, vaccines, stem cells, and cloning (Sadler, Romine, et al., 2016) Sotério et al., 2023; Arslan & Durak, 2024).

Several studies have explored the development of socio-scientific issues (SSI)-based modules to enhance various 21st-century skills in students. Research by Pursitasari et al. (2022) developed an SSI-based module on biotechnology topics to improve creative thinking skills in junior high school students. Another study focused on the immune system, where an SSI-based e-module was created to enhance scientific literacy skills in senior high school students (Dalaila et al., 2022). Additionally, Febriana et al. (2023) developed an SSI-based e-module on the theme of "Food Loss and Food Waste," which successfully fostered critical thinking skills in middle school students. Although these studies have proven effective in enhancing various student skills, several gaps remain. Most notably, previous studies have primarily focused on developing individual skills, such as general scientific literacy, creative thinking, or critical thinking, without combining creative thinking and problem-solving skills in an

integrated approach. Moreover, studies specifically targeting creative thinking and problem-solving in the context of biotechnology at the senior high school level are limited, with existing research focusing primarily on junior high school contexts. Additionally, this module emphasizes socio-scientific issues that are not only relevant to local and regional contexts but also incorporate national and global perspectives, enabling students to understand and address real-world problems effectively.

This research aims to develop an SSI-based module on biotechnology to improve students' creative thinking and problem-solving skills. The results of this study are expected to contribute to the development of teaching materials that support 21st-century learning and serve as a reference for future research in the field of SSI-based module development.

METHODS

Research Design

This study employed a Research and Development (R&D) approach, following the 4D development model proposed by Thiagarajan et al. (1976) that includes four stages: define, design, develop, and disseminate. During the dissemination stage, a pre-test and post-test will be conducted to measure the improvement in students' creative thinking and problem-solving abilities using a quasi-experimental design with a non-equivalent control group, as seen in Table 1.

Table 1
Quasi-Experimental Non-Equivalent Control Group Design.

Group	Pre-test	Treatment	Post-test
Grup A (Experiment)	O_1	X_1	O_2
Grup B (Control)	O_1	X_2	O_2

(Creswell, 2014)

Description:
O1: Pre-test of students' creative thinking and problem-solving skills
X1: Treatment using SSI-based learning module
X2: Treatment using the standard books used in school
O2: Post-test of students' creative thinking and problem-solving skills

Participants

The participants of this research consist of 11th-grade science students at MAN Pematangsiantar, including two classes: 11th Grade Science Class 2 and 11th Grade Science Class 3, with a total of 60 students. The participants were selected using purposive sampling, which means that the sample was chosen based on specific considerations relevant to the study. This approach ensures that the sample meets the minimum required number of participants for the research.

Instrument

The assessment instruments developed in this research include an instrument for evaluating the feasibility and quality of the module, adapted from the teaching material quality assessment developed by the Badan Standar Nasional Pendidikan (BSNP), and an instrument to measure students' responses to the use of the module. In addition to the module evaluation instrument, there are also creative thinking and problem-solving questions, which are developed based on indicators of creative thinking (Table 2) and problem-solving skills (Table 3) .

To measure creative thinking skill, a set of indicators has been established to accurately determine the level of creative thinking manifested by each individual. Guilford (1956) identified that the indicators structuring creative thinking include fluency, flexibility, originality, and elaboration. The detailed explanations of these indicators, as presented in Table 2, are derived from the research conducted, Trisnayanti et al. (2020) which examines creative thinking skills in educational settings.

Table 2
Indicator of Creative Thinking Skill's Test.

Indicator	Description
Fluency	Generating many ideas or responses
Flexibility	Viewing things from different perspectives
Originality	Creating new and unique ideas that are uncommon or rare
Elaboration	Adding details or expanding on an idea to make it richer, more interesting, and more complete.

(Guilford, 1956; Trisnayanti et al., 2020)

The problem-solving indicators for the problem-solving questions in this study are derived from indicators modified from Cahaya et al. (2018), which include adjustments to the existing indicators as well as the addition of new elements, as shown in Table 3.

