Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Development of Biology Teaching Materials Based on Biopreneurship for High School Students

Nur Hasanah*, A. Wahab Jufri, Lalu Japa

Biology Education Study Program, University of Mataram, Mataram, Indonesia.
*e-mail: n.hasanah171199@gmail.com.

Received: August 21, 2025. Accepted: September 9, 2025. Published: October 4, 2025

Abstract: Biology learning in high school often faces challenges due to students' reliance on teacher explanations and conventional textbooks, which tend to be less engaging and limit the development of critical and entrepreneurial skills. To address this issue, innovative teaching materials are needed that not only improve students' understanding of biological concepts but also foster creativity and independence through entrepreneurship-based approaches. This study aims to develop and test the validity of biopreneurship-based biology teaching materials for high school students. The research employed a 4D development model (Define, Design, Develop, and Disseminate) with a focus on the first three stages. Validation of the teaching materials was conducted by three expert validators using questionnaires, and the results were analyzed with the Aiken index. The construct validity assessment produced values ranging from 0.58 to 0.94, while content validity ranged from 0.63 to 0.75, both categorized as valid. Additionally, the readability test using the Flesch-Kincaid Grade Level showed that most of the text fell within the easy-to-moderate range, making it suitable for high school students. These findings indicate that the developed materials meet the scientific and pedagogical standards required for classroom use. Furthermore, the integration of biopreneurship elements into the biology content provides an innovative approach that not only enhances students' conceptual understanding but also motivates them to develop an entrepreneurial spirit, particularly in managing biological resources. Overall, this study concludes that the developed teaching materials are valid, relevant, and beneficial for high school biology learning, making biology both meaningful and applicable to students' real-life contexts.

Keywords: Biology Teaching Materials; Biopreneurship; High School; Validity.

Introdaction

Teaching materials are a fundamental element in the biology learning process, serving not only as organized sources of information but also as tools to foster creativity, critical thinking, and problem-solving skills among students. Effective teaching materials should be relevant, contextual, and designed to encourage student independence and engagement. In biology education, the use of diverse instructional materials such as textbooks, laboratory apparatus, digital resources, and multimedia has been shown to enhance active learning and deepen students' understanding of scientific concepts [1][2][3]. However, relying solely on printed materials can limit student interaction and impede effective learning, highlighting the need for a broader range of resources, including digital and inquiry-based materials [4],[5].

Biology education in schools continues to rely predominantly on teacher-centered explanations and conventional textbooks. This traditional approach often yields a monotonous learning environment, limiting student engagement and making it challenging for learners to grasp complex biological concepts, such as scientific terminology, biological mechanisms, and data interpretation. Consequently, students' scientific literacy remains underdeveloped, and their entrepreneurial potential is largely untapped. These challenges are particularly concerning given the demands of the 21st century, which require students to be creative, independent, and adaptable in response to limited employment opportunities after graduation [6], [7].

The creation of creative teaching modules, the use of contextual learning techniques, and the application of project-based learning models are some of the alternative solutions that have been proposed to solve these problems [8], [9]. One promising solution is the integration of entrepreneurship education into biology learning, often referred to as biopreneurship. This approach not only provides students with meaningful and relevant learning experiences but also equips them with entrepreneurial skills by encouraging the transformation of biological resources into products or services with economic value [10], [11].

Recent studies have demonstrated the effectiveness of entrepreneurship-based teaching materials. For example, integrating entrepreneurship into biology curricula has been shown to enhance student engagement, motivation, and learning outcomes, as well as to increase entrepreneurial interest and self-efficacy [12]. These findings underscore the importance of combining scientific content with entrepreneurship education to foster both cognitive and practical competencies in students, preparing them for future challenges and opportunities.

The novelty of this study lies in the development of biopreneurship-based biology teaching materials that integrate entrepreneurial values with biotechnology content, aligning with the Merdeka Curriculum and the Pancasila

How to Cite:
N. Hasanah, A. W. Jufri, and L. Japa, "Development of Biology Teaching Materials Based on Biopreneurship for High School Students", *J. Pijar.MIPA*, vol. 20, no. 6, pp. 1123–1131, Oct. 2025. https://doi.org/10.29303/jpm.v20i6.10028

student profile values. Unlike conventional textbooks, these teaching materials are designed not only to improve students' conceptual understanding but also to foster entrepreneurial competencies through contextual biological applications. Therefore, this study aims to develop and validate biopreneurship-based biology teaching materials for high school students by assessing their construct validity, content validity, and readability.

Research Method

This study employed a Research and Development (R&D) design using the 4D model (Define, Design, Develop, and Disseminate) proposed by Indaryanti et al. [13]. The study was limited to the first three stages, namely define, design, and develop, as the focus was on producing valid and feasible teaching materials. The research was conducted at SMA Negeri 1 Gunungsari, where observations and interviews were carried out with biology teachers and students to identify existing problems in the use of teaching resources.

The define stage involved identifying learning needs and challenges, particularly in the biotechnology topic. Data collection included classroom observations, teacher interviews, and curriculum analysis to determine learning objectives and competency standards. The design stage focused on creating a prototype of the biopreneurship-based teaching materials by selecting the content, structure, format, and media. At this stage, the module components included learning objectives, biopreneurship-oriented content, student worksheets, assessments, and a glossary. The development stage emphasized expert validation and product improvement. The validation process was conducted by three expert validators who assessed construct validity and content validity using questionnaires. Construct and content validity were analyzed using the Aiken index [14], which categorized results as less valid ($V \leq 0.4$), valid ($0.4 \leq V \leq 0.8$), and very valid ($0.8 \leq V \leq 1$).

In addition, the readability test was conducted using the Flesch-Kincaid Grade Level formula to measure the complexity and suitability of the language for high school students [15]. This ensured that the materials were accessible and understandable for the target users. The effectiveness of the developed teaching materials was further tested through a quasi-experimental design with a pretest-posttest control group. The experimental class used the developed materials, while the control class used conventional textbooks. Data were analyzed using the normalized gain (N-Gain) formula to determine learning improvement [16]. The effectiveness criteria followed Hake's classification, namely high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), and low ($g < 0.3$).

