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Web-Based Module on Biotechnology: Fostering Preservice Science Teachers' Eco-literacy Skills

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Abstract: Pre-service science teachers need to be aware of eco-literacy and biotechnology as they will teach science subjects to students from the perspectives of 21st-century skills. This study aimed to develop a web-based module on biotechnology and examine preservice science teachers' eco-literacy skills after using the developed module. The study used a research and development design adopting Molenda's product development model (Analysis, Design, Development, Implementation, and Evaluation/ADDIE). There were 60 students majoring in science education as the research participants. The data were collected using a needs analysis questionnaire, a curriculum analysis form, a validation sheet, tests, and a response questionnaire. The obtained quantitative data were analyzed using IBM SPSS 25 with descriptive statistical tests with Swanson's quantifications. Results showed that the web-based module on biotechnology could be developed through ADDIE stages with experts' high validity results (M = 4.59, valid with revision). The module significantly improved the teachers' eco-literacy skills on biotechnology topics (F = 14.053, p = .000, N = 60). This result implies that the web-based module on biotechnology can assist preservice science teachers in improving their eco-literacy skills.

Keywords: *Biotechnology, eco-literacy, preservice science teachers, web-based module.*

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Introduction

Eco-literacy is important to many stakeholders today because of massive technological growth and the simultaneous possibility of environmental damage, e.g., from irresponsible actions such as poor technology and waste management. Eco-literacy or ecological literacy is necessary for students to realize that they must respect their environment and develop appropriate skills (Keraf, 2013). These skills are about being literate and providing effective and wise solutions related to critical environmental issues to create an eco-friendlier environment for beings to live on Earth (Keraf, 2014; Nabhan et al., 2020; Nugraha et al., 2022; S. U. Putri & Nikawanti, 2017; Setiawati et al., 2020). The eco-literacy contents prioritize students' authentic experience of natural science phenomena and should be taught in a student-centered model rather than just cognitive emphasis (R. Carver, 1996; R. L. Carver, 1997; Corney & Reid, 2007). So, eco-literacy must be able to encourage students to be more sensitive in realizing (cognitive aspect), feeling (affective aspect), and having the desire to act (psychomotor aspect) to protect the earth. In eco-literacy teaching, teachers can use project-based learning (PjBL) to introduce its materials and skills. The application of eco-literacy can be started by focusing on the understanding of changes in the physical environment and their effects on land and the description of ways to prevent environmental damages (e.g., erosion, abrasion, floods, and landslides) (Van Dyck et al., 2022).

Unfortunately, the introduction of eco-literacy has not been taken seriously. This situation is reflected in the most un-environmentally friendly behaviors on biotechnology issues such as harming the environment, bioterrorism, laboratory unsureness, and ethical issues (Haszeldine et al., 2018) (Echeonwu et al., 2018; Hannan & Aigbogun, 2021; Naik et al., 2019; Ott et al., 2018; Rathjen & Shahbodaghi, 2021; Saudy et al., 2020; Walubita et al., 2018). These typical behaviors refer to low critical and creative thinking skills, especially in being aware of the environment and what to do with the issue's causes. Critical thinking skills are the first characteristic of students' ecological intelligence that lets them do

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scientific analysis (Pratama & Lestari, 2015; Siburian et al., 2019; Trilling & Fadel, 2009). These pathetic phenomena might be based on education services emphasizing less eco-literacy content and skills. Thus, before leading to the real-life teaching and learning process, preservice science teachers need to master both critical and creative thinking and eco-literacy skills. They must experience eco-literacy teaching during their study times in the teacher training institution by having various types of learning media, especially in coping with biotechnology subject matters (e.g., books, videos, news, handbooks, or modules) (Hamilton et al., 2021; Karaarslan Semiz & Teksöz, 2020; Muthukrishnan, 2019; Nugraha et al., 2022; Reisoğlu & Çebi, 2020). A teacher or lecturer can use IT-based learning media, for instance, mobile learning applications (Frisnoiry et al., 2019; Pursitasari et al., 2022) or website-based learning media (Firdausi & Wulandari, 2021; Hidayah et al., 2018). A mobile learning application or website-based learning media allows the students to be more comfortable and simpler in learning regardless of the times and places and gives an online-based experience so the media can cover a wider scope of learners in different regions or countries (Keogh et al., 2018; Marianingsih et al., 2021; Susanti et al., 2020; Wuryani et al., 2018).

Regrettably, to the researcher's knowledge, no studies have developed a website-based module to train eco-literacy skills with the topic of biotechnology. Thus, the present study aimed to develop a website-based module to increase preservice science teachers' eco-literacy skills in biotechnology. Moreover, the present study also aimed to examine preservice science teachers' eco-literacy skills after the treatment using the website-based module. This study was only limited to the Indonesian context and teacher training program undertaken in the science education department at one of the universities in East Java Province. This small-scale research was the initial investigation of how influential the developed website-based module was in enhancing Indonesian preservice science teachers' eco-literacy skills in biotechnology. The present study is useful in enriching the literature on developing a website-based module to advance eco-literacy skills. Moreover, this study benefits Indonesian and international science teachers by introducing easy biotechnology materials with the mastery of eco-literacy skills. The study formulates the following research questions:

1. How is the development process of the web-based module on biotechnology?
2. How effective is the developed web-based module at improving Indonesian preservice science teachers' eco-literacy skills?