Table 3
Indicator of Problem Solving Skill's Test.

No	Problem Solving Stages	Indicator
1	Identifying the Problem	Gather relevant facts about the issue classify it within a specific concept or category
2	Examining the Problem	Investigate the root causes of the issue Explore the cause-and-effect relationships
3	Planning a Solution	Create a problem-solving strategy based on the root cause Outline the sub-problems and corresponding sub-solutions
4	Implementing the Plan	Organize the steps needed to execute the solution according to the plan
5	Evaluation	Assess the effectiveness and feasibility of the proposed solution

(Cahaya et al., 2018)

Procedure

This research comprises four primary stages: define, design, develop, and disseminate. In the Define stage, several key analyses are conducted, including front-end analysis, learner analysis, task analysis, concept analysis, and the specification of instructional objectives. The front-end analysis highlights that teachers have limited knowledge and experience in using socio-scientific issue-based (SSI) teaching materials. In the design stage, the focus is on developing tests and instruments to assess the feasibility of the module and gather student feedback, ensuring that the SSI framework is integrated at local, national, and global levels. The module structure is determined, including components such as a cover, table of contents, concept maps, learning objectives, SSI-based activities, and evaluations. Initial drafts of the module are developed using software tools such as Canva Pro and MS Word, after which they undergo reviews by experts and subsequent revisions. The development stage involves validation by experts in content, media, and language, whose feedback guides further revisions. Then, the module undergoes developmental testing in 10 students to gauge responses and refine the module accordingly. The dissemination stage involved implementing the module on a larger scale to validate its effectiveness. The module was tested on 30 students in classes: 11th Grade Science Class 2 as an experiment group, where they completed a pre-test before using the module and a post-test afterward, along with a response questionnaire. The pre-test and post-test were implemented in the control group.

Data Analysis Techniques

Analysis Techniques of Module Validation Data

The developed module must undergo a validation process by subject matter experts, media experts, and language experts. The scoring system for evaluating the module's quality has been predefined Each aspect of the module is rated based on its level of appropriateness, with scores assigned as follows: 5 for "Very Appropriate," 4 for "Appropriate," 3 for "Less Appropriate," 2 for "Fairly Appropriate," and 1 for "Not Appropriate." This system ensures a structured and comprehensive evaluation of the module's content, design, and language (Riduwan, 2015). The results of the module quality score are classified into five categories as Table 4.

Table 4
Percentage Categories of Module Quality.

No.	Percentage Interval	Category
1	< 20%	Poor
2	21% - 40%	Below Average
3	41% - 60%	Adequate
4	61% - 80%	Good
5	81% - 100%	Excellent

(Arikunto, 2021)

Analysis Techniques of Student Response

The collected data, in the form of numerical values, were then categorized based on percentage intervals to analyze student responses. Scores below 20% were categorized as "Poor", 21% to 40% as "Below Average", 41% to 60% as "Adequate", 61% to 80% as "Good", and 81% to 100% as "Excellent" (Arikunto, 2021).

Standard Gain

Standard gain analysis is used to determine the improvement in students' creative thinking and problem-solving skills before and after using the module. Based on the data obtained through standard gain analysis, students' concept comprehension is classified according to the interpretation listed in Table 5, which shows the standard gain interpretation.

Table 5
Classification of Normalized Gain (N-Gain Score).

No.	Normalized Gain Score	Category
1.	N-Gain > 0.7	High
2.	0.30 < N-Gain < 0.70	Medium
3.	N-Gain < 0.30	Low

(Hake, 1999)

RESULTS AND DISCUSSION

The research was conducted using the 4D model (Define, Design, Develop, and Disseminate). Each stage of the 4D model was implemented to ensure the development and effectiveness of the SSI-based biotechnology module, aimed at enhancing students' problem-solving and creative thinking skills.