Results and Discussion

Overview of the Developed Product

The product developed in this study is a biopreneurship-based biology teaching material designed for high school students, specifically for the biotechnology topic. The teaching material was structured in accordance with the Merdeka Curriculum and the values of the Pancasila student profile, which emphasize critical reasoning, creativity, independence, and collaboration. The main purpose of the product is to make biology learning more meaningful by connecting biotechnology concepts with entrepreneurial applications that are relevant to students' daily lives.

The developed teaching material consists of several main components: (1) a cover page displaying the identity of the module and its biopreneurship focus, (2) usage instructions for students and teachers, (3) learning objectives and initial competencies, (4) biotechnology content covering both conventional and modern biotechnology, (5) student worksheets (LKPD) to promote active learning and problem-solving, (6) evaluation questions for formative and summative assessment, and (7) a glossary of terms to help students understand biological terminology. Each component was designed to be clear, systematic, and easy to follow, ensuring that students can understand the biology content.

Product Samples and Descriptions

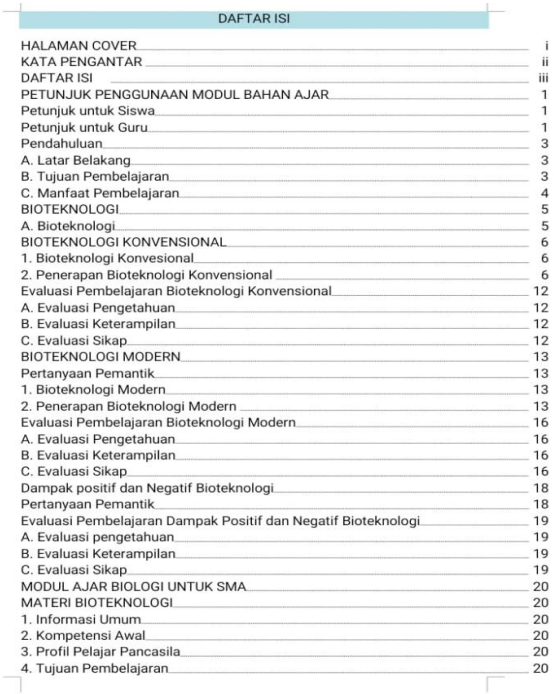
To provide a clearer illustration of the developed product, several examples of the biopreneurship-based biology teaching material are presented (Figures 1–7). Figure 1 illustrates the cover page, which highlights the module's identity and its focus on integrating biology with entrepreneurial values. Figure 2 presents the table of contents, offering a systematic overview of the material structure, including biotechnology concepts, learning objectives, activities, and evaluations. Figure 3 displays the user guide, which provides instructions for both teachers and students on how to utilize the module effectively during classroom learning.

Figure 4 presents a sample excerpt of the biotechnology material, which explains concepts using accessible language and contextual examples, making it easier for students to connect scientific content with real-life applications. Figure 5 shows a sample of the student worksheet (LKPD) designed to guide learners in problem-solving and project-based tasks. These activities require students to design small-scale products, thereby reinforcing their mastery of biotechnology while cultivating entrepreneurial skills.

Furthermore, Figure 6 illustrates the evaluation section, which contains both multiple-choice and essay questions designed to assess students' conceptual understanding, analytical skills, and ability to apply biological concepts in entrepreneurial contexts. Finally, Figure 7 presents the glossary, which compiles key biological and entrepreneurial terms used in the module, helping students overcome difficulties in understanding technical vocabulary.

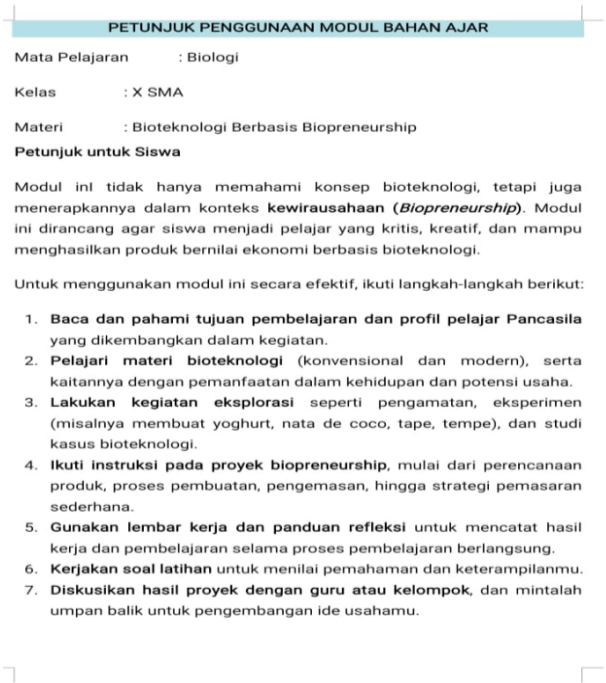
The creation of creative teaching modules, the use of contextual learning techniques, and the application of project-based learning models are among the alternative solutions proposed to address these issues. The integration of biopreneurship into the module encourages students to view biology as a subject that has direct links to their daily lives and future career opportunities.

Figure 1. Cover page of the biopreneurship-based biology teaching material



DAFTAR ISI

Figure 2. Table of contents of the developed teaching material



PETUNJUK PENGGUNAAN MODUL BAHAN AJAR

Mata Pelajaran : Biologi

Kelas : X SMA

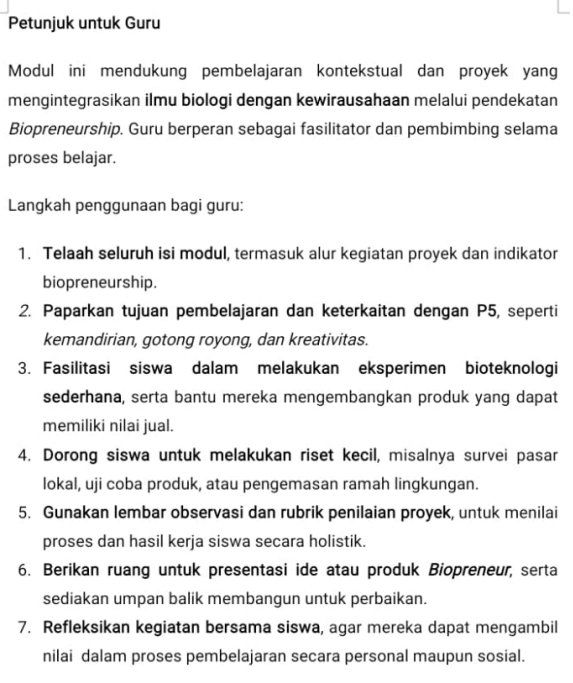
Materi : Bioteknologi Berbasis Biopreneurship

Petunjuk untuk Siswa

Modul ini tidak hanya memahami konsep bioteknologi, tetapi juga menerapkannya dalam konteks **kewirausahaan (*Biopreneurship*)**. Modul ini dirancang agar siswa menjadi pelajar yang kritis, kreatif, dan mampu menghasilkan produk bernilai ekonomi berbasis bioteknologi.