Literature Review

Several previous studies have researched eco-literacy skills in different fields and settings. Nadiroh et al. (2019) stated that eco-literacy is an attempt to understand how important it is to preserve the environment. In their studies, eco-literacy and critical thinking skills are two aspects that can force people to do more eco-friendly actions, regardless of gender. Nadiroh et al. (2019) also conveyed that teaching eco-literacy skills should be undertaken early by integrating it into some interesting IT-based learning media according to the education level. At the university level, they argued that eco-literacy teaching can emerge in generating innovations for advanced environments. Hilmi et al. (2021) conducted a study to describe household waste management based on eco-literacy activities as part of eco-friendly activities. They found that people, regardless of age, are aware of recycling activities based on the eco-literacy content in waste management. In measuring their eco-literacy skills, Hilmi et al. (2021) used four aspects of eco-literacy skills, namely knowing environmental problems, formulating an effective troubleshooting strategy, monitoring ongoing procedures in alleviating environmental problems, and having quality in responding to environmental problems and perceiving a good personal attitude. In the school context, Bigler and Hanegan (2011) explained several steps for implementing eco-literacy skills in schools, including transmitting this eco-literacy movement to students by delivering eco-literacy theories. It can be undertaken through activities to maintain and make good use of the environment. The third step is to evaluate by providing advice and input to the school policymakers about implementing the eco-literacy program. Hence, eco-literacy skills should be introduced to students earlier to sharpen their perspectives on preserving the ecology. According to previous studies, eco-literacy skills should be taught very early.

Methodology

Research Design

The study used a research and development (R&D) design by adopting the ADDIE model of analysis, design, development, implementation, and evaluation stages (Molenda, 2003). The model used a quantitative approach at most to process the data to get the impact results of the developed module.

Sample and Data Collection

The study involved 60 participants from two classes in the same academic year. Table 1 illustrates the participants' demographic data.

Table 1. Participants' Demographic Information

Information	Categories	Percentage
Gender	Male	31.67%
	Female	68.33%
Current Semester	3	100%
Undertaken Courses	Basic Chemistry	100%
	Microbiology	100%
	Basic Physics	100%
	Bioethics	100%
	Genetics	100%
Class	A	50%
	B	50%

Table 1 explains that most participants were female preservice teachers (68.33 percent). However, the other information (e.g., current semester, courses taken, and class) was evenly distributed and did not pose any problems. As for the uneven gender distribution, the conclusion of the present study should be reconfirmed whether eco-literacy ability was influenced by gender, as some studies have found that female students have better literacy skills (Michalak et al., 2017; Mukti et al., 2019; Siddiq & Scherer, 2019). Although this study did not focus on gender and eco-literacy, it is important for future research.

In addition to the ADDIE model, the present study employed the model based on its visibility to develop learning media and its familiarity with creating instructional media, which had been undertaken by many researchers (Durak & Ataizi, 2016; Gusmida & Islami, 2017; Jumiarni et al., 2022; Molenda, 2003; Muruganantham, 2015). Table 2 shows several actions commenced in each ADDIE stage.

Table 2. Description of Action Conducted in Each ADDIE Stage

Stage	Actions	Instruments
Analysis	Conducting preservice science teachers' needs analysis and curriculum analysis	• Needs analysis questionnaire • Curriculum analysis form
Design	Generating appropriate media designs in accordance with the results of needs analysis	• Needs analysis questionnaire
Development	Creating the web-based module and conducting face and content validity	• Validation sheet
Implementation	Implementing the web-based module in a project-based learning model and conducting pretest and posttest using a static-group pretest-posttest experimental research design.	• Eco-literacy in Biotechnology Test
Evaluation	Colliding preservice teachers' feedback and reflecting on the implementation of the web-based module in a project-based learning model through a one-group pretest-posttest design	• Response questionnaire

Analyzing of Data

Five instruments were employed in the ADDIE stages: a needs analysis questionnaire, curriculum analysis form, validation sheet, eco-literacy in biotechnology test, and response questionnaire. The needs analysis questionnaire and curriculum analysis form were employed to gather initial information to determine the module's content and face. The needs analysis questionnaire was a six-point Likert scale from strongly disagree to agree strongly. It consisted of 10 questions distributed fairly into previous learning materials and future learning material needs. Each aspect included five sub-skills: flexibility, usability, material completeness, design and interface, and millennial-based value. Because the questionnaire was first constructed on the needs of the students and institutions, the questionnaire was trialed with 60 participants who enrolled in classes A and B, with 15 participants representing each class. The chosen participants of each class used random sampling to support the generalization of the reliability test results. After the pilot study revealed the students' needs, the questionnaire was proven reliable with a Cronbach's alpha (α) value of .877, categorized as very high reliability. Moreover, the experts' evaluations showed a valid result with modifying items on the millennial-based value.