Define Stage

The front-end analysis reveals that biology teachers face several challenges in teaching biotechnology, including limited time allocation and 67% reporting insufficient relevant teaching materials. This is aligned with Rahmadani et al. (2017), who state that one of the primary challenges faced by teachers in teaching biotechnology is the time limitation. Most teachers primarily use textbooks and student worksheets, with only one teacher having ever used a module. In terms of their knowledge of Socio-scientific Issues (SSI), 67% are familiar with the concept, but none have applied SSI-based modules in their classrooms. Additionally, all respondents recognize the importance of 21st-century skills, indicating a strong interest in resources that enhance students' creative thinking and problem-solving abilities. Overall, there is a need for more comprehensive and innovative teaching materials to support effective learning. In learner analysis, preliminary testing revealed the following Table 6.

Table 6
Percentage of Students' Creative Thinking Skill in Preliminary Test.

No.	Indicator	Percentage (%)
1.	Fluency	53.00
2.	Flexibility	34.00
3.	Originality	36.00
4	Elaboration	30.00
	Average	38.,00

Table 7
Percentage of Students' Problem Solving Skill in Preliminary Test.

No.	Indicator	Percentage (%)
1.	Identifying Problems	50.00
2.	Examining Problems	38.00
3.	Planning Solutions	27.00
4	Implementing Plans	39.00
5	Evaluation	42.00
	Average	39.00

The task analysis highlights that the primary tasks outlined in the module involve discussions and exercises cantered on SSI, culminating in an assessment of students' critical and creative thinking skills through questions related to biotechnology. The Concept Analysis focuses on developing content that includes conventional and modern biotechnology, the use of microorganisms, genetic engineering, and cloning, particularly emphasizing controversial topics such as using microorganisms and animal cloning. The Specifying Instructional Objectives involved curriculum analysis to identify the targeted learning outcomes. The curriculum used was the Merdeka Curriculum, where the analysis was conducted by defining Learning Outcomes and Learning Objectives, which were then organized into a Learning Objectives Pathway. In the Merdeka Curriculum, biotechnology materials were placed in Phase E, with the expected outcomes aiming for students to develop solutions to problems based on local, national, or global issues.

Design Stage

At the design stage, researchers develop outlines, write content, and design the covers and module layout using CanvaPro, which are then finalized in PDF format. The biotechnology module created in this study incorporates socio-scientific issues (SSI) as a core framework, aiming to foster students' creative thinking and problem-solving abilities. The issues featured in this module are carefully designed to be controversial and ill-structured, relevant to real-world problems, and integrated with ethical considerations (Zeidler & Nichols, 2009; Sadler et al., 2007; Sadler, 2004; Zeidler, 2015). They also incorporate social aspects that require scientific concepts, procedures, or technologies to inform decision-making processes with societal impacts (Sadler & Zeidler, 2004). By selecting such issues, the module emphasizes the intersection between science and society, encouraging students to explore the multifaceted dimensions of biotechnology challenges.

A key highlight of the module is its unique approach to presenting issues by categorizing them into three distinct contexts: local, national, and global, providing a comprehensive perspective for students to analyze and engage with real-world challenges. These categorizations are further detailed and illustrated in Table 8, ensuring clarity and alignment with the module's objectives.

Table 8
Socio-scientific Issues at Local, National, and Global Levels.

Topic	Issue	Issues' Level
Using Microorganism in Biotechnology	Bioethanol Project in Merauke	Local
	Polio Vaccination Rejection	National
	Bio-plastic Issue	Global
Genetic Engineering	Local Protest over Genetically Modified Mosquito Plan in Florida Keys	Local
	The Indonesian Farmers Union's Rejection of GMO Soybean Development in Indonesia	National
	Heart Transplantation from Genetic Modified Pig	Global
	"Designer Baby"	Global
Animal Cloning	Cloning of Rhesus Monkeys	Global
	Cloning of Arctic Wolves, an Endangered Species	Global
	Pet Cloning in South Korea	Global
	Stem Cell Therapy for Stroke Treatment	Global

Local issues directly impact specific communities or regions, involving residents, local governments, and community organizations as shown in Figure 1. National issues affect the entire country, involving the central government, national organizations, and large as shown in Figure 2. Global

issues, on the other hand, have a broad, international impact, involve countries, international organizations, and sparking complex ethical, social, economic, and environmental debates on a global scale as shown in Figure 2. This structured presentation of local, national, and global issues helps students grasp the broader societal implications of biotechnology at different levels.


