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Development of e-LKPD with a Scientific Approach to Improve Critical Thinking Abilities and Science Process Skills In Biotechnology

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Abstract

Technological development in the globalization era requires integration of digital media into learning. Students need interactive learning materials that support independent study; therefore, this research aims to develop a scientific-approach-based electronic worksheet (e-LKPD/ Lembar Kerja Peserta Didik Elektronik) on Biotechnology Material. The e-worksheet hopefully valid and effective in improving tenth-grade students' Critical Thinking Skills (CTS) and Science Process Skills (SPS). This study employed a Research and Development (R&D) method using the 4D model, consisting of Define, Design, Develop, and Disseminate stages. The collected data include validity, readability, and the effectiveness of the e-LKPD in enhancing students' critical thinking and science process skills. A small-scale trial was conducted at SMAN 8 Semarang, while a large-scale trial took place at SMAN 14 Semarang, based on school readiness. The results indicate that the e-LKPD is highly valid according to material and media experts and demonstrates excellent readability based on teacher and student evaluations. Furthermore, the e-LKPD proved effective in improving students' critical thinking and science process skills into a high category. This research implies that the e-LKPD can serve as a biology learning supplement, functioning both as a biotechnology practicum guide for students and as an supplementary resource for biotechnology learning for teachers.

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INTRODUCTION

The education sector is currently facing the era of globalization and the rapid development of technology 4.0, which is marked by the extensive use of information and communication technology. Learning processes in this modern era require the integration of technology to facilitate the delivery of information. According to Wahono, Supeno, and Sutomo (2022), technology-supported science learning can facilitate students' learning and enhance their thinking skills. One technological innovation that can be used as a supplementary learning resource is the electronic student worksheet (e-LKPD), a digital teaching material containing text, images, animations, videos, and interactive navigation features that help students understand learning materials more deeply (Lathifah, Hidayati, & Zulandri, 2019; Ramadani & Marhaeni, 2024).

Previous studies by Ariq and Fitrihidajati (2022) as well as Wahono, Supeno, and Sutomo (2022) reported that e-LKPD integrating a scientific approach can serve as an innovative tool for teachers to improve students' thinking abilities. Along with technological advancements, the quality of education can continuously develop through varied online learning media. Biology learning becomes more effective when applying a scientific approach. As stated by Liana (2020), the scientific approach is designed to guide students in strengthening their Science Process Skills (SPS) by constructing concepts, laws, or principles through stages such as observing (identifying problems), formulating problems, developing hypotheses, collecting data, analyzing data, drawing conclusions, and communicating the findings more actively. A study by Nugraha, Suyitno, and Susilaningsih (2017) also found a strong relationship between SPS and Critical Thinking Skills (CTS). Students with high SPS tend to demonstrate high CTS. Their study further highlighted that learning activities that train both CTS and SPS can foster scientific thinking, working, and attitudes, enabling students to solve problems and apply classroom knowledge to real-world situations.

Biotechnology is one of the biology topics that aligns well with the scientific approach because it allows students to apply SPS directly (Gusti *et al.*, 2023). Based on an interview with a biology teacher at SMA Negeri 14 Semarang, the curriculum used for Grade X is the Independent Curriculum (Kurikulum Merdeka). The learning model frequently applied in biotechnology lessons is Problem-Based Learning (PBL). Grade XII students usually perform biotechnology fermentation practices such as making tempeh, yogurt, tape, and other products. However, a challenge remains in biotechnology learning: the current student worksheet instructs students to find YouTube videos of biotechnology product preparation and then analyze the tools, materials, and procedures used. Although this worksheet supports interactive student discussion, it does not provide direct practical instructions, resulting in limited hands-on laboratory experience for students.

Among common biotechnology products, yogurt and tempeh are widely consumed and easy for students to produce. Yogurt is a fermented milk product produced by lactic acid bacteria (Kurniawan, 2018). It is commonly made from cow's milk, but advances in biotechnology have enabled the development of plant-based yogurt alternatives such as soyghurt, which is made from soybean milk. Soyghurt offers several advantages: it contains no lactose, making it suitable for individuals with lactose intolerance; it requires less starter; and it can be fermented at room temperature (Mulyani, Fajariyah, & Pratiwi, 2016). Tempeh is also a widely known fermented product made from soybeans. The selection of soyghurt and tempeh as biotechnology products in this research is based on several considerations: soybeans are more affordable and accessible than cow's milk, and both products can be easily varied in preparation through adjustments in sugar concentration and inoculum levels.

Based on the issues described above, particularly the need for developing a supplementary learning resource such as a scientific-based e-LKPD that provides direct practicum instructions for biotechnology and optimizes students' CTS and SPS, the researcher conducted a study entitled "Development of a Scientific-Based e-LKPD to Enhance Critical Thinking Skills and Science Process Skills in Biotechnology Learning."