Second, the curriculum analysis form encompassed ten items revealing the learning topic, time allocation, the goal of the learning process, learning indicators, learning objectives, pre-learning activities, during-learning activities, post-learning activities, assignments, and assessments. The researcher used this form with colleagues in the Biology Education

Department to conduct a forum group discussion (FGD) to disclose each curriculum needs items. The involvement of colleagues served to maintain the goals and validity of the curriculum needs assessment results. Third, the validation sheet was provided to three experts to validate the developed module. The validation sheet consisted of a face (e.g., color, font, readability, layout, design, and accessibility) and content (e.g., curriculum appropriateness, relevant extended materials, and consistent materials) validity. The three experts received the validation sheet along with the scoring rubric. The experts had expertise in science education, biotechnology, and eco-literacy. Finally, the response questionnaire was a structured model designed to determine teachers' feelings, comfort with learning, ease of learning, and willingness to continue using the module in learning biotechnology. The questionnaire consisted of eight items and was tested similarly to the needs analysis questionnaire. The internal consistency test of the questionnaire showed very high validity (α = .977). Table 3 shows how the data obtained from the different instruments were analyzed.

Table 3. Scheme of Data Analysis Technique for Each Instrument

Instruments	Types of data	Data analysis technique
Needs analysis questionnaire	• Quantitative	• Descriptive statistics with a focus on *M* score classification. $M < 3$ = low agreement $3 \le M < 4$ = moderate agreement $4 \le M \le 5$ = high agreement
Curriculum analysis form	• Qualitative in the form of sentences or descriptions	• The syllabus was analyzed qualitatively to look for the answers to the aforementioned ten items.
Validation sheet	• Quantitative	• M score classification $M < 3$ = not valid and needed revisions $3 \le M < 4$ = valid with some revisions $4 \le M \le 5$ = very valid with no revisions
Response questionnaire	• Quantitative	• Descriptive statistics with Swanson's *M%* score classification $M < 25\%$ = low interest $25\% \le M < 50\%$ = moderate interest $50\% \le M < 75\%$ = high interest $M \ge 75\%$ = very high interest

Web-Based Module in Project-Based Learning: Implementation and Measurement

The project-based learning (PjBL) process was conducted in three phases: pre-, during, and post-learning. The pre-learning activities required the lecturer to greet the preservice teachers and ensure they were in good condition. Then, the lecturer started a small talk with the preservice teachers on daily scientific phenomena. In this case, the lecturer acted as a facilitator who gave provocation questions to run the small talk effectively. This role was necessary since zero schemata on the topic discussed was possible. While the lecturer addressed several questions to be responded to and discussed by the whole class, the preservice teachers could deliver their responses. In this case, there was no correction of knowledge, meaning that the lecturer only aimed to reveal their prior knowledge on the topic discussed. The preservice teachers also responded to their peers' answers or ideas, so they communicated with them. Afterward, the lecturer explained the essential presence of food security and the interference of biotechnology in it as an example of daily scientific phenomena. In this phase, the lecturer ensured that the preservice teachers were ready and willing to discuss the concept and practice of food biotechnology. She was encouraged to explain that the web-based learning module would assist the learning activities in completing the learning objectives. Regarding the use of the web-based module, before moving to the during-learning phase, the lecturer had to introduce the module to the preservice teachers in connection with the site address, the operation procedures (i.e., the materials followed the learning phase needs), and the contents within it. The preservice teachers could address several questions if they had trouble understanding the module use protocols.

The lecturer divided the class into five smaller groups regarding learning activities. Each group was given different assignments, including describing biotechnology in conceptual form, explaining the history of biotechnology, teaching the types of biotechnology, identifying biotechnology problems, and determining an effective strategy to avoid food abundance. In this stage, the preservice teachers could refer the materials to the available information on the developed website, especially the earlier parts of the module, which addressed the five topics. In a group, the preservice teachers discussed the materials of the given topic with their peers. They provided clear information on the given topic by reading the module, connecting it to their prior knowledge, or finding some reference support. While they had time to do group work and discussion, the lecturer monitored the classroom activities and supervised every question and difficulty faced by each individual. After the group discussion, the preservice teachers were asked to present the discussion results classically to exchange understanding. The preservice teachers had to use their critical and creative thinking skills to generate appropriate presentation materials.

After all preservice teachers understood the five basic knowledge of biotechnology (e.g., biotechnology in conceptual form, the history of biotechnology, types of biotechnology, problems of biotechnology, and effective strategies to avoid food abundance), the lecturer gave them problems and instructed them to point out and solve the problems. This practice was conducted as a group project in which the project was in the form of a product presentation. Each group was given similar news regarding the use of biotechnology to support food security and nutrition in Indonesia (see Appendix 1). The text was adapted from a national news site, with some modifications consistent with the learning objectives and describing biotechnology in a conventional and modern way. Each member of each group participated in identifying the problems facing Indonesia in the area of food security. Then, they had to develop innovative actions to exploit Indonesia's opportunities through biotechnology to produce affordable but nutritious food. The resulting product was presented to the class to share knowledge and creativity about biotechnology-produced food. In this learning stage, the lecturer gave the preservice teachers more opportunities to explore their knowledge about the materials and connect it to the given topic. In other words, there was no further guidance on how to conduct the discussion. The lecturer only addressed technical issues (i.e., working times and presentation procedures). Finally, the lecturer provided an overview of the product or project presented in the wrap-up session and evaluated it. The overview was auditory feedback to provide more input on what was missing from the presentation. The lecturer was required to provide positive and constructive feedback and not negative comments that might decrease the preservice teachers' motivation to learn. Then, the lecturer can reward the group, regardless of the type of reward.