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B. ISU-ISU SOSIOSAINTIFIK

ISU LOKAL

Menyoal Proyek Bioetanol di Merauke

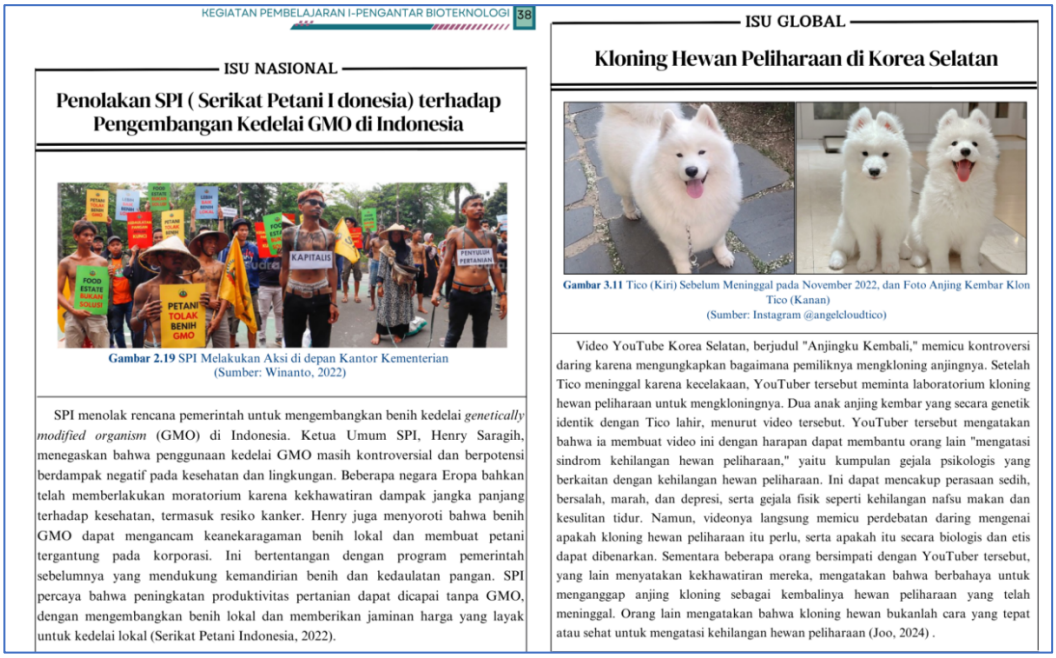
Gambar 1.13 Protes masyarakat adat Malind dan Yei Meminta Pemberhentian Proyek Perkebunan Tebu dan Bioetanol (Sumber: Walhinasional, 2024)

Gambar 1.14 Lahan di Papua yang mulai ditebangi (Sumber: Maulana, 2024)

Rencana pemerintah untuk mengembangkan industri gula dan bioetanol di Kabupaten Merauke, Papua Selatan, mendapat tanggapan beragam dari masyarakat. Proyek strategis nasional (PSN) ini memicu kekhawatiran di kalangan berbagai pihak, yang mempertanyakan apakah industri raksasa ini akan memberikan manfaat bagi masyarakat lokal atau justru memperburuk kondisi mereka.