Untuk menggunakan modul ini secara efektif, ikuti langkah-langkah berikut:

1. **Baca dan pahami tujuan pembelajaran dan profil pelajar Pancasila** yang dikembangkan dalam kegiatan.
2. **Pelajari materi bioteknologi** (konvensional dan modern), serta kaitannya dengan pemanfaatan dalam kehidupan dan potensi usaha.
3. **Lakukan kegiatan eksplorasi** seperti pengamatan, eksperimen (misalnya membuat yoghurt, nata de coco, tape, tempe), dan studi kasus bioteknologi.
4. **Ikuti instruksi pada proyek biopreneurship**, mulai dari perencanaan produk, proses pembuatan, pengemasan, hingga strategi pemasaran sederhana.
5. **Gunakan lembar kerja dan panduan refleksi** untuk mencatat hasil kerja dan pembelajaran selama proses pembelajaran berlangsung.
6. **Kerjakan soal latihan** untuk menilai pemahaman dan keterampilanmu.
7. **Diskusikan hasil proyek dengan guru atau kelompok**, dan mintalah umpan balik untuk pengembangan ide usahamu.



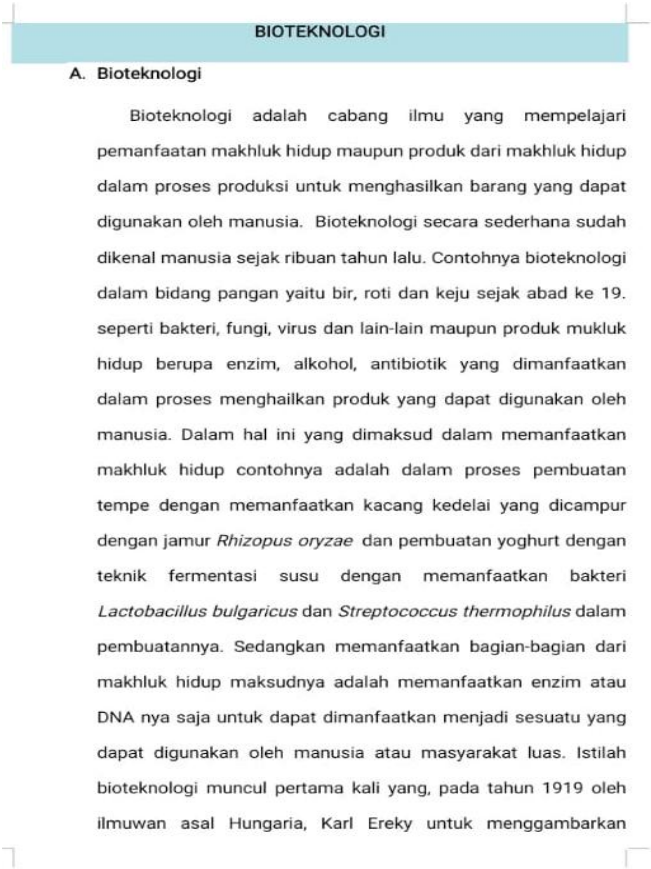
Petunjuk untuk Guru

Modul ini mendukung pembelajaran kontekstual dan proyek yang mengintegrasikan **ilmu biologi dengan kewirausahaan** melalui pendekatan *Biopreneurship*. Guru berperan sebagai fasilitator dan pembimbing selama proses belajar.

Langkah penggunaan bagi guru:

1. **Telaah seluruh isi modul**, termasuk alur kegiatan proyek dan indikator biopreneurship.
2. **Paparkan tujuan pembelajaran dan keterkaitan dengan P5**, seperti *kemandirian, gotong royong, dan kreativitas.*
3. **Fasilitasi siswa dalam melakukan eksperimen bioteknologi sederhana**, serta bantu mereka mengembangkan produk yang dapat memiliki nilai jual.
4. **Dorong siswa untuk melakukan riset kecil**, misalnya survei pasar lokal, uji coba produk, atau pengemasan ramah lingkungan.
5. **Gunakan lembar observasi dan rubrik penilaian proyek**, untuk menilai proses dan hasil kerja siswa secara holistik.
6. **Berikan ruang untuk presentasi ide atau produk *Biopreneur***, serta sediakan umpan balik membangun untuk perbaikan.
7. **Refleksikan kegiatan bersama siswa**, agar mereka dapat mengambil nilai dalam proses pembelajaran secara personal maupun sosial.