A static group pretest-posttest experimental design was used to examine how effectively the module improved preservice science teachers' eco-literacy skills, particularly with biotechnology topics, within the experimental class and compared to the control class (Fraenkel et al., 2018). Two classes were A and B, each with 30 preservice science teachers. Class A was designated the control class, and class B was the experimental class. The distribution of participants in each class was fair, with equal proportions of abilities and backgrounds. Class A did not receive the opportunity to use the developed module, while Class B received the implementation of the PjBL mode using the web-based module on biotechnology. All participants in the study had basic knowledge of chemistry, microbiology, physics, bioethics, and genetics. The first hypothesis (H0) was that the developed web-based module significantly influenced preservice science teachers' eco-literacy skills. The second hypothesis (H1) was that the developed web-based module did not significantly influence the teachers' eco-literacy skills. A pre-test was conducted to determine the preservice teachers' initial eco-literacy skills. A post-test was undertaken to understand the final learning achievement for the control and experimental classes. The pre-test and post-test questions were similar to obtain reliable results (see Appendix 2). There were two texts with four questions, each asking for teachers' understanding of food security and coffee fermentation. The questions were in the form of multiple choice with four options. The objectives of the four questions between the first and second texts were similar, namely analyzing the fundamental problems of the given biotechnology issues (indicator eco-literacy 1), generating effective ecological-based troubleshooting (indicator eco-literacy 2), providing sequent and creative ecological-based procedures to conduct the problem solving (indicator eco-literacy 3), and presenting appropriate attitudes (indicator eco-literacy, 4), The total score was calculated by dividing the correct answers by eight (the total number of questions) and multiplying by 100. The minimum score was 75 (the minimum curriculum passing score). After obtaining the pre-test and post-test scores, a paired sample t-test was performed using IBM SPSS 25 to determine the difference. The present study used to test the independent samples t-test, the extent to which the eco-literacy of the preservice teachers in class A differs from that in class B. Researchers used the t-test for paired samples within a group. At the end of the statistical tests, it was possible to determine how much the developed web-based module on biotechnology influenced the eco-literacy of the preservice teachers.

Results

The following results portray the ADDIE model's step-by-step development. The results are presented for each stage.

Developing a Web-Based Module Using Molenda's ADDIE Stages

The web-based module in biotechnology was developed in five stages: analysis, design, development, implementation, and evaluation. First, in the analysis stage, preservice science teachers' needs were revealed, covering the information of previous learning media and the expected media. Table 4 shows the results of the needs analysis.

Table 4. Results of Needs Analysis for Preservice Science Teachers

Aspects	SD	M
Previous learning media	0.27	2.11
- Flexibility	0.70	2.16
- Usability	0.54	2.22
- Material completeness	0.58	2.11
- Design and Interface	0.59	2.00
- Millennial-based value	0.63	2.05

Table 4. Continued

Aspects	SD	M
Expected learning media	0.34	5.11
- Flexibility	0.63	5.05
- Usability	0.64	5.22
- Material completeness	0.51	5.16
- Design and Interface	0.58	5.11
- Millennial-based value	0.59	5.00

Table 4 shows that the *M* score of the aggregate value of previous learning media showed low agreement with the questionnaire items ($M < 3$). This result implied that the preservice science teachers did not think that the current learning media they had reflected good flexibility in usage, easy usage, complete biotechnology materials, attractive design and interface, and up-to-date to the current information and technology (IT) era. On the contrary, the expected learning media was to be flexible in usage (e.g., teachers could access the media wherever and whenever), easy usage (e.g., teachers could use it easily without going to the library or doing initial registration), complete biotechnology materials (e.g., introduction to biotechnology, history of biotechnology, conventional and modern technology, and assessments), and up-to-date to the current information and technology (IT) era (e.g., integrating website-based media) ($M > 5$). In addition, ten important aspects were considered in coping with the results of the curriculum analysis, such as the learning topic, the timing, the goal of the learning process, the learning indicators, the learning objectives, pre-learning activities during learning, the activities post- learning, activities, the tasks, and the assessments. Table 5 shows the results of the curriculum analysis.

Table 5. Results of Curriculum Analysis

Aspects	Descriptions of the needs
Learning topic	The topic should cover the concept of biotechnology, especially conventional biotechnology as it was associated with the phenomena of the environment of most preservice science teachers.
Time allocation	The subject matters should be within four learning hours.
Learning goal	The preservice science teachers mastered the concept of biotechnology and the application of eco-literacy.
Learning objectives	The preservice science teachers compare and contrast the concept of biotechnology and disseminate the difference between conventional and modern biotechnology. They could analyze the biotechnology problems and raise effective and creative troubleshoots of the problems.
Learning indicators	The learning indicators were similar to the learning objectives with more specific competencies (e.g., conceptual and practical biotechnology mastery and analysis skills in eco-literacy skills).
Pre-learning activities	The preservice science teachers were introduced to the learning goals of the biotechnology topic and were introduced to the web-based module in biotechnology.
During-learning activities	The preservice teachers were encouraged to explore biotechnology materials in the developed web-based module.
Post-learning activities	The preservice teachers were directed to have autonomous learning in developing their perspectives on biotechnology.
Assignments	The preservice science teachers were given a product presentation project as a part of the project-based learning (PjBL).
Assessments	The assessments were conducted to evaluate the learning process (e.g., process assessment) and the product (e.g., product assessment).