RESEARCH METHOD

The type of research used in this study was Research and Development (R&D), employing the 4D development model proposed by Thiagarajan *et al*. (1974), which consists of the Define, Design, Develop, and Disseminate stages. The product trial employed a pre-experimental (non-design) method using a one-group pre-test–post-test design, in which all students from two classes were combined into one treatment group that received a pre-test and post-test before and after using the e-LKPD.

The research procedures consisted of 4 stages. (1) **Define**, in which a needs analysis was conducted through interviews with the biology teacher at SMAN 14 Semarang. The interview results indicated a major issue: the absence of practical guidelines that enabled students to compare the resulting products and conduct an in-depth analysis due to the lack of a control variable in the practicum design used. (2) **Design**, in which the e-LKPD was designed based on the needs analysis. This stage included determining the material, learning objectives, practicum activities, and types of practice questions. A layout design was created using Canva, converted into a PDF format, and uploaded to liveworksheet.com. Research instruments were also developed at this stage, including material and media validation sheets, readability questionnaires, CTS assessment instruments in the form of multiple-choice questions, and SPS assessment instruments in the form of multiple-choice questions and observation sheets.

The next stage, (3) **Development**, included feasibility validation and readability testing of the e-LKPD. Feasibility was assessed through expert validation by media and material experts using a Likert-scale questionnaire (1–4). The e-LKPD was considered valid if the score percentage exceeded 62.50%. Readability testing was conducted through a small-scale trial involving 33 students from class X5 and the biology teacher at SMAN 8 Semarang. A score percentage above 62.50% indicated good readability. Validation and readability instruments were equipped with comment and suggestion sections, which were used to revise the product. Instrument validation for CTS and SPS tests was also conducted in class X5. Validity, reliability, difficulty level, and discrimination index were analyzed using IBM SPSS version 26. A total of 27 items were deemed suitable for use in the large-scale trial. The SPS observation assessment was carried out by four observers using "YES" (score 1) and "NO" (score 0) responses. The percentage of each indicator was compared to the SPS criteria, where scores ≥ 51% were categorized as good and very good.

The final stage, (4) **Dissemination**, included limited distribution of the e-LKPD through a large-scale trial to assess its effectiveness in improving students' CTS and SPS. Effectiveness was evaluated based on the N-gain scores for each CTS and SPS indicator. The final version of the e-LKPD can be accessed online at the following link:
https://www.liveworksheets.com/worksheet/id/science-biology/8122343.

RESULTS AND DISCUSSION

The results obtained from the development of an e-LKPD using a scientific approach to improve students' Critical Thinking Skills (CTS) and Science Process Skills (SPS) on biotechnology material include: (1) Results of Interviews with Biology Teacher; (2) Results of Material and Media Validation Data Analysis; (3) Results of Readability Test Data Analysis; (4) Results of Effectiveness Test Data Analysis on Students' CTS Improvement; (5) Results of Effectiveness Test Data Analysis on Students' SPS Improvement; (6) Limitations of the e-LKPD; and (7) Advantages of the e-LKPD.

Results of Interviews with the Biology Teacher

Interviews with the biology teacher at SMAN 14 Semarang showed that biology learning in Grade X uses the Merdeka Curriculum with inquiry-based and problem-based learning models through discussions, presentations, case studies, and assignments using teaching materials in the form of PDF and PowerPoint files, printed and electronic LKPD, and videos from YouTube sources. Biotechnology practicum has never been carried out in Grade X due to limited facilities and time, so students only analyze videos of biotechnology product-making by identifying the tools, materials, procedures, and benefits of the product.

Biotechnology practicum is provided in Grade XII; however, the practicum instructions currently used require students to search for biotechnology product-making videos on YouTube, resulting in different products and ingredient measurements. This causes the outcomes obtained to be incomparable, making it difficult to identify the factors that influence the fermentation process. When conducting fermentation practicum, students do not always succeed in producing a fermentation product. The failure is then analyzed together, but the analysis of the causes of failure is not supported by strong comparative data. As a result, students' ability to connect results with concepts and compare data has not developed optimally.

The teacher agreed on the importance of an engaging and informative e-LKPD as a practicum guide but emphasized that CTS and SPS have never been specifically measured, and are only observed through material comprehension, scores, task completion, cooperation, and student attitudes in class and in groups activities.

Results of Material and Media Validation Data Analysis

The material expert provided several suggestions and recommendations for improvement to the developed e-LKPD, namely adding instructions for observations related to treatment variations and adding material about the operational concept of fermentation in accordance with what students do at the beginning of the e-LKPD. The details of the e-LKPD revisions are presented in Figure 1.

