

Development of Flipbook E-Module of Biofuel Practice as an Alternative Fuel with Guided Inquiry Model to Improve Science Process Skills and Analytical Thinking of High School Students

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ABSTRACT The need for alternative energy is urgent due to finite fossil fuel supplies and the threat of climate change. This has led to increased interest in biofuels, with a particular focus on producing bioethanol from materials such as water hyacinth and soybean hulls. The utilization of waste is important for reducing CO₂ emissions and providing alternative energy sources. High school students' understanding and practical skills in biological technology innovations, particularly biofuels, remain limited. The concept of renewable energy (biofuel) needs to be instilled in students through practical experiments. The purpose of this research is to create and evaluate a practical experiment. It uses a flipbook e-module on biofuels with a guided inquiry model. The goal is to boost 10th-grade students' knowledge, skills, and analytical thinking. For this research, the ADDIE model was applied within the Educational Design Research (EDR) framework. Flipbook e-module practical learning materials align with the components of practical learning by integrating text, images, videos, and animations, designed to support self-directed and interactive learning while optimizing multimedia principles in education. The research findings show that the product we developed is highly viable, with an average score of 3.6. The application of the product in biofuel laboratory learning, as an alternative fuel, through guided inquiry has been shown to enhance students' Science Process Skills (SPS) and analytical thinking abilities. The MANOVA test results ($\alpha = 0.00$) showed a significant difference between the two groups, with the experimental group performing better. This suggests that using the flipbook e-module for the biofuel practical session successfully improved students' science process skills and analytical thinking in biological technology innovation.

Keywords Analytical thinking, Biofuel practical lessons, Flipbook e-module, Biofuel practical lessons, guided Inquiry, Science process skills.

1. INTRODUCTION

The importance of biofuels has increased significantly in recent years due to dwindling oil reserves, energy security concerns, and global issues such as climate change, greenhouse gas emissions, and sustainability (Mahapatra et al., 2021). Significant increases in energy demand, driven by technological advancements, have led to excessive consumption of fossil fuels today (Hafeez et al., 2020). Global climate change is primarily caused by carbon dioxide emissions from fossil fuels (Wang & Azam, 2024). CO₂ emissions from fossil fuels are the primary cause of global climate change (Chavan et al., 2024). There has been a nearly 60% increase from 22.7 billion tons in 1990 to approximately 36.44 billion tons in 2019. Carbon dioxide emissions from fossil fuels such as natural gas, coal, and petroleum increased by 57.5%, from 21.8 billion tons to

34.33 billion tons, over the same period (Statistical Review of World Energy, 2022).

The development of biofuels has emerged as a crucial biotechnology solution for the future of renewable energy (Nath, 2024). Biofuels are fuels derived from organic matter, including plants and agricultural by-products, to replace traditional petroleum fuels (Demirbas et al., 2016). One of the most promising types of biofuels is bioethanol. Bioethanol is environmentally friendly, typically derived from lignocellulosic waste (food waste) (Chavan et al., 2024) with a 35% oxygen content. Through the fermentation of sugars, starches, and cellulose using yeast or bacteria, the oxygen in the substrate enables more

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efficient combustion, resulting in reduced hydrocarbon emissions (Mihajlovski et al., 2021; Nayab et al., 2022). Ethanol is primarily produced by yeast, which ferments carbohydrates in the absence of oxygen. Ethanol has 33% less energy than gasoline, but its energy density is still higher, with an 11.3 MJ/l difference (Mahapatra et al., 2021). This allows it to be stored as pure fuel, enabling it to be stored in its pure fuel form (Restiawaty et al., 2020).

Using food crops as the primary raw material for bioethanol production creates competition with human food needs. Therefore, lignocellulosic sources have emerged as an alternative feedstock solution. Lignocellulosic biofuel feedstocks for bioethanol production include water hyacinth and soybean hulls. Water hyacinth (*Eichhornia crassipes* Mart.) is an invasive aquatic weed whose uncontrolled growth can pose problems for aquatic ecosystem health, including blocking waterways, accelerating sedimentation, and causing river water evaporation. Therefore, it is necessary to utilize it as a bioethanol feedstock by converting it into a renewable, environmentally friendly alternative energy source. Similarly, soybean hulls are a potential agro-industrial waste/residue produced in large quantities by the tempeh industry, which are currently discarded and partially used as animal feed.

Water hyacinth (*Eichhornia crassipes* Mart.) and soybean hulls have a lignocellulosic structure that can be converted into reducing sugars and have the potential to be used to produce bioethanol, an alternative fuel. Lignocellulose is considered the most advantageous source of bioethanol due to its abundant availability and relatively low cost. Water hyacinth contains 18% cellulose, 48% hemicellulose, and 3.5% lignin (Naufala et al., 2015), while soybean hulls contain cellulose (42–49%), hemicellulose (29–34%), and lignin (1–3%) (Jaufani Rahman et al., 2021). The bioethanol production process from lignocellulose involves four stages: pretreatment to break down lignin and damage cellulose; hydrolysis to convert cellulose into glucose; fermentation to convert glucose into ethanol with the help of microorganisms; and distillation for ethanol purification. Echoing the findings of Febriyanti et al. (2016) and Handayani et al. (2017), water hyacinth and fruit peel waste can be repurposed as lignocellulosic feedstocks for bioethanol production.

The concept of utilizing water hyacinth and fruit peel waste as alternative fuels needs to be instilled in school communities, particularly students. This aims to build knowledge and practical skills regarding biofuels as a sustainable alternative to fossil fuels (Handayani et al., 2017). The instillation of these concepts and skills is ideally carried out through scientific activities, namely, practical work. Laboratories, as observational activities for hypothesis testing, can optimize the development of cognitive, psychomotor, and affective learning outcomes among students. (Agnesa & Sari, 2024; Harahap et al., 2022;

Hindriana, 2016; Ramadhan & Suyanto, 2020). One subject in school that is highly relevant for linking laboratory experiments on the utilization of waste as biofuel is Biology.

Biology education is one of the science subjects that emphasizes hands-on experience to develop scientific skills and competencies (Ramadhan & Suyanto, 2020; Zuanita & Purwanti, 2018). Biology is not only about theory but also about implementing theory through practical experiments (Sabilu et al., 2024). Practical experiments are crucial for the success of Biology learning, as they can develop students' abilities to think, analyze, solve problems, prove, and draw conclusions from the material studied (Hendriyani et al., 2020). Knowledge of biofuel as an alternative fuel is not sufficient; students need to apply these concepts through practical laboratory experiments. The material on biological technology innovation in the biology subject is relevant to the laboratory experiment on biofuel as an alternative fuel. According to the 2024/2025 Merdeka Curriculum Learning Objectives Sequence (LOS) for 10th-grade high school students, the learning goals for biological technology innovation must include understanding analytical thinking and Science Process Skills (SPS). Following the findings of Duda et al. (2019) and Wiwin & Kustijono (2018), laboratory experiments are crucial for boosting students' conceptual thinking and SPS. Therefore, as argued by Karacop & Diken (2017) and Listika Yusi Risnani (2017), biology curricula in schools should be developed to train and improve these skills.