Faisal Basri, Ekonom Senior Fakultas Ekonomi dan Bisnis Universitas Indonesia, menyatakan bahwa sejarah menunjukkan bahwa industri di Papua tidak mampu mensejahterakan Orang Asli Papua (OAP). Menurutnya, kurangnya kesesuaian antara proyek-proyek industri dan kebutuhan masyarakat lokal adalah faktor utama yang menyebabkan ketidakberdayaan ekonomi. Sementara itu, Frederika Korain, pengacara Hak Asasi Manusia dan aktivis Perdamaian Papua, memperingatkan bahwa proyek perkebunan tebu dan bioetanol ini dapat membawa dampak negatif bagi masyarakat adat. Ia menekankan bahwa proyek ini berpotensi menimbulkan ketimpangan sosial, kemiskinan, deforestasi, serta bencana lingkungan yang lebih besar. Dari sisi pemerintahan, Dian Patria, Kepala Satuan Tugas Koordinasi dan Supervisi wilayah IV Komisi Pemberantasan Korupsi, menambahkan bahwa masih banyak masalah sosial dan birokrasi yang perlu ditangani oleh pemerintah di Papua. Dia menyatakan pentingnya penanganan isu-isu ini agar pengembangan industri tidak hanya menjadi keuntungan bagi investor, tetapi juga berdampak positif bagi masyarakat setempat (Maulana, 2024).

Figure 1. Local Issue in the Socio-scientific Issue Module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ISU NASIONAL

Penolakan SPI (Serikat Petani I donesia) terhadap Pengembangan Kedelai GMO di Indonesia

Gambar 2.19 SPI Melakukan Aksi di depan Kantor Kementerian (Sumber: Winanto, 2022)

SPI menolak rencana pemerintah untuk mengembangkan benih kedelai *genetically modified organism* (GMO) di Indonesia. Ketua Umum SPI, Henry Saragih, menegaskan bahwa penggunaan kedelai GMO masih kontroversial dan berpotensi berdampak negatif pada kesehatan dan lingkungan. Beberapa negara Eropa bahkan telah memberlakukan moratorium karena kekhawatiran dampak jangka panjang terhadap kesehatan, termasuk resiko kanker. Henry juga menyoroti bahwa benih GMO dapat mengancam keanekaragaman benih lokal dan membuat petani tergantung pada korporasi. Ini bertentangan dengan program pemerintah sebelumnya yang mendukung kemandirian benih dan kedaulatan pangan. SPI percaya bahwa peningkatan produktivitas pertanian dapat dicapai tanpa GMO, dengan mengembangkan benih lokal dan memberikan jaminan harga yang layak untuk kedelai lokal (Serikat Petani Indonesia, 2022).

ISU GLOBAL

Kloning Hewan Peliharaan di Korea Selatan

Gambar 3.11 Tico (Kiri) Sebelum Meninggal pada November 2022, dan Foto Anjing Kembar Klon Tico (Kanan) (Sumber: Instagram @angelcloudtico)

Video YouTube Korea Selatan, berjudul "Anjingku Kembali," memicu kontroversi daring karena mengungkapkan bagaimana pemiliknya mengkloning anjingnya. Setelah Tico meninggal karena kecelakaan, YouTuber tersebut meminta laboratorium kloning hewan peliharaan untuk mengkloningnya. Dua anak anjing kembar yang secara genetik identik dengan Tico lahir, menurut video tersebut. YouTuber tersebut mengatakan bahwa ia membuat video ini dengan harapan dapat membantu orang lain "mengatasi sindrom kehilangan hewan peliharaan," yaitu kumpulan gejala psikologis yang berkaitan dengan kehilangan hewan peliharaan. Ini dapat mencakup perasaan sedih, bersalah, marah, dan depresi, serta gejala fisik seperti kehilangan nafsu makan dan kesulitan tidur. Namun, videonya langsung memicu perdebatan daring mengenai apakah kloning hewan peliharaan itu perlu, serta apakah itu secara biologis dan etis dapat dibenarkan. Sementara beberapa orang bersimpati dengan YouTuber tersebut, yang lain menyatakan kekhawatiran mereka, mengatakan bahwa berbahaya untuk menganggap anjing kloning sebagai kembalinya hewan peliharaan yang telah meninggal. Orang lain mengatakan bahwa kloning hewan bukanlah cara yang tepat atau sehat untuk mengatasi kehilangan hewan peliharaan (Joo, 2024) .