The second stage was to design the web-based module in biotechnology. The color choice was dominated by green and white, adapted to the symbol of nature and originality. The whole look was set to promote ecological preservation and environmentally friendly acts. Figure 1 shows what the web-based module looks like.

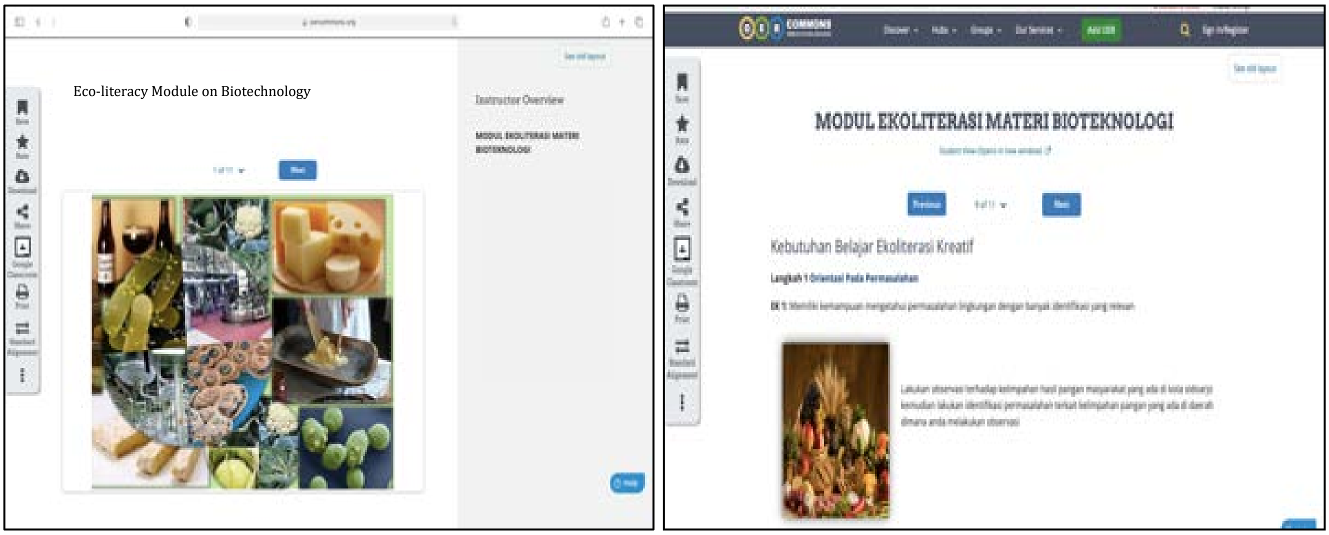

Figure 1. The Design and Interface of a Web-Based Module in Biotechnology: (a) Cover Page and (b) Student's Worksheet

The web-based module comprised eleven pages, including a cover page, a preface, six content pages, a worksheet page, a reference page, and a glossary page. The cover page included some pictures as illustrations of biotechnology and eco-literacy. The preface page covered the writer's statements, learning goals, and indicators. Regarding the content, the third page explains a general concept or theory of biotechnology. The following page four presents the history of technology development, traditional biotechnology, scientific biotechnology, and modern biotechnology. On page five, some experts' definitions of biotechnology are presented. On page six, conventional biotechnology is described with its advantages and disadvantages. On page seven, the application of food biotechnology is explained, for example, yogurt and tempeh. In this study, it was assumed that the materials of yogurt and tempeh are internationally recognized as the results of the conventional biotechnology process (Gómez-Camacho et al., 2022; Kenzheyeva et al., 2022; Khosravi-Darani et al., 2014; Pilco et al., 2019). Page eight explains *Rhizopus oligosporus*. The ninth page consisted of the student worksheet on biotechnology, and the following pages contained references and glossaries. The worksheet evaluated the preservice teachers' eco-literacy skills in biotechnology.

Afterward, the development stage was undertaken to finish the web-based module in biotechnology. In this stage, the experts were asked to validate the website in the form of face and content validity, in which all experts stated that the developed web-based module was valid (*M* = 4.59, valid with revision). The experts suggested revising the font type to be more academic and readable. After the revision, the web-based module was implemented in the classroom experiments. In revealing the effect of the web-based module on teachers' eco-literacy skills, the present study conducted a pretest-posttest experimental research design to examine how effective the media was employed to enhance preservice science teachers' eco-literacy skills, especially in biotechnology topics, within the experiment class itself and compared to the control class (Fraenkel et al., 2018). The analysis first revealed the difference between the pretest and posttest scores of preservice teachers in each group, using the paired-sample t-test to examine the changes in each indicator measured in the test. Then, the t-test for independent samples was used to examine the extent to which the eco-literacy skills of the preservice teachers in the experimental class differed from that of the control group. Table 6 shows the result of the paired samples t-test in the experimental class.