Figure 3. User guide of the module for teachers and students

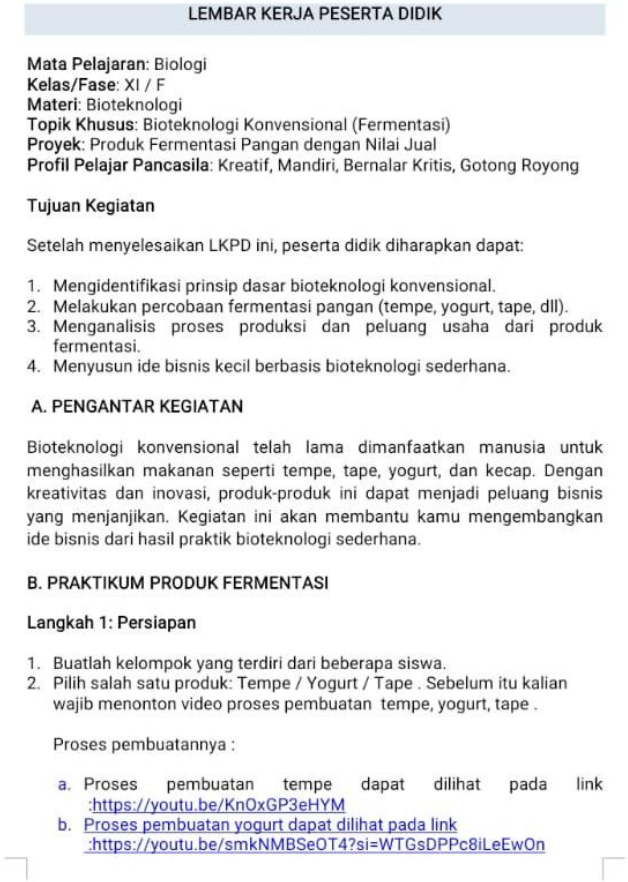


BIOTEKNOLOGI

A. Bioteknologi

Bioteknologi adalah cabang ilmu yang mempelajari pemanfaatan makhluk hidup maupun produk dari makhluk hidup dalam proses produksi untuk menghasilkan barang yang dapat digunakan oleh manusia. Bioteknologi secara sederhana sudah dikenal manusia sejak ribuan tahun lalu. Contohnya bioteknologi dalam bidang pangan yaitu bir, roti dan keju sejak abad ke 19. seperti bakteri, fungi, virus dan lain-lain maupun produk mukluk hidup berupa enzim, alkohol, antibiotik yang dimanfaatkan dalam proses menghailkan produk yang dapat digunakan oleh manusia. Dalam hal ini yang dimaksud dalam memanfaatkan makhluk hidup contohnya adalah dalam proses pembuatan tempe dengan memanfaatkan kacang kedelai yang dicampur dengan jamur *Rhizopus oryzae* dan pembuatan yoghurt dengan teknik fermentasi susu dengan memanfaatkan bakteri *Lactobacillus bulgaricus* dan *Streptococcus thermophilus* dalam pembuatannya. Sedangkan memanfaatkan bagian-bagian dari makhluk hidup maksudnya adalah memanfaatkan enzim atau DNA nya saja untuk dapat dimanfaatkan menjadi sesuatu yang dapat digunakan oleh manusia atau masyarakat luas. Istilah bioteknologi muncul pertama kali yang, pada tahun 1919 oleh ilmuwan asal Hungaria, Karl Ereky untuk menggambarkan

Figure 4. Sample excerpt of biotechnology material in the module



LEMBAR KERJA PESERTA DIDIK

Mata Pelajaran: Biologi
Kelas/Fase: XI / F
Materi: Bioteknologi
Topik Khusus: Bioteknologi Konvensional (Fermentasi)
Proyek: Produk Fermentasi Pangan dengan Nilai Jual
Profil Pelajar Pancasila: Kreatif, Mandiri, Bernalar Kritis, Gotong Royong

Tujuan Kegiatan

Setelah menyelesaikan LKPD ini, peserta didik diharapkan dapat:

1. Mengidentifikasi prinsip dasar bioteknologi konvensional.
2. Melakukan percobaan fermentasi pangan (tempe, yogurt, tape, dll).
3. Menganalisis proses produksi dan peluang usaha dari produk fermentasi.
4. Menyusun ide bisnis kecil berbasis bioteknologi sederhana.

A. PENGANTAR KEGIATAN

Bioteknologi konvensional telah lama dimanfaatkan manusia untuk menghasilkan makanan seperti tempe, tape, yogurt, dan kecap. Dengan kreativitas dan inovasi, produk-produk ini dapat menjadi peluang bisnis yang menjanjikan. Kegiatan ini akan membantu kamu mengembangkan ide bisnis dari hasil praktik bioteknologi sederhana.

B. PRAKTIKUM PRODUK FERMENTASI

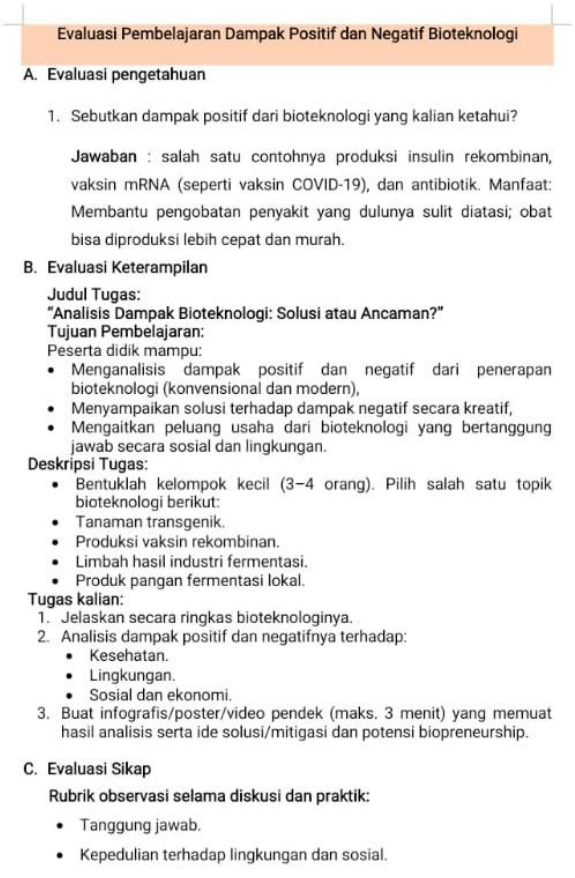
Langkah 1: Persiapan

1. Buatlah kelompok yang terdiri dari beberapa siswa.
2. Pilih salah satu produk: Tempe / Yogurt / Tape . Sebelum itu kalian wajib menonton video proses pembuatan tempe, yogurt, tape .

Proses pembuatannya :

a. Proses pembuatan tempe dapat dilihat pada link :https://youtu.be/KnOxGP3eHYM
b. Proses pembuatan yogurt dapat dilihat pada link :https://youtu.be/smkNMBSeOT4?si=WTGsDPPc8iLeEwOn

Figure 5. Sample student worksheet (LKPD) from the developed product



Evaluasi Pembelajaran Dampak Positif dan Negatif Bioteknologi

A. Evaluasi pengetahuan

1. Sebutkan dampak positif dari bioteknologi yang kalian ketahui?

Jawaban : salah satu contohnya produksi insulin rekombinan, vaksin mRNA (seperti vaksin COVID-19), dan antibiotik. Manfaat: Membantu pengobatan penyakit yang dulunya sulit diatasi; obat bisa diproduksi lebih cepat dan murah.