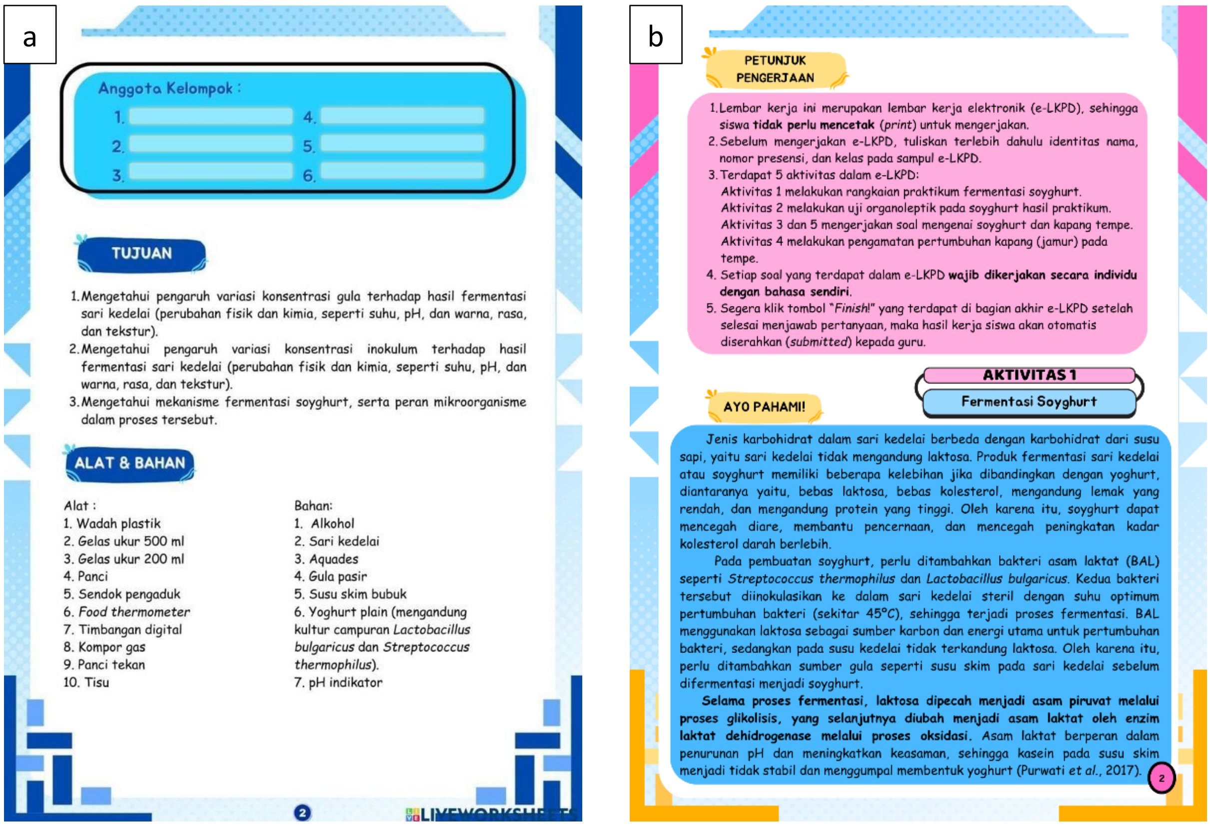
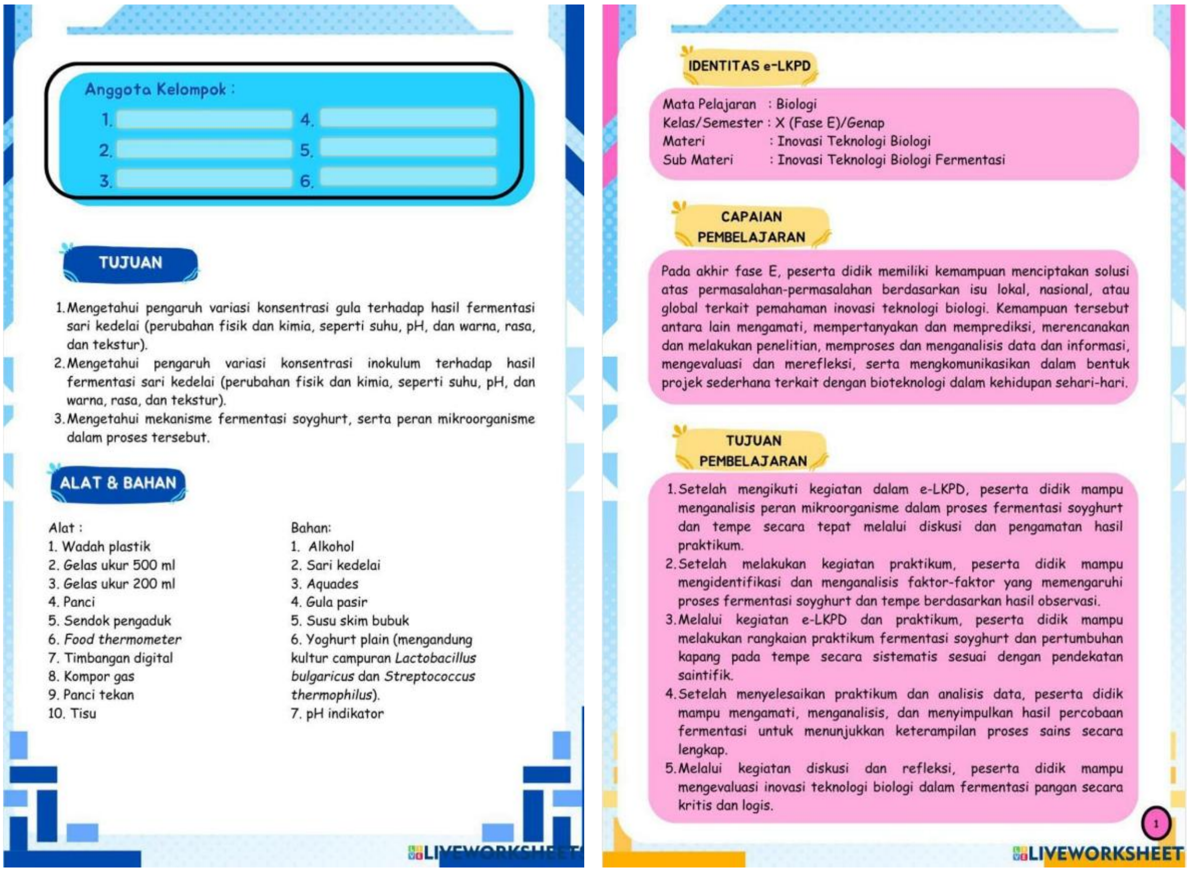