Developing students' complex abilities to understand knowledge, find concepts, and independently build facts, concepts, and values is the primary focus of Science Process Skills (SPS) instruction (Duda et al., 2019; Rauf et al., 2013; Siahaan et al., 2017). Science Process Skills (SPS) are crucial for scientific inquiry, enabling students to produce scientific products, master the scientific method, and think like scientists (Dwianto et al., 2017; Handayani et al., 2018; Nugraheni & Wuryandani, 2018; Ristanto et al., 2018). In addition to scientific process skills, mastering knowledge of scientific concepts is crucial. Through laboratory activities, analytical thinking skills can be developed. Analytical thinking skills are mental processes involving analysis, assessment, evaluation, comparison, and problem-solving of abstract issues (Anwar, 2014; Phurikultong & Kantathanawat, 2022; Ramadhan & Suyanto, 2020). Analytical thinking is categorized as a Higher Order Thinking Skill (HOTS), the fourth domain of Bloom's Taxonomy revision (Buch et al., 2021). Sternberg (2006) defines analytical thinking as the capacity to (1) analyze by breaking down problems, (2) explain a system's function or a solution's rationale (judge/explaining), (3) compare and contrast different elements, or (4) evaluate and critique an object's features. According to Blegur et al. (2023), analytical thinkers are problem-solvers who can find careful, reflective solutions.

They have the skill to investigate and clarify the key facts of a problem rather than acting impulsively.

Science Process Skills (SPS) and analytical thinking are interrelated. Through practical work and active learning in the laboratory, curiosity is encouraged, SPS is trained through direct experience, and students build concepts and theories while developing creative, critical, and analytical thinking to solve problems (Prajoko et al., 2017; Ade et al., 2017). Teachers play a crucial role in teaching SPS and analytical thinking through the scientific learning process, supported by interconnected instructional components such as instructional materials, media, learning models, methods, and evaluations (Pane & Dasopang, 2017). One learning model with teacher guidance for teaching SPS and analytical thinking is the guided inquiry model. The guided inquiry model, with the teacher acting as a facilitator, effectively enhances both of these skills. This aligns with the views of Rauf et al. (2013) and Krohmer & Budke (2018), who argue that this model can lead to successful teaching and learning.

Inquiry is a continuous investigative process through experimental activities that motivate students to understand, not just memorize, scientific concepts, including asking questions, researching, translating, presenting, and reflecting (Awaliyah et al., 2023; Jeffery et al., 2016; Nurwahid et al., 2024). The guided inquiry model is learner-centered, with the teacher acting as a facilitator who guides learners' exploration of ideas and answers to their questions based on their capacities (Awaliyah et al., 2023; Baharom et al., 2020). According to research by Erlina et al. (2022) and Baharom et al. (2020), the guided inquiry learning model can enhance students' scientific process skills and improve their analytical thinking (Maulani et al., 2016; Ramadani et al., 2021). Additionally, the use of effective learning media is crucial to support educators and improve students' understanding (Yendrita & Syafitri, 2019), as ineffective media can lead to lower learning outcomes and reduced student engagement in the learning process.

Based on initial observations of 102 tenth-grade students, 56.9% had difficulty understanding biology, and 40 students found biological technology innovations most challenging. These difficulties are primarily due to foreign terms (68.6%), memorization (48%), abstract material (28.4%), uninteresting media (22.5%), and lack of applicability (19.6%). Teachers predominantly use textbooks (70.6%) and worksheets (55.9%), with e-modules accounting for only 17.6%. Although technology is used, its integration with practical work and scientific process skills remains minimal, and practical work is generally conventional.

The results show that teachers in schools still use conventional practical guides or modules, consistent with the findings of Furqan et al. (2016). This condition

negatively impacts students' ability to apply scientific approaches, conduct experiments, and produce scientific works (Romadona et al., 2022; Romayanti et al., 2020). Conventional modules, which only contain instructional statements and tasks, hinder the development of students' process skills and analytical thinking (Ningsi et al., 2021). Teachers reported that the main challenges include students' inability to categorize problems, plan experiments (only following instructions), apply concepts to different problems, and explain and discuss experimental results. Therefore, the development of better modules or laboratory guides is essential to support the implementation of effective laboratory methods.

One effort to develop learning media is to create guided inquiry-based e-laboratory modules, designed according to learning theory to support learning objectives. Electronic-based learning can be developed to optimize students' learning flexibility. E-laboratory modules are innovative digital media that provide guidelines for preparing, implementing, analyzing, and reporting experiments. This medium is designed to enhance students' learning abilities and independence, and presents content in various formats such as text, images, videos, simulations, and attractive designs (Puspitasari, 2019; Prayudha, 2017). With high flexibility and interactivity, along with internet access (Herditiya et al., 2023), it can increase students' interest in learning (Herawati & Muhtadi, 2018).

Flipbook-based learning modules are one type of practical e-module that can be implemented. Flipbooks, as audiovisual media (sound slides), combine text, animation, video, and sound in a 3D e-book format, providing a reading experience on a monitor screen similar to turning physical pages (Oktaviani & Arini, 2021). Such electronic learning can optimize the flexibility of student learning. The development of flipbook e-modules for practical learning using an inquiry-based model aims to enhance students' Science Process Skills (SPS) and analytical thinking. This e-module integrates instructional materials and practical videos into a single interactive electronic module that has the potential to enhance students' experimental abilities independently, especially in biofuel experiments. This study explores how flipbook e-module-based teaching materials stimulate science process skills (SPS) and enhance students' analytical thinking in biology, technology, and innovation.

2. METHOD

The research methodology for this study was Educational Design Research (EDR), specifically employing the ADDIE model. The ADDIE model, as described by Branch (2009), involves a sequence of steps: analysis, design, development, implementation, and evaluation. The phases of the ADDIE Model instructional

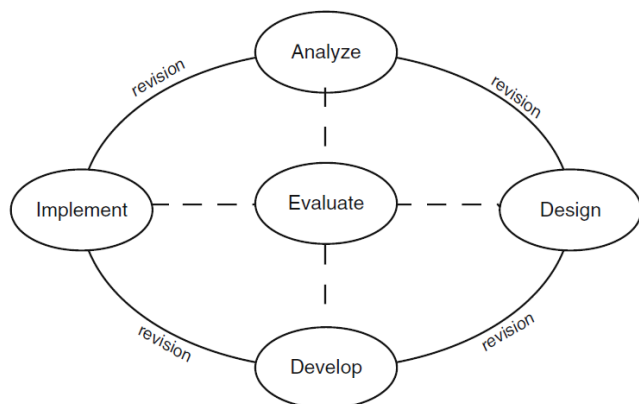


Figure 1 ADDIE model

Table 1. Control Group Pretest-Posttest Design

Class	Pre-test	Treatment	Post-test
E (R)	O _{A1} O _{B1}	X	O _{A2} O _{B2}
C (R)	O _{A1} O _{B1}	O	O _{A2} O _{B2}

design framework, as described by Branch (2009), are shown in Figure 1.

From March to May 2025, a study was carried out at a high school in Jakarta, Indonesia. Using cluster random sampling, we assigned 53 students to an experimental group and 53 to a control group at SMAN 99 Jakarta. The experimental class used a flipbook e-module for biofuel practicals, employing a guided inquiry approach. In contrast, the control class followed a traditional format, with a printed module and a discovery-learning method. The research used a pretest-posttest design with a control group, as shown in Table 1, in which the pretest was administered before the learning intervention and the posttest was administered after the intervention.

E: Experimental group (practicum e-module & guided inquiry model)

C: Control group (practicum module & discovery learning model)

R: Sample in each class

X: Treatment (practicum e-module with guided inquiry learning model)

O: Control (printed practicum module with discovery learning model)

OA1: Pretest for Science Process Skills (SPS)

OA2: Posttest for Science Process Skills (SPS)

OB1: Pretest for Analytical Thinking

OB2: Posttest for Analytical Thinking

Data collection was carried out using validation instruments, and product testing was conducted before and after product development. The first step was to distribute the student and teacher needs analysis instruments via Google Forms. The student needs analysis instrument used a questionnaire containing 24 statement items, grouped into four elements: perceptions regarding biology learning; supporting resources for biology learning; students'

knowledge and interaction with gadgets (smartphones); and views on the flipbook practicum e-module with a guided inquiry model as the teaching material. Meanwhile, the teacher needs analysis instrument was distributed to 3 Biology teachers to gather an overview of biology learning practices in the school, the teaching materials frequently used, constraints in the teaching process, and the teachers' views on the development of the flipbook practicum e-module teaching material content.