B. Evaluasi Keterampilan

Judul Tugas:
"Analisis Dampak Bioteknologi: Solusi atau Ancaman?"
Tujuan Pembelajaran:
Peserta didik mampu:

- Menganalisis dampak positif dan negatif dari penerapan bioteknologi (konvensional dan modern),
- Menyampaikan solusi terhadap dampak negatif secara kreatif,
- Mengaitkan peluang usaha dari bioteknologi yang bertanggung jawab secara sosial dan lingkungan.

Deskripsi Tugas:

- Bentuklah kelompok kecil (3–4 orang). Pilih salah satu topik bioteknologi berikut:
- Tanaman transgenik.
- Produksi vaksin rekombinan.
- Limbah hasil industri fermentasi.
- Produk pangan fermentasi lokal.

Tugas kalian:

1. Jelaskan secara ringkas bioteknologinya.
2. Analisis dampak positif dan negatifnya terhadap:
   - Kesehatan.
   - Lingkungan.
   - Sosial dan ekonomi.
3. Buat infografis/poster/video pendek (maks. 3 menit) yang memuat hasil analisis serta ide solusi/mitigasi dan potensi biopreneurship.

C. Evaluasi Sikap

Rubrik observasi selama diskusi dan praktik:

- Tanggung jawab.
- Kepedulian terhadap lingkungan dan sosial.

Figure 6. Sample evaluation section containing multiple-choice and essay questions

Glosarium Bioteknologi

Istilah	Pengertian
Bioteknologi	Cabang ilmu yang memanfaatkan makhluk hidup atau enzim untuk menghasilkan produk atau jasa.
Fermentasi	Proses bioteknologi konvensional yang menggunakan mikroorganisme untuk mengubah bahan organik menjadi produk lain.
Mikroorganisme	Organisme berukuran mikroskopis seperti bakteri, jamur, dan kapang yang sering digunakan dalam bioteknologi.
Enzim	Protein yang mempercepat reaksi kimia tanpa ikut bereaksi secara permanen.
Rhizopus	Jenis kapang yang digunakan dalam fermentasi kedelai untuk membuat tempe.
Saccharomyces cerevisiae	Ragi yang digunakan untuk membuat roti dan minuman fermentasi seperti tape.
Lactobacillus	Bakteri yang digunakan dalam fermentasi susu untuk membuat yogurt.
Bioteknologi Konvensional	Penerapan teknologi menggunakan organisme secara alami, seperti fermentasi tradisional.
Bioteknologi Modern	Penerapan teknologi yang melibatkan rekayasa genetika, seperti kultur jaringan dan DNA rekombinan.
DNA Rekombinan	Teknologi menggabungkan DNA dari dua organisme yang berbeda.
Transgenik	Organisme yang telah dimodifikasi genetiknya dengan menyisipkan gen dari organisme lain.
Kultur Jaringan	Teknik menumbuhkan bagian tumbuhan (sel/jaringan) di media buatan secara steril untuk memperbanyak tanaman.
Plasmid	Materi genetik berbentuk lingkaran kecil yang terdapat dalam bakteri, sering digunakan dalam rekayasa genetika.
Antibiotik	Zat yang dihasilkan mikroorganisme untuk membunuh atau menghambat pertumbuhan mikroba lain.
Biopreneurship	Kewirausahaan yang berbasis pada inovasi bioteknologi, terutama produk yang dihasilkan dari mikroorganisme.

Figure 7. Glossary of biological and entrepreneurial terms included in the module

The inclusion of biopreneurship components in biology education products demonstrates a deliberate effort to deliver not only scientific content but also to develop student competencies aligned with the demands of 21st-century learning. Integrating biopreneurship encourages students to perceive biology as a subject with direct relevance to daily life and future career opportunities, fostering both scientific and entrepreneurial mindsets [17].

Biopreneurship-based learning has been shown to enhance a range of student competencies. For example, project-based biopreneurship modules and activities significantly improve students' entrepreneurial literacy, creativity, and motivation [18]. These modules are designed to be contextual and interactive, allowing students to apply biological concepts in real-world scenarios, such as transforming biological resources into marketable products or services [19]. This approach not only increases engagement but also helps students develop critical thinking, problem-solving, and collaboration skills, key competencies for the 21st century [20].

Furthermore, the integration of biopreneurship in biology education supports the development of life skills and scientific literacy. Studies have found that students exposed to biopreneurship learning show improvements in decision-making, independence, and the ability to connect scientific knowledge with entrepreneurial opportunities [21]. The use of innovative teaching materials, such as comics, e-books, and augmented reality, further enhances the effectiveness of biopreneurship education by making learning more interactive and accessible [22].

Construct Validity Results

The construct validity analysis was conducted to evaluate whether the developed biopreneurship-based biology teaching material met the requirements of structural feasibility and systematic organization. This assessment was conducted by three expert validators, who reviewed several aspects, including learning content, component integration, clarity of instructions, format and presentation, language and terminology, as well as the measurability of activities and evaluations. The results of the assessment, analyzed using Aiken's V Index, are presented in Table 1.

Table 1. Construct Validity Results

No	Rated aspect	Aiken's Index	Category
1	Learning material	0.70	Valid
2	Component Integration	0.94	Valid
3	Clarity of Instructions	0.79	Valid
4	Format and presentation	0.58	Valid
5	Language and terms	0.70	Valid
6	Measurability of activities and evaluation	0.62	Valid

Based on Table 1, all aspects assessed in the construct validity test fall within the valid category, with Aiken's Index ranging from 0.58 to 0.94. The highest score was obtained in the aspect of component integration (0.94), indicating that the relationship between sections in the teaching material was highly coherent and logically arranged. This suggests that the developed product successfully integrated different components, objectives, materials, activities, and assessments into a cohesive and meaningful learning resource. However, the lowest score was found in the format and presentation (0.58), which, although still valid, shows that the product requires further improvement in visual design and layout to increase its attractiveness and readability for students.