Figure 1. Addition of Fermentation Concept Material (a) Before Revision and (b) After Revision

The media expert provided input and suggestions for improvement, namely ensuring that the e-LKPD can be filled in and is user friendly for users, adding pictures of tools and materials so that they are easier for students to understand, and improving the formulation of learning objectives in accordance with



measurable operational verbs (KKO). The details of the e-LKPD revisions are presented in Figure 2.

Figure 2. Learning Objectives Adjusted with Operational Verbs (a) Before Revision and (b) After Revision

The results of the material validation, according to the data in Table 1, show that the e-LKPD obtained a "very valid" category in the aspects of content feasibility, language, and presentation. The content feasibility aspect was rated very valid because the e-LKPD is aligned with the Learning Outcomes (CP) of Fermentation Biotechnology for Phase E of the Merdeka Curriculum, namely that at the end of Phase E, students are expected to be able to create solutions to problems based on local, national, or global issues related to innovations in biological technology (Badan Standar, 2022). The material and practicum activities in the e-LKPD were also assessed to be in accordance with the learning objectives. The e-LKPD was also considered capable of training students' critical thinking skills (KBK) and science process skills (KPS). The activities in the e-LKPD, which include formulating practicum objectives, carrying out practicum activities, and completing practice questions, were arranged based on a scientific approach that guides students to find out from various sources through observation, not only from teacher explanation, so that students' critical thinking skills can be developed (Pratiwi & Sandi, 2024).

Table 1. Percentage of Media and Material Validation Score Results

Material				Media			
Aspect	**Obtained Score**	**Maximum Score**	**Lecturer Validation**	**Aspect**	**Obtained Score**	**Maximum Score**	**Lecturer Validation**
Content Feasibility	28	28	100%	Graphics	13	16	81,25%
Language	11	12	91,67%	Presentation	23	24	95,83%

Presentation	12	12	100%		
Average Material Validity			**97,22%**	**Average Media Validity**	**88,54%**
Criteria			**Highly Valid**	**Criteria**	**Highly Valid**

The linguistic aspect was rated as very valid because the practicum procedures and instructions in the e-LKPD were written in simple language, presented through written text, and equipped with explanatory text in the video, making them easy to understand and allowing students to carry out the practicum independently. In accordance with the statement of Tukan *et al*. (2020), LKPD generally consists of instructions and procedures for completing a task that can help students learn, understand, and complete tasks independently.

The presentation aspect was rated as very valid because the activity steps in the e-LKPD were explained in detail and sequentially using flowcharts and tutorial videos. The flowchart includes the treatments given, such as material concentration, temperature, and the duration needed at each stage of the soyghurt fermentation process. Flowcharts can help students understand the workflow of the practicum to be carried out and monitor their progress during the practicum activities (Grosskinsky *et al*., 2019). The inclusion of explanations in short-duration videos (1 to 4 minutes) helps students stay focused, avoid boredom, and quickly begin the practicum. According to research by Farhan *et al*. (2024), the use of short video learning can prevent students from becoming bored and increase their interest in learning. The practice questions in the e-LKPD were considered helpful for students in understanding the concept of fermentation more effectively because they were designed for students to complete based on their direct experience from the practicum, thus helping them connect the practicum activities with the biotechnology concepts being studied (Ariyansah *et al*., 2021).