Subsequently, data collection on product validation test results was conducted by subject matter experts, media experts, and language experts after media development by two validators. After the product was validated, a small-group product trial was conducted with 15 students, and a large-group trial was conducted with 53 students from Class X of SMA N 99 Jakarta. The small-group trial was conducted to assess responses to the e-learning practical module before revision and testing on the large group. In contrast, the large-group trial was conducted to assess the effectiveness of the learning media in improving scientific process skills (SPS) and analytical thinking. After the media trial on the large group, an analysis of the large group's responses to the developed media was conducted.

Data collection was conducted before and after product development. Initial data was obtained from a needs analysis questionnaire for students and teachers. Subsequently, validation data were collected from two expert validators (content, media, and language). After validation, product trial data were collected from the small group of 15 students and the large group of 53 Grade X students. Pre- and post-trials were conducted during the trial to assess effectiveness. The needs analysis questionnaire for students consisted of 24 items, and the one for teachers, 25. The expert validation questionnaire consisted of 21 items for content, 21 items for media, and 15 items for language. The product trial questionnaire for students consisted of 18 items, and for teachers, 20 items. All questionnaires used a Likert scale. The Science Process Skills (SPS) instrument was a multiple-choice test with 33 items designed to assess different dimensions. The analytical thinking instrument consisted of 15 multiple-choice questions, each representing a dimension of analytical thinking. These instruments were administered as pre-tests at the first meeting and post-tests at the last meeting, with student scores evaluated on a scale of 1 to 100.

The Science Process Skills (SPS) instrument was a 33-item multiple-choice test. Each item was designed to assess specific SPS dimensions and their indicators from Dacumos (2021), as detailed in Table 2. The Analytical Thinking instrument was a 15-item multiple-choice test. Each item was designed to assess specific analytical thinking dimensions and their indicators, as detailed, based on Sternberg's Table 3.

The data analysis was carried out using Microsoft Excel and SPSS 27, which included validity, reliability, descriptive, prerequisite, and effectiveness tests. The validity of the SPS and analytical thinking instruments was evaluated using Pearson product-moment correlations, ensuring that the instruments accurately measure the intended function and that each item is valid. An item was considered valid if its calculated r value was greater than the r -table value. To ensure the consistency and reliability of our measurements for both the SPS and analytical thinking instruments, we calculated Cronbach's alpha. Descriptive analysis involved quantitative data from various sources. These scores were processed statistically, both numerically and graphically. A specific scale was used to interpret the feasibility test scores from experts, students, and teachers from Ratumanan & Laurens (2011) in Table 4.

For product trial responses, a percentage formula (score obtained / maximum score) was used, with interpretations ranging as follows: (Table 5)

Prerequisite tests were conducted to meet the assumptions required for the chosen effectiveness test, MANOVA. The analysis relies on several key assumptions: that there are at least two dependent variables measured on an interval or ratio scale, and that there is at least one independent variable with at least two separate categorical groups. It also requires that observations are independent within these groups, that the sample sizes are sufficient, and that the data follow a multivariate normal distribution (confirmed if the Shapiro-Wilk test p -value is >0.05). Furthermore, a linear relationship must exist between each pair of dependent variables within each group, and the variance-covariance matrices must be homogeneous (as indicated by a Box's M test with $p > 0.05$).

A MANOVA was conducted after prerequisite tests to assess how the flipbook e-module impacted students' Science Process Skills (SPS) and analytical thinking regarding biofuel production as an alternative fuel. MANOVA was applicable if certain conditions were met, such as the presence of significant differences. This test compared pretest and posttest scores at the $\alpha=0.05$ significance level to evaluate the product's effectiveness (Tables 6&7). The MANOVA test was conducted to determine whether the increase in pretest-posttest results between the experimental and control classes was significant. The increase in students' SPS and analytical thinking was quantified using Normalized Gain (N-Gain), calculated by Hake's formula.

$$n - gain = \frac{\text{score posttest} - \text{score pretest}}{\text{score ideal} - \text{score pretest}}$$

Table 2. Science Process Skills (SPS) Instrument

No	Science Process Skill	Items	Number of Items
1	Defining and Identifying Variables	2, 6, 9	3
2	Formulation of Scientific Questions	5, 19, 21	3
3	Designing Experiments	23, 24, 25	3
4	Communication of Scientific Procedure	4, 10, 20	3
5	Collection of Data	11, 13, 26	3
6	Organization of Data	3, 18, 16	3
7	Creation of Visual Representation	28, 29, 30	3
8	Analysis of Data	7, 8, 27	3
9	Conclusion/Problem Solving	12, 14, 15	3
10	Use of Models to Explain Results	31, 32, 33	3
11	Use of Scientific Knowledge to Communicate Results	1, 17, 22	3
Total Items			33

Table 3. The Analytical Thinking instrument

No.	Dimension	Items	Number of Items
1	Analyze	1, 3, 5, 10	4
2	Explain or Judge	2, 7, 9, 15	4
3	Compare and Contrast	4, 6, 8, 14	4
4	Evaluate	11, 12, 13	3
Total Items			15

Table 4. Interpretation of the Results of the Feasibility Test of the e-module Practical Work flipbook

Interval	Criteria	Description
3,25 – 4,00	Very Valid	Can be used without revision
2,50 – 3,25	Valid	Can be used with minor revisions
1,75 – 2,50	Less Valid	Can be used with extensive revisions
1,00 – 1,75	Not Valid	Cannot be used, requires consultation

Table 5. Criteria for Interpreting Student and Teacher Test Scores

Score (%)	Category
81 – 100	Very Good
61 – 80	Good
41 – 60	Sufficient
21 – 40	Insufficient
0 – 20	Very insufficient

3. RESULT AND DISCUSSION

Based on the ADDIE model (Branch, 2009), the development of the practical work e-module flipbook was

Table 6. Standards for Normalized Gain

Gain (N)	Interpretation
$N \geq 0.70$	High
$0.30 < N < 0.70$	Moderate
$N < 0.30$	Low

Table 7. N-Gain Effectiveness Interpretation Category

N-Gain Effectiveness	Interpretation Category
Percentage	Interpretation
< 40 %	Ineffective
40% – 55%	Less Effective
56% – 75%	Moderately Effective
> 76%	Effective

carried out through five stages: analysis, design, development, implementation, and evaluation. The study involved students, teachers, and subject matter experts. The detailed outcomes from each stage of this research and development project are outlined below:

3.1 Analysis

During the analysis phase, data were collected from both student and teacher needs assessments. The student needs assessment aimed to thoroughly investigate learning requirements, student characteristics, subject matter, and learning objectives to design relevant, effective teaching materials that optimally meet student learning needs. The assessment involved 102 tenth-grade students studying biotechnology innovation. A questionnaire with 24 items was used, categorized into four elements: perception of biology learning, supporting biology learning resources, student knowledge and interaction with smartphones, and views on a flipbook e-module for practical with a guided inquiry model as a learning material.

Student perceptions of biology learning were evaluated through several question items. The results showed that 73.5% of respondents were interested in biology lessons, and 56.9% of students reported difficulty understanding biology material. In the context of 10th-grade biology material, 67.6% of respondents were interested in biological technology innovation. The topic of biological technology innovation is one of the five biology topics in 10th grade that 39.20% of students consider difficult.