Figure 2. National Issue (Left) and Global Issue (Right) in the Socio-scientific Issue Module

In addition to presenting relevant issues, the module is designed to actively engage students and enhance their creative thinking and problem-solving skills through various activities. These activities, including Spot It! (identifying problems), Dig Deeper (Examining the Problem), Solve It! (planning solutions), Create It! (Implementing innovative solutions), and Check It! (evaluating and revising solutions). The "Spot It!" (identifying problems) activity helps students develop their ability to recognize the main issues in a problem, this stage allow students to develop their fluency. The “Dig Deeper” activity pushes students to identify problems further and explore their impacts from various perspectives. The "Solve It!" activity encouraging students to apply their knowledge and devise actionable strategies to address the identified problems. This stage emphasizes fluency and originality, as students are encouraged to generate a variety of potential solutions and select the most viable ones. The "Create It!"

activity allows students to implement their innovative solutions, translating abstract ideas into concrete actions. This activity fosters originality and elaboration by requiring students to detail and refine their solutions, ensuring they are practical and impactful. By engaging in this step, students enhance their ability to innovate and think critically about how their solutions can be applied in real-world scenarios. The "Check It!" activity focuses on evaluating and revising solutions. Students critically assess the effectiveness of their implemented solutions, considering their strengths and weaknesses. This reflective stage not only improves problem-solving by promoting adaptability and revision based on feedback but also deepens creative thinking, as students identify ways to enhance their solutions further. Each activity is grounded in relevant biotechnology issues, as shown in Figure 1 and 2.

Develop Stage

The validation process focused on different aspects of the module: content feasibility, display Feasibility, socio-scientific issues, graphical elements, and language feasibility. The validation process was conducted three times, and the average results from each expert show in Table 9**.**

Table 9
Subject Matter Expert Validation Result.

Aspect	Component	Validator Score
Content Feasibility	Relevance of content to Learning Outcomes and Learning Objectives	3.62
	Accuracy of content	3.87
	Socio-scientific issue	4.00
	Modernity of the content	4.00
Presentation Feasibility	Presentation techniques	3.62
Average		3.82
Percentage		76.50 %
Category		Good

Table 10.
Media Expert Validation Result

Aspect	Component	Average
Graphic Feasibility	Module Size	4.35
	Cover Design	4.30
	Content Design	4.65
Average		4.43
Percentage		88.60%
Category		Excellent

Table 11.
Language Expert Validation Result

Aspect	Component	Average
Language Feasibility	Conciseness	4.50
	Communicativeness	4.25
	Dialogic and interactive	3.87
	Appropriateness with student development	3.87
	Adherence to language rules	4.12
Average		4.12
Percentage		82.50 %
Category		Excellent

Based on Table 9 in content feasibility, the module received an average score of 3.82 for the relevance of content to the learning outcomes, indicating that the content aligns well The accuracy of the content was rated slightly higher at 3.87, showing that most information is accurate. The socio-scientific issues aspect scored 4, showing that it's well integrated into the module. However, adding more recent biotechnology topics could make it even more interesting for students. The modernity of the content also received a solid 4, indicating that the module keeps pace with current developments in biotechnology. The presentation techniques, which assess how smoothly the content is organized and

how well the concepts are presented, scored 3.62. While the structure is clear, improving the flow of the concepts could help students understand the material more easily

According to the media expert validation results, the module received a strong performance rating, with an average score of 4.05 and a feasibility rating of 88.6%, placing it in the "excellent" category. Both the cover and content design scored particularly well. However, adding more visual aids like process diagrams and info graphics could help students better understand complex topics. The language validation results were also positive, with an average score of 4.12 or 82.5%, also rated "excellent." The language was found to be concise, clear, and appropriate for students. Still, there is potential to improve the dialogic and interactive elements to make the module more engaging.