The media validation results, as shown in Table 1, indicate that the e-LKPD received valid and very valid categories in the aspects of graphics and presentation. The graphic aspect was rated valid because the cover design and each page of the e-LKPD were harmoniously arranged, which included appealing e-LKPD colors, the use of readable fonts and sizes, and image layouts adjusted to the content of the e-LKPD to ensure clear delivery of information. One of the requirements for developing an e-LKPD is the inclusion of images and clear descriptions to make it attractive and enjoyable for students, as well as the design of the cover and pages in such a way that it becomes appealing and enjoyable for learners (Syaifudin, 2022).

The presentation aspect was rated as very valid because the title of the e-LKPD provides clear information, the sentence structure follows Indonesian language rules, and it is adjusted to the developmental level of the students, which is one of the requirements for developing an e-LKPD (Syaifudin, 2022). The addition of images and tutorial videos provides clear visualization and makes the appearance of the e-LKPD more attractive. In the procedure section of the LKPD, it is necessary to add appealing and relevant images so that students become more motivated, more interested, and find it easier to conduct the practicum (Tukan *et al*., 2020). The use of instructional videos can improve students' absorption of information, facilitate understanding, make learning more engaging, and motivate students to be more active (Biantoro, 2024). The e-LKPD is also equipped with a practicum report writing format, making it easier for students to prepare their practicum reports.

The material and media validity obtained a result of 92.88%, indicating that the scientific-approach-based e-LKPD designed to improve critical thinking skills and science process skills in biotechnology material is very valid or feasible to be used in the learning process according to the revisions made based on comments and suggestions from the media validators.

Results of Reaibility Test Data Analysis of the e-LKPD

The readability questionnaire completed by the teacher and 33 students of class X5 indicated that the e-LKPD was already good overall, as shown in Table 2.

Table 2. Percentage of Readability Score Results from Teachers and Students

Aspect	Teacher			Students		
	Obtained Score	**Maximum Score**	**Lecturer Validation**	**Obtained Score**	**Maximum Score**	**Lecturer Validation**
Graphics	16	16	100%	82,77%	Highly Valid	82,77%
Language	12	12	100%	84,34%	Highly Valid	84,34%
Presentation	20	20	100%	84,85%	Highly Valid	84,85%
Average Material Validity			**100%**	**Average Material Validity**		**83,99%**
Criteria			**Highly Valid**	**Criteria**		**Highly Valid**

The graphical aspect was rated as highly valid because the composition of the title, images, font types, and layout in the e-LKPD is harmonious and easy to understand. An attractive presentation of the e-LKPD can increase students' enthusiasm and interest in using it (Trissa *et al.*, 2022). The use of appropriate and representative images and videos throughout the e-LKPD ensures that the messages related to the material being studied are conveyed effectively and enhances students' enthusiasm. LKPD products designed using various colorful images make students more enthusiastic about studying the LKPD (Pawestri & Zulfiati, 2020). The instructional videos embedded in the e-LKPD also facilitate students in using it independently (Nianti *et al.*, 2022).

The language aspect was rated as highly valid because of the use of communicative language that is easy for students to understand. The term *communicative* refers to texts or information in the media as well as the language used that can be easily understood by users (Sumarsono & Sugiyanto, 2019). In line with the study by Rahmawati & Asri (2023), the sentences in the e-LKPD are constructed using simple, clear words that do not create ambiguity when read, making them easy for students to comprehend.

The presentation aspect was rated as highly valid because it supports laboratory activities in accordance with the learning objectives, is equipped with relevant evaluation questions, and includes instructional videos arranged sequentially to facilitate students in conducting the practicum. The availability of space to answer questions also serves as a prompt for discussing practicum results. Learning media with good presentation have advantages such as ease of use due to systematic organization, attractive appearance that can increase students' interest in learning, time efficiency during the learning process, and facilitating students' conceptual understanding (Wulandari *et al.*, 2018). The e-LKPD developed in this study can serve as a support tool for teachers in delivering fermentation material. This is in line with the purpose of developing the e-LKPD, which is to assist teachers in providing conceptual understanding, to serve as a learning tool that promotes students' independence and responsibility, and to make the learning process more effective and less monotonous (Amelia, 2024).

Analysis of the Effectiveness Test of the e-LKPD on Improving Students' Critical Thinking Skills

The improvement of students' critical thinking skills after using the e-LKPD was analyzed by comparing the pre-test and post-test scores for each indicator. The results of the critical thinking assessment are presented in Table 3.