This study focuses on biological technology innovation materials, which are carried out in the second semester. Biological technology innovation spans various fields, including environmental biotechnology. Within environmental biotechnology, biofuels are being developed as a renewable energy source. Biofuels, such as bioethanol from water hyacinth and soybean hull waste, are renewable energy alternatives.

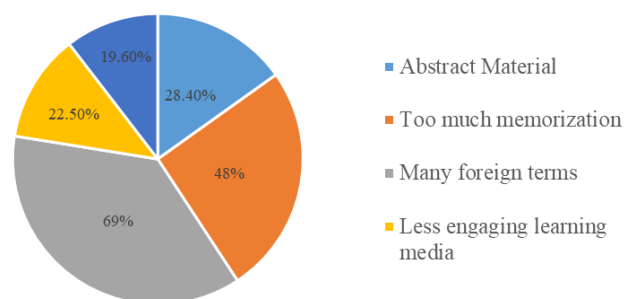
Biological technology innovation is not merely a theory, but an applied solution for problems such as the energy crisis and environmental pollution, making it crucial to explore further. Environmental biotechnology can be utilized to develop biofuels as an environmentally friendly alternative to fossil fuels. Through this innovation,

microorganisms can convert biomass into renewable energy sources, thereby reducing greenhouse gas emissions (CO₂) that contribute to global warming. This process creates a more balanced carbon cycle, where the released CO₂ is reabsorbed by plants, unlike the burning of fossil fuels, which continuously adds CO₂ to the atmosphere.

By understanding these biological processes, students not only learn theory but also realize that biological material offers a sustainable approach to preserving the environment and is relevant to their rapidly evolving daily lives in the future. The selection of this material focuses on a highly relevant and continuously evolving topic, which can motivate students to think critically and innovatively. Thus, this study aims not only to identify learning difficulties but also to connect the material considered difficult with crucial real-world applications for the future of the Earth.

The factors of difficulty and constraints students experience in learning Biology material in general are shown in Figure 2.

Based on Figure 2, the most dominant factor causing

**Figure 2.** Factors Contributing to Difficulties in Learning Biology

students' difficulties in learning Biology material is the large number of foreign terms. The factor of excessive memorization burden is also felt by 48% of students. Meanwhile, the least significant difficulty factor is the material's lack of relevance to daily life, which also contributes to learning difficulties. These findings align with various studies indicating that students' difficulties in learning Biology are often triggered by complex terminology and a lack of varied teaching methods (Ferry, 2024).

The teaching materials used by teachers in Biology learning also serve as a reference in the design and development of this research. Supporting sources for Biology teaching materials are shown in Figure 3.

The findings in Figure 3 show that conventional teaching materials, such as textbooks and worksheets, are the most frequently used by teachers. Conversely, the use of more modern, technology-based teaching materials, such as e-modules, remains very low at 17.6%. This condition serves as a strong basis for making the use of e-modules the focus of the research. The e-module is not just a digital version of a printed book. This teaching material

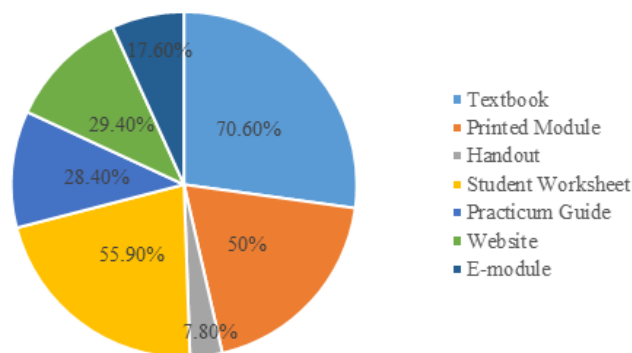


Figure 3. Teacher Teaching Materials in Biology Learning

has great potential to present learning material more interactively through multimedia elements such as videos, animations, simulations, and interactive quizzes. The research can examine how effective e-modules are in enhancing students' understanding of complex Biology concepts, how adaptive they are—able to adjust the level of material difficulty to students' individual abilities—and how flexible they are, being connected to digital devices that greatly assist independent learning.

The desired content of teaching materials for students in Biology learning is shown in Figure 4.

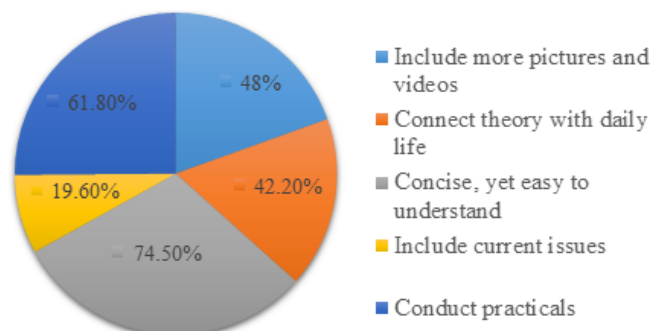


Figure 4. Teaching Material Content

The preference for concise material aligns with cognitive load theory, which posits that a limited working memory can become overloaded by overly lengthy and complex material. A concise, explicit, and logical structure helps reduce this cognitive burden, thereby improving comprehension and long-term retention. Student interest in practical activities indicates that effective Biology learning relies on direct experience rather than just verbal information. This aligns with experiential learning, where practicals allow students to interact directly with biological phenomena. Engaging the senses and motor skills during these activities strengthens neural connections and enhances memory retention.

In addition to these two points, students also emphasized the importance of including more images and videos, connecting theory to real-world contexts, and incorporating current issues. They also emphasized the

importance of more images and videos, theoretical relevance to daily life, and the inclusion of current issues. Teachers must innovate in developing essential material that suits the characteristics of digital-native generations, who demand tailored learning approaches (Kristy et al., 2024). This includes supporting digital practical learning materials, which further strengthens the urgency of developing such resources.

Overall, students have a clear need for Biology teaching materials that are concise, easy to understand, support practical work, are visually rich, and are relevant to daily life. 80.4% of students would be motivated to learn if the teaching materials used in Biology were engaging and interactive. Students frequently use gadgets as a medium for Biology learning. A total of 85.3% of students agreed and were willing to participate in a practicum on making biofuel as an alternative fuel, to be used as content in the flipbook e-module-based learning with a guided inquiry model for the biological technology innovation topic.

3.2 Design

Based on a detailed needs analysis of students and Biology teachers, a flipbook e-module for practicals was designed. This phase encompassed the design of learning tools, the creation of a storyboard as a visual reference, the development of learning flow objectives (ATP) and teaching modules (MA), and the design of research instruments. The needs assessment indicated a demand for digital practical learning materials for biotechnology innovation that could present content through images, videos, and interactive elements. A sample cover for the Flipbook e-module practical incorporating a guided inquiry learning model is provided below (Figure 5). The guided inquiry approach is characterized by a continuous investigative process that facilitates conceptual understanding rather than rote memorization of scientific principles, and this can be achieved through experimental activities ranging from questioning to reflection (Awaliyah et al., 2023; Jeffery et al., 2016; Nurwahid et al., 2024). The teacher's role in this student-centered model is to act as a facilitator, providing guidance and support to help students explore ideas and develop problem-solving skills tailored to their individual abilities (Awaliyah et al., 2023; Baharom et al., 2020).