Table 6. Paired Sample t-Test Results in Experimental Class

Pair	Indicators Paired from Pre- and Post-test	Text	M	SD	df	t
1	Analyzing the fundamental problems of the given biotechnology issues (pre and post-test)	Text 1	0.26	0.44	29	3.24*
		Text 2	0.53	0.50	29	5.75*
2	Generating effective ecological-based troubleshot	Text 1	0.53	0.52	29	7.71*
		Text 2	0.73	0.52	29	9.37*
3	Providing sequent and creative ecological-based procedures to conduct the problem-solving for pre and post-test	Text 1	0.86	0.34	29	13.73*
		Text 2	0.80	0.40	29	10.77*
4	Presenting appropriate attitudes for pre and post-test	Text 1	0.53	0.46	29	4.57*
		Text 2	0.86	0.52	29	7.71*
5	Total Score Pre-test – Total Score Post-test		74.16	8.64	29	46.99*

*Significant at $p < .01$; $N = 30$

Table 6 indicates that all indicators from the two texts administered in the pre-test significantly improved in the post-test. The preservice teachers were able to analyze the fundamental problems of the biotechnology issues after the treatment, proven by the significant improvement. Moreover, they were able to generate effective ecological-based troubleshoots for text one about the utilization of microbes in Indonesian Coffee Fermentation and text two about food security. The preservice teachers improved their eco-literacy skills by providing sequential and creative ecological-based problem-solving procedures. At last, their presentation attitudes were also improved. The results indicate that they successfully adopted the developed web-based module on biotechnology to improve their eco-literacy skills. The preservice science teachers were assisted in acquiring eco-literacy skills, especially in biotechnology.

At some points, the control class had lower eco-literacy skills than the experimental class. Table 7 shows the results of the paired sample t-test for the control class.

Table 7. Paired Sample T-test Results in Control Class

Pair	Indicator Paired from Pre- and Post-test	Text	M	SD	df	t*
1	Analyzing the fundamental problems of the given biotechnology issues (pre and post-test)	Text 1	0.06	0.25	29	1.43
		Text 2	0.03	0.18	29	1.00
2	Generating effective ecological-based troubleshot	Text 1	0.10	0.30	29	1.79
		Text 2	0.03	0.18	29	1.00
3	Providing sequent and creative ecological-based procedures to conduct the problem solving for pre and post-test	Text 1	0.06	0.25	29	1.43
		Text 2	0.10	0.40	29	1.36
4	Presenting appropriate attitudes for pre and post-test	Text 1	0.03	0.31	29	.57
		Text 2	0.16	0.37	29	2.40
5	Total Score Pre-test – Total Score Post-test		2.50	6.05	29	2.26

*Significant at $p < .01$; $N = 30$

Table 7 showed an insignificant improvement in the preservice teachers' eco-literacy skills. In other words, the control class participants could not elevate their eco-literacy skills. This result means that the conventional teaching method about eco-literacy in biotechnology could not enhance preservice teachers' eco-literacy skills. In other words, using a web-based module was significant compared to the experimental class results. To ensure the results of within-group case analysis, an independent sample t-test was carried out to compare the experimental and control classes. Table 8 shows the results of the independent sample t-test.

Table 8. Results of Independent Sample t-Test

Comparing Experimental and Control Groups	F	Sig. (2-tailed)	t	df
	14.053	.000	28.544	58

At the end of the learning process, the preservice science teachers were given a questionnaire to reveal their responses after using the module, including their opinions, learning comfortability, learning easiness, and eagerness to use the module further when learning biotechnology. Most preservice teachers were very interested in each aspect (see Table 9).

Table 9. Preservice Science Teachers' Responses

Aspects	SD	M	M%	Description
Feelings	0.51	5.50	91.67%	Very high interest
Learning comfortability	0.51	5.55	92.59%	Very high interest
Learning easiness	0.42	5.77	96.30%	Very high interest
Eagerness to further use the module	0.42	5.77	96.30%	Very high interest

Table 9 describes the preservice teachers' interests in using the web-based module. Their interest in using the module to master eco-literacy skills created their learning comfortability, which was also determined as a very high interest. They also stated that the developed module was easy to use. Thus, the flexibility and usability aspects were completed. At last, they were excited to use the web-based module and wanted to recommend it for learning eco-literacy skills, especially in biotechnology.

Discussion

The validity test of the developed web-based module resulted in a very valid category due to the required points of the interface and readability rules. In addition, it was also consistent with the curriculum and the preservice science teacher's needs. Similarly, some previous studies have successfully developed learning media using the ADDIE model and demonstrated their effectiveness in improving student learning performance. Wahyuni and Sudarma (2018) also conducted a study on developing website-based learning media in science using the ADDIE model used in the present study. However, the study did not specifically address ecological literacy, which modern natural sciences should also address. Consequently, the media developed were only relevant to those who wanted to master science at a glance; thus, more specific topics were still under-covered. Sumardi et al. (2021) also created a website-based module based on the ADDIE model. However, the module was only for learning chemistry and did not promote users' awareness of environmental problems and damage (ecology literacy competencies). Finally, Febriani et al. (2021) also conducted a study on developing a website-based learning media to improve students' science literacy using the ADDIE model. This study had almost a similar focus to the present study. The difference was that Febriani et al.'s study did not focus on ecological literacy and biotechnology issues relevant to current food security and environmental challenges. Therefore, the ADDIE model could assist many learning media developers produce innovative and helpful media.