Table 3. Students' Critical Thinking Assessment Results

No.	Critical Thinking Aspect	Pre-test	Post-test	N-Gain	N-Gain Criteria
1.	Providing simple explanations	42,16	88,73	0,81	High

2.	Building basic skills	**54,04**	92,65	0,84	High
3.	Drawing conclusions	52,94	**96,32**	0,92	High
4.	Providing further explanations	**40,69**	**74,02**	0,56	Medium
	Average			**0,78**	**High**

Table 3 shows that students' post-test scores increased compared to their pre-test scores. This statement is supported by the research of Wahono *et al*. (2022b), which shows that the use of an e-LKPD with a scientific approach can improve students' critical thinking skills. The effectiveness of the e-LKPD in improving critical thinking skills was determined by calculating the increase between pre-test and post-test scores using the N-Gain formula. Table 3 shows that the highest N-Gain score was obtained in the indicator of drawing conclusions, while the lowest was in the indicator of providing further explanations.

In the learning process, students were trained to draw conclusions from group or class discussions and write them down as answers to the questions in the e-LKPD, so their critical thinking skills could develop through activities such as evaluating decisions, identifying the relationship between sugar and inoculum variations and the organoleptic characteristics of soyghurt, and identifying the role of oxygen in the growth of tempe mold. Students also searched for information from various sources to connect relevant assumptions, establish answers based on data, and communicate findings through group discussions. This discussion process provided multiple perspectives and allowed verification of understanding among group members, resulting in an optimal increase in the ability to draw conclusions and producing a high N-Gain score (Haerunnisa *et al*., 2019).

The critical thinking indicator of providing further explanations helps students plan strategies for completing tasks and manage time so that answers become more precise and efficient. Thus, the activities in the e-LKPD contribute to improving students' critical thinking skills, in line with the findings of Ma'rufah (2023), which state that an e-LKPD based on a scientific approach is effective in training critical thinking. Nevertheless, the indicator of providing further explanations obtained the lowest N-Gain score, although it is still categorized as medium. Based on the effectiveness test and observations, students still require guidance to analyze questions, connect answers with practicum results, and identify implicit reasons. The low achievement on this indicator is also influenced by low reading motivation, as most students did not utilize the supporting articles in the e-LKPD and preferred to obtain answers directly from their peers.

Improvements occurred across all critical thinking indicators because the e-LKPD with a scientific approach trained students to formulate practicum objectives, analyze problems, ask questions, rewrite practicum steps according to their understanding, and answer the questions in the e-LKPD. At the beginning of learning, students were asked to read excerpts of material in the e-LKPD and watch the practicum tutorial video, then were given the opportunity to ask and answer questions from other students. These activities trained their ability to focus and analyze questions as well as their questioning and answering skills, which are indicators of providing simple explanations (Rachmawati *et al*., 2015).

The aspect of building basic skills was trained through activities such as rewriting practicum steps based on each student's understanding, carrying out soyghurt fermentation and mold observation on tempe, as well as organizing and analyzing the results of organoleptic tests and observation data. Students compared the data with reference articles before drawing conclusions, so their ability to align data with scientific sources could develop. This is in line with the findings of Istiqomah *et al*. (2022), which state that the implementation of the PjBL model integrated with practicum can improve students' critical thinking skills.

Analysis of the Effectiveness Test of the e-LKPD on Improving Students' Science Process Skills

The results of the effectiveness test of the e-LKPD on improving students' science process skills were obtained by calculating the increase between the pre-test and post-test scores using the N-Gain formula, as well as through observations of students' attitudes during learning activities using the e-LKPD as presented in Figure 4.

Table 4. Students' SPS Assessment Results

No.	SPS Aspect	Pre-test	Post-test	*N-Gain*	N-Gain Criteria	Observation	Observation Criteria
1.	Observing	52,94	97,06	0,94	High	73,53	Good
2.	Formulating problems	43,38	82,35	0,69	Medium	72,06	Good
3.	Conducting experiments	43,75	88,24	0,79	High	85,29	Very Good
4.	Measuring and using numbers	54,41	94,85	0,89	High	88,24	Very Good
5.	Classifying	52,94	91,18	0,81	High	100	Very Good
6.	Interpreting data	41,18	71,32	0,51	Medium	83,82	Very Good
7.	Drawing conclusions	54,90	87,25	0,72	High	86,03	Very Good
	Average			**0,75**	**High**	**84,14**	**Very Good**

Figure 4 shows an increase in post-test scores compared to pre-test scores. This finding is consistent with Mustofa & Trimulyono (2022), who state that an e-LKPD based on a scientific approach is proven to be highly valid in training SPS and is feasible to be used as a learning medium. The highest N-Gain score is found in the observing indicator, which falls into the high category, while the lowest N-Gain score is found in the interpreting data indicator, which falls into the medium category. Overall, the average N-Gain score for all indicators is in the high category.

A total of 49 out of 68 students were able to formulate problems related to the practicum activity, while 19 students were still unable to do so even after receiving prompting questions. Observation results showed that students who were unable to formulate problems tended to be passive, reluctant to express their thoughts, and dependent on guidance from group members. This finding is in line with Yunita & Nurita (2021), who reported that students' problem-formulation skills fall into the medium category. Some students were able to give correct answers, while others still struggled to understand how to formulate problems appropriately.