The development of this media began with the research design, followed by planning learning scenarios, selecting competencies, aligning initial tool planning with subject competencies, and designing learning materials and evaluation tools. Instruments and teaching modules were specifically tailored to the objectives and content of biofuel practicals. The guided inquiry learning model was incorporated into the design of the flipbook e-module to enhance students' analytical thinking and science process skills (SPS). It incorporates practical e-module content, supported by images, videos, hyperlinks, quizzes, and summative assessment questions linked to Google Forms,

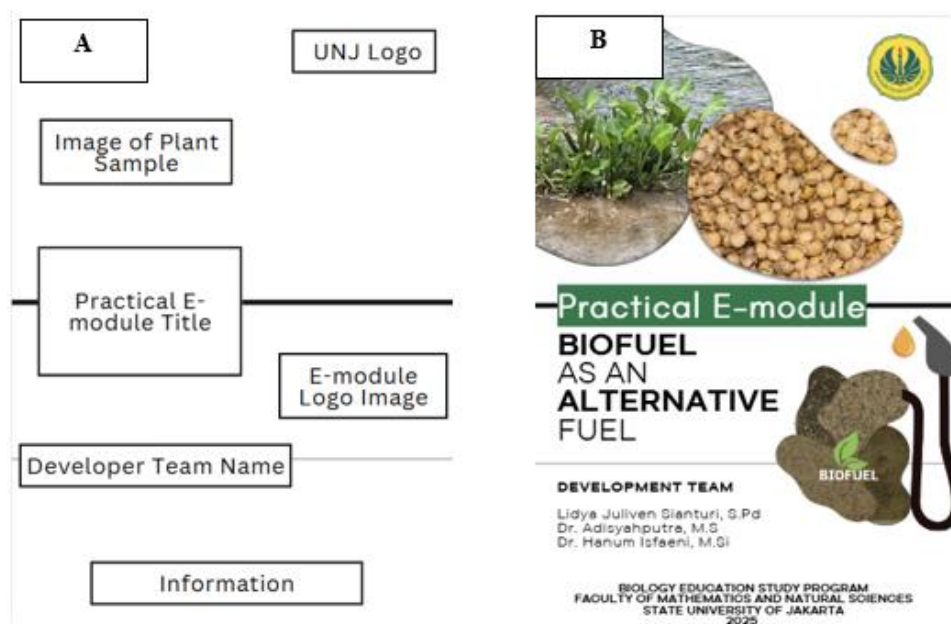


Figure 5. Storyboard: (A) Initial design of cover page (B) Final result of cover page

all aligned with the ATP and teaching modules. This phase involved creating research instruments and a storyboard as the blueprint, guided by a needs analysis. Key tools included Canva for e-module design and its Heyzine flipbook feature, and Wondershare Filmora for creating practical tutorial videos. Videos are crucial for providing concrete learning experiences, enhancing understanding of abstract concepts, and boosting student engagement (Kadir et al., 2024; Latifah et al., 2018; Saufiannor et al., 2022). The e-module also integrates Google Forms for quizzes and assessments, accessible via QR codes.

The flipbook e-module practical is designed around a guided inquiry learning model, combining its syntax with standard practical components (e.g., objectives, procedures). This approach, supported by images, videos, and hyperlinks, aims to actively engage students in investigation and discovery, thereby significantly enhancing their Science Process Skills (SPS) and analytical thinking (Duda et al., 2019; Lovisia, 2018; Nulhakim et al., 2022). In this model, teachers serve as facilitators, diagnosing difficulties and supporting student inquiry (Jeffery et al., 2016; Maulani et al., 2016; Nurussaniah & Nurhayati, 2016).

During the design phase, the necessary questionnaire instruments for this research and development were also developed, taking into account analytical thinking and SPS. These instruments were then subjected to validity and reliability testing to assess their feasibility. The SPS instrument comprised 33 multiple-choice questions, while the analytical thinking instrument comprised 15 multiple-choice questions, both administered to 49 student samples.

For validity testing using Pearson's product-moment correlation, an item was considered valid if its r -value exceeded the r -table value (0.281 for this study). For the SPS instrument, two items were found to be invalid because their r -values were below 0.281, and they were subsequently excluded from further measurement. Reliability testing using Cronbach's Alpha further supported these findings, demonstrating that both instruments were reliable. The SPS instrument showed a reliability coefficient of 0.945, and the analytical thinking instrument showed a coefficient of 0.944. Since both values were greater than $\alpha=0.05$, this indicates consistency in their measurement. Thus, both instruments are considered adequate for measuring science process skills and analytical thinking (Table 8-9).

3.3 Development

The development phase (develop) transformed the product blueprint from the design phase (storyboard) into concrete learning materials. This stage involved several activities: first, developing the flipbook e-module practical. To ensure quality, the e-module then underwent feasibility testing by media, content, and language experts. After incorporating feedback from these experts, the learning material was piloted with small groups of students and biology teachers to gather direct user feedback. Following all development and refinement processes, the material was then tested with large groups to validate its effectiveness on a broader scale.

The flipbook e-module practical, which integrates a guided inquiry learning model, was primarily developed in Canva (<https://canva.com>). Images and videos were either sourced from the researchers' personal archives or

Table 8. Science process skills (SPS) validity result

Item Number	r-table	r-count	Criterion	Item Number	r-table	r-count	Criterion
1	0.281	0.319	Valid	18	0.281	0.304	Valid
2	0.281	0.666	Valid	19	0.281	0.704	Valid
3	0.281	0.542	Valid	20	0.281	0.911	Valid
4	0.281	0.589	Valid	21	0.281	0.553	Valid
5	0.281	0.688	Valid	22	0.281	0.480	Valid
6	0.281	0.757	Valid	23	0.281	0.759	Valid
7	0.281	0.485	Valid	24	0.281	0.677	Valid
8	0.281	0.448	Valid	25	0.281	0.900	Valid
9	0.281	0.497	Valid	26	0.281	0.040	Not Valid
10	0.281	0.609	Valid	27	0.281	0.566	Valid
11	0.281	0.730	Valid	28	0.281	0.706	Valid
12	0.281	0.614	Valid	39	0.281	0.553	Valid
13	0.281	0.837	Valid	30	0.281	0.155	Not Valid
14	0.281	0.635	Valid	31	0.281	0.425	Valid
15	0.281	0.868	Valid	32	0.281	0.539	Valid
16	0.281	0.847	Valid	33	0.281	0.587	Valid
17	0.281	0.679	Valid				

Table 9. Results of the analytical thinking instrument validity test

Item Number	r-table	r-count	Criterion	Item Number	r-table	r-count	Criterion
1	0.281	0.930	Valid	9	0.281	0.804	Valid
2	0.281	0.663	Valid	10	0.281	0.594	Valid
3	0.281	0.866	Valid	11	0.281	0.601	Valid
4	0.281	0.874	Valid	12	0.281	0.827	Valid
5	0.281	0.703	Valid	13	0.281	0.896	Valid
6	0.281	0.723	Valid	14	0.281	0.639	Valid
7	0.281	0.642	Valid	15	0.281	0.816	Valid
8	0.281	0.688	Valid				

designed in Canva. Video creation utilized specific software. Exercise questions were implemented via Google Forms, and quizzes were used with Online Puzzle Maker (<https://puzzel.org/en>). Reports and assignments were uploaded to Google Drive.

The e-module's development integrated the guided inquiry learning model's syntax into essential practical e-module components, following the sequential flow outlined in the storyboard. Once all e-module features and components were designed in Canva, the files were downloaded as PDFs and uploaded to the Heyzine Flipbooks maker web server (<https://heyzine.com/>). The e-module's cover prominently displays its identity, featuring representative biomass illustrations, the practical title, institutional details, developer information, and interactive Heyzine Flipbooks formatting. The flipbook e-module integrates the guided inquiry model's syntax and practical elements, including titles, objectives, theoretical

bases, tools, procedures, and questions. To enhance students' Science Process Skills (SPS) and analytical thinking, these sections are supplemented with images, videos, and hyperlinks. The e-module allows users to navigate pages like a physical book and click on available links for an interactive learning experience.