After validation, a limited trial was conducted with 10 students to assess their responses to the SSI-based module. The result of this trial is shown in Table 12.

Table 12
Students' Responses to the SSI Module at the Development Stage.

Aspect	Average Score	Percentage	Criteria
Module Design	4.00	80%	Good
Concept Mastery	3.70	74%	Good
Learning Motivation	4.30	86%	Excellent
Average	4.00	80%	Good

Based on the results, the overall average score for the students' responses was 4.0, or 80%, which falls under the "good" category. The module design received a score of 4.0 (80%), indicating that students found the module design satisfactory. The concept mastery aspect scored slightly lower at 3.7 (74%), suggesting that while students generally understood the concepts, there is room for improvement. The highest score was for learning motivation, with an average of 4.3 (86%), indicating that the module successfully motivated students to learn and was rated as "excellent." Since the students responded positively, the module will be shared on a larger scale.

Disseminate

The dissemination stage involved implementing the SSI-based module on a larger scale to assess whether students' skills improved before and after using the module. After conducting both a pre-test and post-test, it was evident that the use of the SSI-based module enhanced students' problem-solving and creative thinking skills.

Students' Problem-Solving and Creative Thinking Skills

The improvement in problem-solving and creative thinking skills can be observed through an analysis of the N-Gain value. Overall, the N-gain scores for problem-solving and creative thinking skills are shown in Table 13.

Table 13.
N-gain Score of Problem Solving and Creative Thinking Skills in Experiment and Control Class

Skill	Pre-Test Score		Post-Test Score		N-Gain Score	
	Experiment	Control	Experiment	Control	Experiment	Control
Problem Solving	44.00	41.00	78.16	58.11	0.61	0.29
Creative Thinking	45.00	44.50	85.15	60.60	0.73	0.29

The result showed that the average N-Gain in experiment class for problem-solving skills was medium and creative thinking skills was high. These improvements in students' problem-solving and creative thinking skills can be attributed to the effectiveness of incorporating socio-scientific issues (SSI)-based modules into the learning process. In the experimental class, the students were exposed to issues that mirrored the complexity of real-world situations, controversial and ill-structured, and integrated with ethical and social considerations. The use of real-world problems is particularly impactful in enhancing students' problem-solving skills. When problems are relevant and familiar, students become more motivated and actively engaged, which strengthens their ability to analyze, evaluate, and generate solutions (Weng et al., 2022). The exposure to ill-structured problems, as typical in SSI-based modules, has been shown to enhance problem-solving skill (Klegeris et al., 2013). As Dori

et al. (2003) note, integrating biotechnology modules with controversial issues significantly boosts higher-order thinking skills, including problem solving and creative thinking skills.

The difference in N-Gain values between problem-solving and creative thinking skills reflects the distinct nature of the tasks and cognitive processes involved in each skill. Overall, creative thinking tasks encouraged greater exploration and engagement, resulting in higher improvements in creative thinking skills. Many studies have documented that students engaging with socio-scientific issues can enhance their creative thinking skills. The study Pursitasari et al. (2022) demonstrated that the use of SSI-based modules in biotechnology topics can enhance students' creative thinking skills. Meanwhile, problem-solving tasks, although also demonstrating significant improvement, presented a higher level of complexity in terms of structured analysis and solution development. This led to more medium growth in problem-solving skills.

In the control class, the average N-Gain for problem-solving and creative thinking skills was only 0.29, which is considered low. Although there was some improvement, it was much smaller compared to the experimental class, which used the SSI module designed to encourage problem-solving and creativity in a more structured and meaningful way. The learning process in the control class was not connected to real-world contexts, as opposed to the SSI module in the experimental class, resulting in fewer opportunities for students to engage their skills (Zeidler et al., 2019). Barron & Darling-Hammond (2008) also point out that when learning isn't relevant to real-world, students are less motivated and find it harder to think critically and creatively. On the other hand, students in the experimental class worked with controversial socio-scientific issues, which helped them build a deeper understanding of science concepts and improve their skills (D. Zeidler & Kahn, 2014). This shows a clear difference between the two classes, as the control class didn't have the same opportunities to develop their problem-solving and creative thinking skill.