When compared with previous studies, the present findings reveal both consistencies and distinctions regarding the development of entrepreneurship-based teaching materials. Similar to the results reported by Suticha and Abidin, entrepreneurship-oriented teaching resources are generally valid in terms of integration and content structure; however, these authors noted that visual presentation is often neglected during the development process, which can limit student engagement and the overall effectiveness of the materials [23]. Highlighted that while the structural organization of biotechnology modules is robust, improvements in layout and visual clarity are necessary to optimize student motivation and learning outcomes [24].

These observations are echoed in other research, which emphasizes that although content validity and structural feasibility are frequently achieved, the visual and design aspects of teaching materials require greater attention to fully support student learning [25]. For instance, studies on entrepreneurship modules and economic teaching materials have found high scores for content and presentation validity, yet also stress the importance of attractive, clear, and well-organized visual elements to enhance usability and student interest [26].

In conclusion, the construct validity analysis demonstrates that the developed teaching material is structurally feasible and valid for use in high school biology learning. The main strength lies in the high integration between components, while the limitation is in the presentation format, which still needs refinement. The implication of this result is that future improvements should focus on enhancing visual design and layout, such as the use of more attractive graphics, colors, and systematic arrangements, to further support the effectiveness of the product in classroom learning.

Content Validity Results

The content validity analysis was conducted to assess the suitability of the developed teaching material in terms of accuracy, completeness, and relevance to learning objectives and student contexts. This stage is crucial to ensure that the material not only covers biotechnology concepts but also incorporates entrepreneurial elements in a manner that is both scientifically accurate and pedagogically suitable. Three expert validators assessed the

content using a questionnaire, and the results were analyzed with Aiken's V Index. The detailed findings are presented in Table 2.

Table 2. Content Validity Results

No	Rated aspect	Aiken's Index	Category
1	Suitability of Material with CP and Objectives	0.69	Valid
2	Truth and Accuracy of Material	0.70	Valid
3	Integration and interconnectedness of material	0.75	Valid
4	Completeness and Adequacy of Information	0.69	Valid
5	Relevant to Student Context and Environment	0.63	Valid

The results in Table 2 indicate that all aspects of content validity achieved scores within the valid category, with Aiken's Index values ranging from 0.63 to 0.75. The highest score was recorded for the integration and interconnectedness of content (0.75), indicating that the material effectively connected biotechnology topics with biopreneurship in a coherent and meaningful manner. This is important because content integration provides students with a holistic understanding of how scientific knowledge can be applied in real-life entrepreneurial contexts. On the other hand, the lowest score was obtained in relation to the student's context and environment (0.63). Although categorized as valid, this aspect indicates that the material still requires improvement in adapting examples and case studies to be more closely related to students' daily experiences.

When compared with previous studies, the findings on biopreneurship-based teaching materials show both alignment and divergence regarding contextual adaptation and content validity [27]. Several studies confirm that these materials are scientifically accurate and pedagogically sound, with high validity scores in content, structure, and language, making them suitable for high school biology learning [28]. The integration of biotechnology and entrepreneurial concepts is consistently identified as a major strength, supporting the development of students' scientific literacy, entrepreneurial motivation, and life skills [18]. This integration is in line with the objectives of 21st-century education, which not only emphasizes knowledge acquisition but also the cultivation of creativity, problem-solving abilities, and the capacity to apply science in real-world contexts.

However, contextual adaptation remains a recurring challenge. Research highlights that while modules are valid in terms of accuracy and integration, further refinement is often needed to make the content more relatable to students' social and environmental contexts [17]. For example, some studies report that although the teaching materials are well-structured and effective in increasing student creativity and cognitive abilities, they may lack sufficient contextual relevance to students' everyday lives and local environments [29]. This limitation can reduce the effectiveness of learning because students may perceive the material as abstract and disconnected from their lived experiences. As a result, the full potential of biopreneurship-based teaching materials in fostering independence and entrepreneurial spirit is not optimally realized.

In contrast, other research demonstrates that contextual relevance can be a strong aspect when materials are specifically designed with local examples and real-life applications, leading to higher student engagement and practical skill development [30]. Studies that incorporate community-based projects, local biological resources, and culturally relevant entrepreneurial practices often show better outcomes in terms of both academic achievement and entrepreneurial interest. This indicates that the effectiveness of biopreneurship-based teaching materials is highly dependent on the extent to which they are contextualized to students' realities.

Readability Test Results

The readability test was conducted to evaluate whether the language and sentence structures used in the developed biopreneurship-based biology teaching material were suitable for high school students. Readability is an important aspect to ensure that students can easily comprehend the information provided without unnecessary complexity. The Flesch-Kincaid Grade Level formula was used to measure the readability level of the text. The results are presented in Table 3, which shows the readability scores across different sections of the material.

Table 3. Flesch-Kincaid Grade Level Readability Test Results

No	Topic	Score	Category	Age (Year)
1	P-1	50.2	easy to understand	17-18
2	P-2	26.3	difficult to understand	20-21
3	P-3	24.4	difficult to understand	20-21
4	P-4	51.2	easy to understand	18-19
5	P-5	34.1	easy to understand	20-21
6	P-6	35.0	easy to understand	19-20
7	P-7	34.3	easy to understand	18-19
8	P-8	56.3	easy to understand	15-16
9	P-9	40.8	easy to understand	18-19
10	P-10	37.0	easy to understand	19-20

The results in Table 3 show that the readability scores of the developed material ranged from 24.4 to 56.3. Most sections fall into the easy-to-understand or moderate category, indicating that the text is generally suitable for high school students. The highest score was obtained in the section Examples of Conventional Biotechnology Products (56.3), which suggests that the topic was presented in simple and familiar language for students aged 15–16. On the other hand, the lowest score was found in the Modern Biotechnology section (24.4), categorized as difficult to understand and requiring the comprehension level of university students. This finding suggests that certain aspects of the content should be simplified further to align with the reading abilities of high school learners.

The issue of readability in high school biology materials is a common concern, as many students struggle with technical terminology and complex sentence structures, which can hinder comprehension and engagement [31]. Studies have shown that biology textbooks and modules often fall into the "medium difficulty" category, indicating that while some sections are accessible, others remain challenging for students at this level [32]. For example, research on electronic and printed biology textbooks found that certain texts were appropriate for the intended grade, but others were either too easy or too difficult, highlighting inconsistencies in readability across different materials [33].