The flipbook e-module practical, integrating a guided inquiry learning model, presented material content evaluated against two indicators: material suitability and the feasibility of its practical presentation. Expert validation of the 21-question assessment confirmed that the biofuel practicals flipbook e-module was "Very Feasible," achieving a score of 3.6. This positive outcome came from the material feasibility testing by two expert validators (Table 10).

The experts provided several suggestions and comments to improve the practicality of the flipbook e-module, focusing on the clarity of concepts and the

5 Renewable Energies

- 1 Solar Energy**: Produced from sunlight using solar panels.
- 2 Wind Energy**: Produced from the blowing wind using wind turbines.
- 3 Hydropower**: Electricity can be generated from water using dams and water turbines.
- 4 Biomass Energy**: Produced from organic materials for electricity, heating, and vehicle fuel.
- 5 Geothermal Energy**: Produced from the natural heat inside the Earth and used for power generation, water heating, and cooling.

BIOFUEL AS AN ALTERNATIVE FUEL

Bacalah wacana berikut

The development of biofuels is a biotechnology product that has emerged as a crucial tool for creating sustainable solutions for the future of renewable energy (Nath, 2024). Biofuels are fuels derived from and produced using organic materials like plants and their residues, agricultural crops, and by-products, which can serve as a substitute for petroleum-based fuels (Demirbas et al., 2016).

Rising energy demands and environmental concerns are driving the development of bioethanol as a sustainable fuel alternative. Bioethanol produced from lignocellulosic waste such as water hyacinth and soybean hulls holds great potential due to its availability and the fact that it doesn't compete with food needs. Ethanol has a value approximately one-third lower than gasoline, with an energy content that's better than gasoline, with a difference of 11.3 MJ/L (Mahapatra et al., 2021), allowing it to be stored as a pure fuel (Restiawaty et al., 2020).

Figure 1. Water Hyacinth (<i>Eichhornia crassipes</i> Mart.)	Figure 2. Soybean Hulls
<ul style="list-style-type: none"> Cellulose (42-49%) Hemicellulose (29-34%) Lignin (1-3%) 	<ul style="list-style-type: none"> Cellulose (18%) Hemicellulose (48%) Lignin (3,5%)

Figure 1. Water Hyacinth (*Eichhornia crassipes* Mart.)
Naufala et al., 2015

Figure 2. Soybean Hulls
Jaufani Rahman et al., 2021

Photo source: Author's document (2025)

LET'S DISCUSS

Creating Questions and Problems

https://bit.ly/Pertanyaan_masalah

Please click the link above and write your analysis. You can also scan the barcode.

RESEARCH OBJECTIVES

- To perform the process of making bioethanol from lignocellulosic materials (soybean hulls and water hyacinth).
- To analyze the stages of bioethanol production from lignocellulosic materials, including pre-treatment, hydrolysis, fermentation, and distillation.
- To analyze the effect of raw material particle size on bioethanol production.

Let's watch the following video to broaden our horizons.

<https://bit.ly/Videobioetanol>

BIOFUEL

PEMBUATAN BIOETANOL SEBAGAI BAHAN BAKAR ALTERNATIF

OLEH : LIQYA J. SIANTURI

Source: Author's document (2025)

Figure 6. Materials/Content and Video Links

accuracy of terms, words, and images. Below is the table detailing the product revisions based on feedback from the material experts.

A media feasibility test was conducted on the flipbook e-module practical, which utilized a guided inquiry model. The test, consisting of 21 questions, evaluated three indicators: language, appearance, and media presentation. Based on the media feasibility test, the biofuel practical flipbook e-module was categorized as "Very Feasible," scoring 3.6. Table 12. presents detailed media feasibility test results from two media experts. Experts provided several suggestions for improving the e-module's media, specifically regarding font size accuracy for clear readability in the appearance indicator. It was also recommended to ensure consistency in font size and uniformity in image sizes. The experts provided several suggestions and




comments for media improvements in the flipbook e-module practical. These primarily concerned the accuracy of font sizes for clear readability under the "appearance" indicator. They also emphasized the need for consistency in font size and uniformity in image sizes.

Table 10. Product Feasibility Test Results by Material Experts

Assessment Indicator	Item Number	Material Expert		Average	Description
		I	II		
Material Suitability	1.	4	4	4	Very Feasible
	2.	4	3	3,5	Very Feasible
	3.	4	3	3,5	Very Feasible
	4.	3	4	3,5	Very Feasible
	5.	4	4	4	Very Feasible
	6.	3	3	3	Feasible
	7.	4	3	3,5	Very Feasible
	8.	4	4	4	Very Feasible
	9.	4	4	4	Very Feasible
	10.	4	3	3,5	Very Feasible
	11.	4	3	3,5	Very Feasible
	12.	3	3	3	Feasible
Presentati on Feasibility	13.	3	4	3,5	Very Feasible
	14.	4	3	3,5	Very Feasible
	15.	4	3	3,5	Very Feasible
	16.	4	4	4	Very Feasible
	17.	4	4	4	Very Feasible
	18.	4	3	3,5	Very Feasible
	19.	4	3	3,5	Very Feasible
	20.	4	3	3,5	Very Feasible
	21.	4	4	4	Very Feasible
Average				3,6	Very Feasible

The language feasibility of the flipbook practical e-module, which is integrated with a guided inquiry model, was evaluated using 15 questions across five indicators. These indicators included: suitability for the student's development level, readability, sentence conciseness, and the use of terms and symbols. The assessment concluded that the biofuel practical flipbook e-module is "Very Feasible," with a score of 3.5. The complete results of the

Table 11. Product Revisions Based on Suggestions from Subject Matter Experts

No	Before Revision	After Revision
1		
The image on the cover must be original or used with permission from the owner, due to copyright concerns.		
2		
Advertisements appear on the flipbook display, and the embedded links are not clickable. It is recommended to find an application that does not display ads, as they hinder reader comfort and cover content.		
3		
Sources and captions for images/videos should be included.		

language feasibility test conducted by two expert validators are detailed in Table 13. These experts offered specific recommendations for enhancing the module's linguistic quality. These primarily concerned the continued use of foreign-language terms that did not conform to Indonesian spelling rules (EYD) and the inconsistent italicization of foreign terms. Experts recommended primarily using Bahasa Indonesia since the e-module is in Indonesian. All suggestions and feedback from the experts were incorporated for product revision.

Following its feasibility testing, the flipbook e-module with a guided inquiry model was piloted by a biology teacher at SMAN 99 Jakarta. This trial utilized an instrument containing 20 questions covering three assessment indicators: content, appearance, and benefits. Based on the Biology teacher's product trial results, the biofuel practical flipbook e-module received an "Excellent"

Table 12. Product Feasibility Test Results by Media Experts

Assessment Indicator	Item Number	Expert Media		Average	Description
		I	II		
Language	1	4	4	4	Very Feasible
	2	4	3	3,5	Very Feasible
	3	4	4	4	Very Feasible
	4	3	3	3	Feasible
	5	4	3	3,5	Very Feasible
	6	3	3	3	Feasible
Appearance	7	4	3	3,5	Very Feasible
	8	4	4	4	Very Feasible
	9	4	4	4	Very Feasible
	10	4	3	3,5	Very Feasible
	11	4	4	4	Very Feasible
	12	3	3	3	Feasible
	13	3	3	3	Feasible
	14	4	3	3,5	Very Feasible
	15	4	4	4	Very Feasible
	16	4	4	4	Very Feasible
Media presentation	17	4	4	4	Very Feasible
	18	4	4	4	Very Feasible
	19	4	3	3,5	Very Feasible
	20	4	3	3,5	Very Feasible
	21	4	3	3,5	Very Feasible
Average				3,6	Very Feasible