The aspect of interpreting data is reflected in students' ability to connect the results of the soyghurt organoleptic test and mold observations with scientific theory in the e-LKPD questions. Based on the N-Gain calculation, this ability falls into the medium category, indicating that some students still had difficulty linking practicum data to relevant theory. Although the observation results fall into the very good category, these difficulties were still apparent in students' answers to e-LKPD exercises. Some students did not answer questions completely, meaning that their analytical ability to connect practicum results with theory still needs improvement. However, the majority of students were able to provide complete and theoretically appropriate answers. This finding aligns with Windari *et al*. (2022), who reported that achievements in SPS related to data presentation tend to be lower because many students do not include all necessary variables.

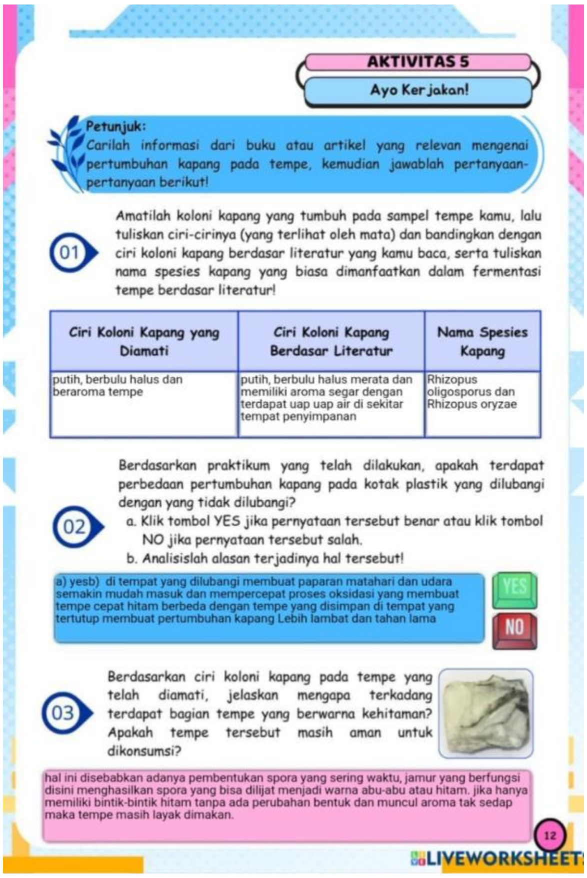
Observing skills were trained through watching tutorial videos and making direct observations during the practicum. The improvement in this skill was supported by observation results categorized as good, marked by active student participation in preparing tools, conducting the practicum, tasting the soyghurt, and assessing its organoleptic properties. Students also used supporting articles in the e-LKPD to answer fact-based questions, consistent with Windari *et al*. (2022), who stated that scientific-based e-LKPDs are highly effective in training observing skills.

The aspect of conducting experiments falls into the high category, supported by observation results categorized as very good. Students were able to explain the reasons for selecting tools and materials and identify experimental variables in the e-LKPD. However, some students did not fully follow the practicum tutorial video. This was evident from their lack of focus when watching the video and their tendency to immediately ask group members for instructions. Nevertheless, most students demonstrated strong cooperation and enthusiasm throughout the practicum. High curiosity also contributed to students' enthusiasm, making them actively participate in all practicum activities (Mursitaningrum *et al*., 2019).

The aspect of measuring and using numbers falls into the high category, as shown by students' ability to measure soybean extract using a measuring cup and weigh sugar, skim milk, and inoculum using a digital scale accurately. Observation results in the very good category reinforce the finding that students were able to operate measuring tools accurately, in accordance with the basic SPS described by Zulirfan *et al*. (2019).

The aspect of classifying falls into the high category because it was trained through identifying, comparing, and grouping the results of soyghurt fermentation and mold growth on tempe. Students recorded the organoleptic results of soyghurt according to the treatments and grouped mold observations based on container conditions, enabling them to identify similarities and differences among treatments systematically. Group discussions also strengthened classification skills because students could exchange perspectives and reach agreements together. This activity simultaneously trained communication and collaboration skills, as stated by Arifah *et al*. (2025), who noted that effective discussions encourage idea exchange and active learning. The classification results were then recorded in the e-LKPD tables for further analysis.

The classification skill improved with an N-Gain value categorized as high and observation results categorized as very good. Students were able to compare organoleptic results based on variations in sugar


AKTIVITAS 5

Ayo Kerjakan!

Petunjuk:
Carilah informasi dari buku atau artikel yang relevan mengenai pertumbuhan kapang pada tempe, kemudian jawablah pertanyaan-pertanyaan berikut!