Efforts to improve readability have focused on simplifying language, shortening sentences, and reducing the use of highly technical terms, all while maintaining scientific accuracy. The integration of contextual examples and local wisdom, as seen in the development of e-books and digital teaching materials, has been shown to enhance both readability and student engagement by making content more relatable and easier to understand [34]. Additionally, the use of visuals, diagrams, and interactive elements in digital resources further supports comprehension and increases students' positive responses to the material [29].

In summary, while the majority of high school biology teaching materials are generally suitable for students, specific sections, particularly those covering advanced topics, may require further revision to enhance accessibility. Simplifying language, incorporating more visuals, and providing real-life examples are recommended strategies to enhance readability and support student learning [35].

Conclusion

Biopreneurship-based biology teaching materials are valid and suitable for high school students, aligning with the curriculum and student needs, providing engaging presentations, being relevant to the students' environment, and encouraging an entrepreneurial spirit in biology. Biopreneurship-based biology teaching materials are suitable for high school students in terms of construct and content validity.

Author's Contribution

Nur Hasanah: the research design, material development, and manuscript writing. A. Wahab Jufri and Lalu Japa: contributed to the conceptual framework, validation of the biopreneurship components, and critical review of the manuscript.

Acknowledgements

The author expresses all praise and gratitude to God Almighty for all His abundant blessings and gifts. I would like to express my gratitude to my supervisor for the guidance and assistance provided. I also extend my gratitude to all parties who supported this research.

References

[1] A. Hassani and P. Gabrieli, "Utilization of instructional materials in supporting biology learning in Tanzania," *Science Education Quarterly*, vol. 2, no. 1, pp. 1–23, Jan. 2025, doi: 10.55056/seq.830.

[2] N. H. Green, M. Walter, and B. N. Anderton, "The Explorer's Guide to Biology: A Free Multimedia Educational Resource to Promote Deep Learning and Understanding of the Scientific Process," *J Microbiol Biol Educ*, vol. 23, no. 1, Apr. 2022, doi: 10.1128/jmbe.00257-21.

[3] H. Sayan and H. Mertoğlu, "Equipment Use in Biology Teaching," *Journal of Educational Issues*, vol. 6, no. 1, p. 357, Jun. 2020, doi: 10.5296/jei.v6i1.17042.

[4] I. Damopolii, J. Hendreik Nunaki, E. Nusantari, and N. Youla Kandowangko, "Designing Teaching Material Oriented Towards Inquiry-Based Learning in Biology," 2018.

[5] B. N. Lee, "Digital Tools & Inquiry-Based Learning in History Education," *Muallim Journal of Social Science and Humanities*, vol. 7, no. 4, pp. 78–88, 2023, doi: 10.33306/mjssh/255.

[6] L. Retnowati, S. Sugianto, and S. Alimah, "The Development of Integrated Biology-Entrepreneurship Learning Design Based STEAM," *Journal of Innovative Science Education*, vol. 10, no. 2, pp. 124–129, [Online]. Available: http://journal.unnes.ac.id/sju/index.php/jise

[7] B. Supriatno, D. Kusumawaty, T. E. Tallei, T. B. Emran, and T. Suwandi, "Introducing CAPAB(L)E: A Learning Model to Promote Prospective Biology Teacher's Entrepreneurship Skills," *Jurnal Pendidikan IPA Indonesia*, vol. 12, no. 2, pp. 265–275, Jun. 2023, doi: 10.15294/jpii.v12i2.40741.

[8] L. Tang and J. Zhang, "Construction of Biological Experiment Curriculum System in the Context of Innovation and Entrepreneurship Education," *Journal of Contemporary Educational Research*, vol. 8, no. 9, 2024, [Online]. Available: http://ojs.bbwpublisher.com/index.php/JCER

[9] M. Gill, H., Ahsan, M., Khalil, Y., Feng, V., Pearce, J., Sharma, T., Radwan, M., Boucinha, A., & Kærn, "The BioExperience Research and Entrepreneurship Challenge: An iGEM-inspired applied research program for BIOSTEM talent and skills development," *Front Bioeng Biotechnol*, vol. 10, no. 1, pp. 1–18, Nov. 2022, doi: 10.3389/fbioe.2022.1046723.

[10] S. Samsudin, "Entrepreneurship Education Assistance Based On Local Wisdom To Increase

Business Interest Among High School Students," *Journal of Community Engagement in Economics*, vol. 02, no. 01, pp. 46–56, 2024, [Online]. Available: https://www.journal.uaindonesia.ac.id/index.php/jcee/article/view/844

[11] M. Muhammad, "Integrating Concept of Entrepreneurship Into Science Education," *IJECA (International Journal of Education and Curriculum Application)*, p. 153, 2018, doi: 10.31764/ijeca.v0i0.1982.

[12] L. L. Gao, S. W. C. Chan, L. You, and X. Li, "Experiences of postpartum depression among first-time mothers in mainland China," *J Adv Nurs*, vol. 66, no. 2, pp. 303–312, Feb. 2010, doi: 10.1111/j.1365-2648.2009.05169.x.

[13] R. Budi Indaryanti, B. Murtiyasa, and B. Soemardjoko, "4D Research and Development Model: Trends, Challenges, and Opportunities Review," 2025. [Online]. Available: http://ejurnal.ubharajaya.ac.id/index.php/JKI

[14] Z. Lyu, J. Wang, and Y. Chen, "4D printing: interdisciplinary integration of smart materials, structural design, and new functionality," Sep. 01, 2023, *Institute of Physics*. doi: 10.1088/2631-7990/ace090.

[15] H. Sun, X., Yue, L., Yu, L., Shao, H., Peng, X., Zhou, K., Demoly, F., Zhao, R., & Qi, "Machine Learning-Evolutionary Algorithm Enabled Design for 4D-Printed Active Composite Structures," *Adv Funct Mater*, vol. 32, no. 10, pp. 1–34, Mar. 2022, doi: 10.1002/adfm.202109805.

[16] B. Subeshan, Y. Baddam, and E. Asmatulu, "Current progress of 4D-printing technology," Aug. 01, 2021, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1007/s40964-021-00182-6.