Table 13. Product Feasibility Test Results by Language Experts

Assessment Indicator	Item Number	Language Experts		Average	Description
		I	II		
Suitability for student development level	1	3	4	3,5	Very Feasible
	2	4	4	4	Very Feasible
Writing systematics	3	4	3	3,5	Very Feasible
	4	3	3	3	Feasible
Readability	5	4	3	3,5	Very Feasible
	6	3	3	3	Feasible
	7	4	3	3,5	Very Feasible
Sentence conciseness	8	3	4	3,5	Very Feasible
	9	4	4	4	Very Feasible
Use of terms and symbols	10	4	3	3,5	Very Feasible
	11	3	4	3,5	Very Feasible
	12	4	3	3,5	Very Feasible
	13	4	3	3,5	Very Feasible
	14	4	3	3,5	Very Feasible
	15	4	3	3,5	Very Feasible
Average				3,5	Very Feasible

category with a score of 98.8%. Table 13. displays the detailed results of the biology teacher's product feasibility test. After its feasibility testing, the flipbook e-module, practical with an inquiry model, underwent a user trial with

a small group of 15 students from SMAN 99 Jakarta. This trial utilized an instrument containing 18 questions focusing on three evaluation indicators: the e-module's effectiveness, appearance, and benefits. The biofuel

practical flipbook e-module received a "Very Good" rating, with an average score of 92%, based on the results of a small-group trial.

3.4 Implementation Stage

The fourth stage of the ADDIE model, implementation, involved using the flipbook e-module practical with tenth-grade students at SMAN 99 Jakarta for the biotechnology innovation material, aligned with the learning objectives (TP) and teaching modules (MA). A sample of 53 students was used for data processing. Following the learning process, students completed a questionnaire regarding their experience using the learning material. The biofuel practical flipbook e-module was assessed as "Very Good" (95% score) and is deemed appropriate for widespread implementation. Before implementing the product in biotechnology innovation lessons, preparations were made with the biology teacher, and students were briefed. The experimental group was assigned a flipbook e-module practical developed with a guided inquiry framework. Conversely, the control group was instructed using the subject teacher's standard approach, which involved conventional practical modules and a discovery learning model. The teaching modules for the biotechnology innovation material were adjusted according to the learning objectives flow (ATP) for the second semester, which had been developed during the design phase.

Student conditioning and division into control and experimental classes were carried out after discussions with the biology teacher. Once both teachers and students were prepared, the biotechnology innovation learning sessions for both experimental and control groups were conducted over five face-to-face meetings, each lasting two hours of instruction. Learning began with the distribution of

pretests for analytical thinking and science process skills (SPS), and concluded with an identical post-test to identify differences in results. The collected data were analyzed using descriptive statistics and MANOVA, aided by MS Excel and SPSS 27.

As shown in Table 13, descriptive test results revealed a clear difference in the improvement of SPS and Analytical Thinking between the experimental and control groups. Initially, the experimental group's average SPS pretest score (68.00) was slightly higher than the control group's (61.51), suggesting comparable starting abilities with a minor edge for the experimental group. Following the intervention, both groups saw substantial increases in their post-test average scores, with the experimental group reaching 90.11 and the control group 84.75. The N-gain for SPS showed that the experimental class experienced a 64% increase (moderately effective), surpassing the control class's 57%

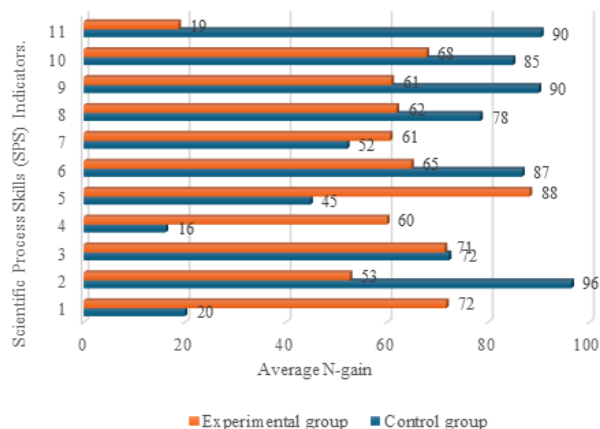


Figure 7. Diagram of the percentage increase in the average science process skills (SPS) for each indicator

Table 14. Descriptive Test Results

Analysis	Class	Science Process Skills (SPS)		Analytical Thinking	
		Pretest	Posttest	Pretest	Posttest
Sample	Experiment	53	53	53	53
	Control	53	53	53	53
Mean	Experiment	68,00	90,11	66,13	90,06
	Control	61,51	84,75	57,19	79,89
Standard Deviation	Experiment	14,420	6,820	17,966	6,350
	Control	15,810	6,542	18,830	5,504
Lowest Value	Experiment	42	77	40	80
	Control	32	61	33	60
Highest Value	Experiment	87	100	87	100
	Control	77	90	87	87
Variance	Experiment	208,03	46,52	322,77	40,32
	Control	249,83	42,80	354,85	30,29
N-gain (category)	Experiment	64%		64%	
	Control	57 %		43%	

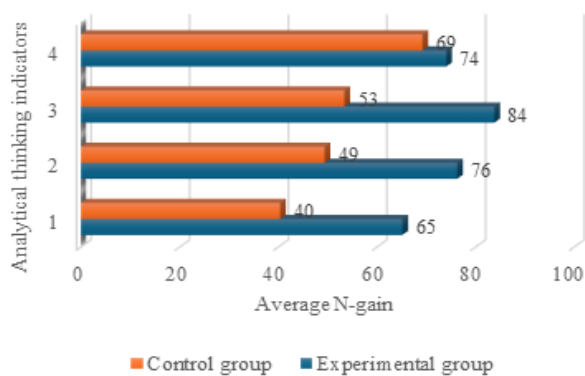


Figure 8. Average Analytical Thinking Increase per Indicator

increase (less effective). The highest percentage increase in SPS indicators for the experimental class was in Formulating Scientific Questions (96%). The experimental class showed a higher overall increase (67%) across all Science Process Skills (SPS) indicators compared to the control class (62%) (Figure 7).

Similarly, analytical thinking ability also showed improvement. The experimental class's pretest mean (66.13) was slightly higher than the control class's (57.19). Post-intervention, both classes' post-test means increased sharply, with the experimental class reaching 90.06 and the control class reaching 79.89. The standard deviation for analytical thinking significantly decreased from pretest to posttest (from around 18 to 5-6), indicating greater uniformity in students' analytical thinking ability after the intervention, with some experimental class students achieving maximum scores (100). Analytical thinking in the experimental class improved substantially, with a 64% N-gain, placing it in the moderately effective category. In contrast, the control class's N-gain was only 43%, a less effective result. The experimental group saw its most significant improvement in the Comparing and Contrasting indicator (84%). Across all indicators, the experimental class's 75% increase in analytical thinking was notably higher than the control class's 53% increase (Figure 8).

An initial standard deviation of 18 in the pretest reflected high variability in analytical thinking among students, with a wide range of abilities. The post-intervention reduction to 5-6 shows a dramatic convergence, making student analytical thinking abilities much more uniform. This means data points for analytical thinking scores are now much more concentrated around the group mean, confirming that the flipbook e-module with a guided inquiry model effectively harmonized

learning outcomes. A lower standard deviation indicates more homogeneous data (Febriani, 2022).

Collectively, these descriptive data suggest substantial improvements in both SPS and analytical thinking across both groups. Consistent with the higher posttest means and N-gain values, the experimental class's teaching intervention proved more effective in fostering students' SPS and analytical thinking skills than the method used in the control class. This superiority was reflected in noticeable differences across all indicators of both science process skills and analytical thinking.