Students Responses

After the biology lessons using the SSI-based biotechnology module were implemented, students provided positive responses. Their feedback reflects an increased engagement and interest in the topics covered, as well as a deeper understanding of the socio-scientific issues presented. This is evident from the data collected in Table 14, which summarizes students responses regarding their experiences with the module.

Table 14.
Students' Responses to the SSI Module at the Disseminate Stage

Aspect	Average Score	Percentage	Criteria
Module Design	4.50	90.00%	Excellent
Concept Mastery	4.00	80.00%	Good
Learning Motivation	4.50	90.00%	Excellent
Average	4.30	86.70%	Excellent

The evaluation of students' responses after using the SSI-based biotechnology module shows positive outcomes across several key aspects, with an overall average score of 4.3, or 86.7%, which is categorized as "Excellent." The module's design received a score of 4.0 (80%), indicating that students appreciated its structure and content. A well-designed module plays a crucial role in supporting student engagement and learning. Mayer (2020) emphasizes that effective instructional design enhances comprehension and motivation by clearly presenting objectives and providing relevant content that students can connect to their own experiences. This approach helps students better understand and engage with the material, leading to more meaningful learning experiences.

In terms of concept mastery, the students achieved a score of 3.7 (74%), which is also categorized as "Good." This suggests that the module helped students understand the core concepts of biotechnology, though there remains some room for improvement in this area. According to Sadler, et al. (2016), SSI-based learning can deepen students' grasp of scientific concepts by encouraging them to apply their knowledge to real-world problems.

The highest score was observed in learning motivation, with an impressive 4.3 (86%), categorized as "Excellent." This high level of student motivation can be attributed to the module's engaging design and well-crafted content. The strong validation results from media experts further support this, with

the module achieving an 88.6% score for its design and 75.5% for its content and presentation. These results indicate that the module's appealing features effectively enhance the learning experience and tap into students' intrinsic motivation. Intrinsic motivation is not a fixed personal characteristic but arises from the interaction between individuals and specific tasks within particular situations. The module's integration of controversial and real-world issues, such as bioethanol project in Merauke, pro and cons Genetic Modified Organism (GMO), and Cloning, likely fosters this motivation by offering tasks that are intellectually stimulating and socially meaningful. This aligns with Slovinsky et al. (2021) findings, which highlight that incorporating socio-scientific issues into science education significantly enhances students' intrinsic motivation by making the learning process more relevant and engaging. Moreover, research by Karunarathne and Calma (2024). shows that individuals tend to be more creative when driven by internal factors such as interest, enjoyment, and the challenge of the task itself, rather than external pressures like competition or supervision.

CONCLUSION

Based on the expert evaluations, the module is considered feasible in terms of media, content, and language, with high ratings across all categories. The module was found to be excellent in terms of both media design and language. The multimedia elements were well-received by students, effectively supporting the learning process and making it more engaging. The module was found to be very suitable in terms of its media design and language, with scores falling into the "excellent" categories. The content or subject matter feasibility used in the module was categorized as “good.” Student responses to the module were positive, with the students' learning motivation scoring categorized as "excellent." The module's engaging design and incorporation of relevant socio-scientific issues contributed significantly to this outcome. The effectiveness of the SSI-based module in enhancing students' problem-solving and creative thinking skills was confirmed through N-Gain analysis. In the experimental class, students demonstrated significant improvement, with an average N-Gain of 0.61 for problem-solving and 0.73 for creative thinking, categorized as “medium” and “high,” respectively. This improvement contrasts with the control class, where traditional teaching methods resulted in much lower N-Gain values. In conclusion, the SSI-based module not only meets feasibility standards but also effectively enhances students' problem solving and creative thinking skills, making it a valuable tool for science education.

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