[17] Y. Putri, R. Y. Gloria, and A. Mulyani, "The Effectiveness of Bioentrepreneurship Learning Using Comics on the Sub Concepts of Angiosperms for High School Students," *Scientiae Educatia*, vol. 7, no. 2, p. 159, Jan. 2019, doi: 10.24235/sc.educatia.v7i2.3154.

[18] I. P. Artayasa, M. A. Rosyidi, M. M. A. Kechik, and M. Yustiqvar, "The Impact of Biopreneurship Project-Based Science Learning on Students' Entrepreneurial Creativity," *Jurnal Pendidikan IPA Indonesia*, vol. 13, no. 3, pp. 436–446, 2024, doi: 10.15294/jpii.v13i3.11055.

[19] X. Z. A. Hidayat, I. P. Artayasa, and A. W. Jufri, "Feasibility of Biopreneurship Project-Based Science Module for Students in the Bagek Kembar Ecotourism Area," *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 10, pp. 7756–7764, Oct. 2024, doi: 10.29303/jppipa.v10i10.9278.

[20] A. Damayanti, Y. S. Rahayu, and P. Yakub, "Project-based learning e-book with Indonesian local wisdom supporting SDGs to facilitate students' bioentrepreneurship skills," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 10, no. 3, pp. 1002–1010, Nov. 2024, doi: 10.22219/jpbi.v10i3.36546.

[21] A. Kurnia, L. Lutfi, and R. Haris, "Internalisation of Entrepreneurial Character through Augmented Reality Integrated Biopreneurship Learning for Students," *DIDAKTIKA : Jurnal Pemikiran Pendidikan*, vol. 31, no. 1, p. 21, Feb. 2025, doi: 10.30587/didaktika.v31i1.9094.

[22] F. Yulastri, A., Hidayat, H., , G., Islami, S., & Edya, "Developing an Entrepreneurship Module by Using Product-Based Learning Approach in Vocational Education," *International journal of environmental and science education*, vol. 12, no. 5, pp. 1097–1109, 2017.

[23] M. Mispandi and Muh. Fahrurrozi, "Development of Economics Teaching Materials Based on Entrepreneurial Values as A Learning Media," *Economic Education Analysis Journal*, vol. 12, no. 1, pp. 1–9, Mar. 2023, doi: 10.15294/eeaj.v12i1.66513.

[24] H. Syarifah, Harwanto, and R. D. Rusmawati, "Development of Teaching Materials Using LEAD Series (Listen, Explore, Analyze, and Do) Craft and Entrepreneurship Subjects Based on Local Potentials Bawean Island, Gresik Regency Assisted by Google Classroom.," *Jurnal Penelitian Pendidikan IPA*, vol. 9, no. 7, pp. 5406–5411, Jul. 2023, doi: 10.29303/jppipa.v9i7.4097.

[25] B. Badawi, A. Prihatmojo, E. Elizar, and D. S. Kuning, "Need Assessment of Islamic Teaching Materials Character-Based Entrepreneurship in University," *Al-Hayat: Journal of Islamic Education*, vol. 7, no. 1, p. 75, Apr. 2023, doi: 10.35723/ajie.v7i1.330.

[26] K. Ellborg, "In the Eye of the Beholder: Visualising Students' Implicit Entrepreneurship Theories," *Entrepreneurship Education and Pedagogy*, vol. 6, no. 3, pp. 458–480, Jul. 2023, doi: 10.1177/25151274221130005.

[27] F. S. F. Shiyamsyah, Y. Yuliani, and Y. S. Rahayu, "Validity and practicality of project-based learning teaching modules to train life skills Era Society 5.0 (bioentrepreneurship)," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 10, no. 1, pp. 96–106, Mar. 2024, doi: 10.22219/jpbi.v10i1.30141.

[28] N. Agustin, M. Ibrahim, and W. Widodo, "Pengembangan Bahan Pembelajaran IPA Berbasis Biotechnopreneurship untuk Melatih Life Skills Siswa SMP," 2016. [Online]. Available: http://ojs.ikipmataram.ac.id/index.php/prismasains/

[29] Ş. Gül and P. D. Kargin, "Text Readability Level Investigation about Biology Subjects-related Units in 'Science 7 Textbook,'" *Journal of Science Learning*, vol. 4, no. 4, pp. 347–356, Aug. 2021, doi: 10.17509/jsl.v4i4.33252.

[30] C. D. Gould, "The readability of school biology textbooks," *J Biol Educ*, vol. 11, no. 4, pp. 248–252, Dec. 1977, doi: 10.1080/00219266.1977.9654155.

[31] Ş. Gül, "Determination of the Readability Levels of the Texts Related to Biology Topics in the Science Textbook-6," *Open Journal for Educational Research*, vol. 5, no. 1, pp. 77–90, Jun. 2021, doi: 10.32591/coas.ojer.0501.07077g.

[32] U. Mursyadah, "Tingkat Keterbacaan Buku Sekolah Elektronik (BSE) Pelajaran Biologi Kelas X SMA/MA," vol. 1, no. 4, 2021, [Online]. Available: http://www.bse.depdiknas.go.id.

[33] Y. Ivaningtias, S. Indana, and N. K. Indah, "Validity of problem-based learning biodiversity e-book integrating Ruwat Petirtaan Jolotundo's local wisdom for science literacy," *JPBI (Jurnal Pendidikan Biologi Indonesia)*, vol. 10, no. 3, pp. 874–886, Nov. 2024, doi: 10.22219/jpbi.v10i3.36690.

[34] K. Zhadan, Y. Romanenko, V. Panchenko, G. Mukhamedzhanova, V. Dundukov, and D. Shaikina, "Teaching biology in senior grades of secondary school: testing an electronic textbook," *Journal of Educational Sciences*, vol. 80, no. 3, pp. 163–174, 2024, doi: 10.26577/JES2024v80.i3.013.

[35] Arica Pavitasari, Dian Puspita, and Mar'atus Sholihah, "Pengembangan Virtual Laboratory pada Materi Inovasi Teknologi Biologi untuk Meningkatkan Pemahaman Konsep Siswa Kelas X SMA," *Jurnal Cakrawala Pendidikan dan Biologi*, vol. 2, no. 1, pp. 151–163, Mar. 2025, doi: 10.61132/jucapenbi.v2i1.255.