The present study revealed that the feelings of the preservice science teachers, learning comfort, ease of learning, and willingness to continue using the module were in a very high percentage (M% > 90%), which means that they had a very high interest in using the developed web-based module on biotechnology subject matters. Their interests were stimulated based on the all-easy features of the media compared to the previous conventional learning media, such as printed books and incomplete eco-literacy news. Another possible reason was that the web-based learning module was relevant to the millennial era, where today's typical students are closed to IT-based use, including but not limited to learning and coping with daily life. Margaryan et al. (2011) also stated that it is important to take advantage of opportunities that Millennial students are interested in rather than forcing them to use conventional methods only veteran teachers can use. The idea of using a website-based method was a good choice because many studies had confirmed the successful use of this method. For example, Jasrial et al. (2022) first conducted a study to develop an e-book that consisted of biology materials for preservice biology teachers during their undergraduate years. The e-book addressed general biology topics, so the materials and competencies assessed were broad. In contrast, the present study focused on biotechnology, including conventional and modern techniques. As in the present study, the media developed were considered valid with some revisions and could capture users' attention to learning the materials.

Moreover, the present study found that increased preservice science teachers' skills in generating effective ecological-based troubleshooting (indicator 2) and providing sequent and creative ecological-based procedures to conduct the problem-solving (indicator 3) had low *t* values, which means that these two indicators were less achieved than other indicators of eco-literacy skills. The factors could be the few practices in creating effective ecological solutions and the lower emphasis on more ecological issues such as non-biotechnologies. S. S. Putri et al. (2019) also noted that limited ecological discussions may only provide packaged ideas that cannot be used to improve students' eco-literacy. In other words, students must be exposed to finding practical solutions to ecological-based problems using sequential processes to obtain the best troubleshooting representation. However, S. S. Putri et al. (2019) found that prior knowledge also contributes to such troubleshooting. Unfortunately, the present study did not focus on how well prior knowledge was constructed, as the researchers believed that prior knowledge is irrelevant to the ability to effectively solve problems as long as the individual understands the correct knowledge and can apply it in real life. Some studies have also found that correct knowledge, acceptable knowledge according to theoretical and practical rationales, was significant in determining what to do and considering the possible outcome in the future (Alam et al., 2022; Buykx et al., 2018; Zhong et al., 2020).

Finally, the present study found that preservice science teachers' eco-literacy skills were improved after treatment with the developed web-based module for biotechnology. The module could stimulate their critical and creative thinking skills so that they develop a better understanding of ecological phenomena. Once their thinking is activated, they could develop feelings and behaviors to acquire and store the knowledge in their memory (Susantini et al., 2022). Similarly, Pursitasari et al. (2022) developed a mobile learning application on eco-literacy topics, and the media could improve students' critical thinking skills. They also mentioned that students can develop problems and solutions to ecological issues using eco-literacy-based interactive teaching materials (EITM). The study also found that using media helped them better understand the ecological issue, which aligns with other studies by Muthukrishnan (2019) and Firdausi and Wulandari (2021). In contrast, Pursitasari et al. (2022) only focused on improving students' critical thinking skills using eco-literacy about environmental change. They mentioned that eco-literacy materials can improve students' critical thinking skills (Pursitasari et al., 2022). In this case of using learning media differently, learning ecological phenomena and improving eco-literacy could be easily achieved by using media that provide thematic materials and representations of real problems (Firdausi & Wulandari, 2021; Muthukrishnan, 2019). Even though Firdausi and Wulandari (2021) also developed a web-based module to improve students' eco-literacy, they used four different indicators: awareness of the environmental condition, interest in the state of the environment, consideration of the state of the environment, and attempt to do recovery actions. In addition, they focused on temperature, expansion, heat, heat transfer, and implementation in daily life, including the mechanism for maintaining body temperature in humans and animals, which was irrelevant to the present study. Unfortunately, no research indicates that a web-based module with a project-based learning model can improve students' eco-literacy skills in biotechnology. Due to this gap, the present study took the initiative to include the web-based module in biotechnology education to enhance eco-literacy skills through a project-based learning model.