A MANOVA was conducted to confirm significant differences in pretest-posttest gains between the experimental and control groups. The dependent variables, Science Process Skills (SPS) and Analytical Thinking, were measured at the interval level, based on pretest-posttest results across both classes. Two independent variables were used: the flipbook e-module practical with a guided inquiry model (experimental class) and conventional print practical modules (control class). Sample data from the experimental and control groups were independent because they originated from distinct classes (Biology A for the control and Biology B for the experimental). A total of 106 students participated in the study, with 53 assigned to the experimental class and 53 to the control class. Tested using the Shapiro-Wilk test, all significance (p) values for both SPS and Analytical Thinking (pretest and posttest in both classes) were greater than 0.05 (e.g., SPS pretest control: 0.060; analytical thinking posttest experimental: 0.075). This indicates that the data are multivariately normally distributed.

Homogeneity of Variance-Covariance Matrices: Levene's test for individual dependent variables and Box's M test for all dependent variables confirmed homogeneity. SPS (Sig. = 0.248) and Analytical Thinking (Sig. = 0.857) showed homogeneity, and Box's M test also indicated homogeneity (Sig. = 0.469), all with p -values > 0.05. The linearity assumption was confirmed, as the significance (Sig.) values for linearity tests between pretest and posttest for both SPS and analytical thinking in each group were greater than 0.05 (e.g., SPS control: 0.257; analytical thinking experimental: 0.703), indicating linear relationships.

A MANOVA was run in SPSS 27, confirming significant differences between the experimental and control classes for each dependent variable (Table 15). The p -values for all tests (Pillai's Trace, Wilks' Lambda,

Table 15. MANOVA Test of the Experimental and Control Groups

		Statistic value	df1	df2	Sig. (p)
Experiment and Control	Pillai's Trace	0.37	4.00	101.00	<0.00
	Wilks' Lambda	0.62	4.00	101.00	<0.00
	Hotelling's Trace	0.61	4.00	101.00	<0.00
	Roy's Largest Root	0.61	4.00	101.00	<0.00

Hotelling's Trace, and Roy's Largest Root) were less than 0.05 ($p < 0.00$), indicating statistical significance.

Based on Table 15, the MANOVA results are presented across several statistical tests. The results indicate a significant difference between the experimental and control classes for each dependent variable. This is because the p -value is less than 0.05 for each type of MANOVA test used. A result is said to be significant if the p -value is < 0.05 . Based on these results, it can be concluded that there is a significant difference between the class that applied the flipbook practicum e-module on biofuel as an alternative fuel with the guided inquiry model as the teaching material, compared to the class that did not use the product. These results indicate that the flipbook biofuel practicum e-module is statistically significant.

After confirming that all MANOVA assumptions were met, the statistical analysis showed a significant difference between the experimental group, which used the biofuel practical flipbook e-module with a guided inquiry model, and the control group. By rejecting the null hypothesis, the results demonstrate that the e-module effectively enhanced students' Science Process Skills (SPS) and analytical thinking. This finding aligns with existing research (Anam et al., 2025) linking interactive digital media and inquiry models to improved higher-order thinking and scientific abilities. The e-module's success can be attributed to its known features, such as accessible, engaging, and interactive content that makes the learning process comfortable for students (Pramana et al., 2020).

This comfort and effectiveness can be further explained by applying Mayer's multimedia learning principles. The design of the flipbook e-module, which integrates relevant text and images simultaneously, adheres to the principles of spatial and temporal contiguity, allowing students to construct a more coherent and deeper representation. Furthermore, the concise presentation of material and focus on essential information (coherence principle) help reduce extraneous cognitive load, enabling students to focus more on processing critical information for the development of SPS and analytical thinking. Adjustments were made by applying the theory of multimedia learning (Mayer & Moreno, 2003) and cognitive load reduction (Sweller et al., 2011).

The arrangement of relevant visual elements in proximity helps students group information. The consistent use of colors or styles for similar elements (similarity) facilitates the identification of practicum material. Smooth transitions between pages, resembling physically turning a book (continuity), create an uninterrupted learning flow. A clear separation between the core material and the background ensures that students' attention is focused on the learning content. The combined application of these Gestalt principles with Mayer's Multimedia Learning principles synergistically enhances the e-module's visual appeal, readability, and cognitive

efficiency, ultimately contributing to improvements in students' science process skills and analytical thinking. The application of Gestalt principles in visual design can enhance memory and message comprehension (Mubarak, 2023).

3.5 Evaluation Stage

The final stage in the ADDIE phase for the development of the biofuel practicum flipbook e-module with a guided inquiry model is conducting a summative evaluation. This stage is carried out at the end of the phase to generally summarize the developed product and the refinement steps of the teaching material, referencing the results of all trials and implementation. The summative evaluation stage is the concluding phase of the ADDIE model, aiming to summarize the results of product development and implementation and identify final refinements. Based on the overall results of the trials and implementation, the biofuel practicum flipbook e-module has demonstrated high feasibility and effectiveness.

The final refinements made during this evaluation stage include rechecking the product display, adding more engaging digital learning media features, and providing the flipbook link directly (without a shortened URL like bit.ly) to make user access easier and more immediate. These revisions reflect a commitment to product quality and user experience, which may have emerged during implementation. This biofuel practicum flipbook e-module, with a guided inquiry model, is expected to be a practical teaching resource for enhancing Science Process Skills (SPS) and analytical thinking among 10th-grade high school students on the topic of biological technology innovation. Its success is supported by validity tests, user trials, and the MANOVA statistical test, proving that this product is a relevant learning innovation in the digital era.

The biofuel practicum flipbook e-module can be an innovative solution to overcome students' difficulties in understanding the biological technology innovation material, which is considered conceptual and rich in foreign terms, by presenting it visually, interactively, and contextually. The implementation of the guided inquiry model integrated into this e-module can serve as an example for other educators to shift the focus of learning from mere memorization to an active, systematic, and analytical investigation process, thereby developing higher-order thinking skills. The use of interactive digital learning media, such as e-modules, enables educators to adapt to the digital-native characteristics of current students, making learning more relevant and engaging.

The developed flipbook biofuel practicum e-module, as an alternative fuel, using the guided inquiry model, is expected to serve as practical teaching material that assists teachers and 10th-grade high school students in enhancing science process skills (SPS) and analytical thinking abilities on the biological technology innovation topic.

4. CONCLUSION

Based on the discussion, which refers to the process and results of data analysis, the conclusions of this research are as follows. This study developed and implemented a teaching material in the form of a biofuel practicum flipbook e-module, structured using the ADDIE model and guided by a guided inquiry model. The product was found to be highly theoretically feasible by material, media, and language experts, as well as feasible and practical based on teacher and student responses.

The use of the biofuel practicum flipbook e-module with the guided inquiry model was found to be significantly more effective in enhancing students' Science Process Skills (SPS) and analytical thinking abilities than conventional modules and the discovery learning model. The increase in Science Process Skills (SPS) and analytical thinking ability in the experimental class was demonstrated by higher average posttest scores and N-gain values (64%), as well as a significant decrease in the standard deviation, which indicates greater homogeneity in student ability after the intervention. The results of the multivariate statistical test (MANOVA) showed a significant difference between the experimental and control classes, strongly supporting the hypothesis that the flipbook e-module is an effective learning medium for achieving learning objectives. The effectiveness of this product is supported by the application of Mayer's multimedia learning principles and Gestalt principles, which help reduce cognitive load, enhance visual appeal, and facilitate a deeper, more structured conceptual understanding.

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