01 Amatilah koloni kapang yang tumbuh pada sampel tempe kamu, lalu tuliskan ciri-cirinya (yang terlihat oleh mata) dan bandingkan dengan ciri koloni kapang berdasar literatur yang kamu baca, serta tuliskan nama spesies kapang yang biasa dimanfaatkan dalam fermentasi tempe berdasar literatur!

Ciri Koloni Kapang yang Diamati	Ciri Koloni Kapang Berdasar Literatur	Nama Spesies Kapang
putih, berbulu halus dan beraroma tempe	putih, berbulu halus merata dan memiliki aroma segar dengan terdapat uap uap air di sekitar tempat penyimpanan	Rhizopus oligosporus dan Rhizopus oryzae

02 Berdasarkan praktikum yang telah dilakukan, apakah terdapat perbedaan pertumbuhan kapang pada kotak plastik yang dilubangi dengan yang tidak dilubangi?
a. Klik tombol YES jika pernyataan tersebut benar atau klik tombol NO jika pernyataan tersebut salah.
b. Analisislah alasan terjadinya hal tersebut!

a) yesb) di tempat yang dilubangi membuat paparan matahari dan udara semakin mudah masuk dan mempercepat proses oksidasi yang membuat tempe cepat hitam berbeda dengan tempe yang disimpan di tempat yang tertutup membuat pertumbuhan kapang Lebih lambat dan tahan lama

YES NO

03 Berdasarkan ciri koloni kapang pada tempe yang telah diamati, jelaskan mengapa terkadang terdapat bagian tempe yang berwarna kehitaman? Apakah tempe tersebut masih aman untuk dikonsumsi?

hal ini disebabkan adanya pembentukan spora yang sering waktu, jamur yang berfungsi disini menghasilkan spora yang bisa dilijat menjadi warna abu-abu atau hitam. jika hanya memiliki bintik-bintik hitam tanpa ada perubahan bentuk dan muncul aroma tak sedap maka tempe masih layak dimakan.

12

LIVEWORKSHEETS

and inoculum and record them systematically in the organoleptic test table. This improvement aligns with the characteristics of classification skills as a basic science process skill (Zulirfan *et al.*, 2019).

Figure 3. Examples of Student Answers for Practice Questions Number 1 and 3 in Activity 5

The aspect of drawing conclusions is trained through learning activities, particularly during the practicum and when students work on practice questions in the e-LKPD. This learning process involves a series of stages such as group discussions, direct observations, data collection, data analysis, and formulating conclusions based on existing evidence. Discussion activities encourage students to exchange ideas in interpreting data to produce rational conclusions. This aspect increased with an N-Gain score in the high category and was supported by observational results in the very good category, indicating that students were able to formulate conclusions based on the practicum results. The implementation of the scientific-based e-LKPD proved effective in training this ability, as reflected in the students' answers to practice questions number 1 and 3 in Activity 5, as shown in Figure 3.

Limitations of the e-LKPD

The limitations of the scientific-based e-LKPD on Biotechnology material intended to improve students' critical thinking skills and science process skills include the absence of offline access, which makes its use dependent on a stable internet connection. The participation of some students during the practicum was low due to fear of making mistakes and lack of motivation despite being encouraged. The supporting article link on mold growth in tempe was not explained clearly, resulting in the *external reading* activity being utilized suboptimally. The practicum instructions were not detailed enough, causing the soyghurt fermentation process to be less optimal and leading to failed results in several samples. The e-LKPD also does not include safety instructions, such as prohibitions against opening the pressure cooker lid before the pressure drops or manually lifting the steam valve, both of which are important for ensuring safety during the practicum.

Advantages of the e-LKPD

The scientific-based e-LKPD on Biotechnology material designed to enhance students' critical thinking skills and science process skills has several advantages, including supporting the digitalization of learning, enabling students to become familiar with digital media, and allowing teachers to distribute and update learning materials easily without reprinting. The use of the e-LKPD is also more efficient in terms of time, cost, and paper usage. Interactive features such as images, videos, and relevant links make learning more contextual and engaging, while students can complete and submit assignments directly through the e-LKPD platform. The inclusion of control variables in the practicum also helps students compare fermentation results and analyze data more deeply, allowing their critical thinking skills (CTS) and science process skills (SPS) to develop more optimally.

CONCLUSION

Based on the research objectives and findings, it can be concluded that the scientific-approach-based e-worksheet (e-LKPD) on Biotechnology meets the eligibility criteria as a digital learning material. The very high validity ratings from material and media experts, along with excellent readability levels reported by teachers and students, further support its feasibility for use in learning. The e-LKPD is proven effective in improving tenth-grade students' critical thinking and science process skills, as indicated by the high-category N-Gain scores and reinforced by the excellent results of practical performance observations. This study provides a scientific contribution in the form of a digital learning material developed using a scientific approach, which can be utilized as a supplementary resource for biotechnology learning and serve as a reference for the development of digital instructional media oriented toward strengthening 21st-century skills.

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