In the current study, project-based learning was suggested to give more experience in dealing with the case of ecological issues. The present study found that using project-based learning as a learning model to accompany the developed web-based module was effective in helping the preservice science teachers improve their eco-literacy skills. The present study divided the learning activities into three phases: pre-, during, and post-learning. Each phase emphasized student participation, so the lecturer became a learning facilitator. This design allowed the students to explore the given biotechnology topics better so that they independently perceived the knowledge that the facilitator had corrected, if necessary. Similar to the present study's finding, Haryudo et al. (2021) also conducted project-based learning to increase students' scientific thinking in three learning phases. Students were exposed to trainer kits in their study, so they directly experienced how to utilize such tools. However, in this project, students were less exposed to presentations to communicate their thoughts and share them with their peers. Consequently, constructive feedback was less exposed in their study design. Compared to the present study, there was feedback given from the lecturer and peers during the classical presentation. This stage served as a critical discussion and a knowledge sharing; thus, the project made by each group was not only left to the lecturer for assessment. Instead, the project was exhibited and discussed. In addition, Hidayati et al. (2023) also used project-based learning to increase students' learning outcomes through three phases. They asked the students to make a video that exhibited their thoughts on certain topics in which the learning process lasted for six months; however, the topics of the video, along with the rationales, were not mentioned. This study only used a single pretest-posttest design to test the effectiveness of project-based learning, which limited the study to the class context. Compared to the present study, two classes were used to test the effectiveness of the media in training eco-literacy skills. With this design, the present study was able to successfully compare the learning process before and after the instruction in the experimental class and compare the environmental education skills of the experimental class eco-literacy skills to the control class. Given this design, the present study was able to determine that the students who were exposed to PjBL through the developed web-based learning module were able to improve their eco-literacy skills.

Conclusion

In the present study, a web-based module on biotechnology was successfully developed that can improve the eco-literacy skills of preservice science teachers by considering four indicators, namely, analyzing the fundamental problems of the given biotechnology issues, developing effective ecologically based troubleshooting, providing sequential and creative ecologically based procedures to carry out problem-solving, and presenting an appropriate attitude. The module can be delivered through project-based learning (PjBL) with three phases of learning, namely before, during, and after learning activities. Preservice science teachers are exposed to both autonomous and classical learning during the learning process. These two learning environments help preservice science teachers reveal their competencies and communicate with others, especially when discussing conventional and modern biotechnology. In this case, students can negotiate before agreeing on a common approach. In addition, the PjBL model used in this study creates a space for the preservice science teachers to explore biotechnology materials beyond those included in the module. This finding occurs because the web-based module materials are easy to follow and produce interesting practices that activate their eagerness to learn critical thinking and creative thinking skills. The study also found that students whose learning process utilized the developed web-based module significantly increased their eco-literacy skills. In contrast, the students who learned using conventional methods increased their eco-literacy skills. This finding suggests that the web-based learning module effectively increases the eco-literacy skills of preservice science teachers. Interestingly, the PjBL model with web-based learning media also enables preservice science teachers to use 21st-century skills such as critical thinking, creativity, collaboration, and communication in the digital literacy mode. The preservice science teachers showed great interest in using this module and are willing to continue using it.

Recommendations

This study suggests that future research can develop more modules in the field of natural sciences that will help improve students' eco-literacy skills. For example, the module could address environmental damage and threats to life caused by the growth of technology. This topic is important for addressing Society 5.0 and possible future environmental challenges. In addition, some innovative modules can be developed in the form of mobile learning applications, flipbooks, or websites that can be used to develop critical thinking skills and other 21st-century skills. Communication, collaboration, creativity, compassion, and citizenship). More effective evaluations and assessment types should be reconsidered so that the module can be used independently with direct feedback from the media. For researchers with extraneous fields from natural sciences, developing learning media that permeate eco-literacy skills can be done through collaborative issues. This learning media creates a multidisciplinary learning environment. For teachers, website-based modules could be useful in this millennium age, so this module can support students who are closed to the use of IT. Specifically for Indonesian teachers teaching biotechnology, the module's content can be further developed in terms of interaction features so that there is an online correction for assignments. Parents of Millennial students should support IT in learning as the current learning situation requires a blended learning mode.

Limitations

This study is limited to the Indonesian context only, as the developed web-based module uses the Indonesian language and is limited to biotechnology topics. It can be further multi-translated so that other educational practitioners from different countries with different language teaching can use the module. In addition, the effectiveness results are limited only to Indonesian preservice science teachers because the design of the topics and the design of the materials are only adapted to the curriculum of Indonesian universities. In addition, this study did not investigate how some aspects (e.g., motivation and perspective to green behaviors) affected one's eco-literacy skills; therefore, further research can also be conducted in this area. Therefore, some aspects of this module can be further developed, and some gaps can be further explored.

Ethics Statements

The studies involving human participants were reviewed and approved by the University. The participants provided their written informed consent to participate in this study.

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Conflict of Interest

The authors have no conflict of interest.

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Authorship Contribution Statement

Wulandari: Writing the manuscript, producing the web-based module, and collecting and analyzing data. Susantini: Generating research concepts and procedures, leading the contents of web-making, providing relevant references, generating the teaching concept using the module, and collecting and analyzing data. Hariyono: Translating and proofreading the manuscript, generating abstract, and undertaking administration problems.

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Appendices

Appendix 1: News for Group Project

The news is written in Indonesian and consists of 508 words, published at https://umsu.ac.id/manfaat-kacang-kedelai-kesehatan/. Regarding the use of the news and the learning objectives of biotechnology, the researcher proposes the news regarding putting biotechnology issues on it.

Indonesian Text (real text used in the class)

Manfaat Kacang Kedelai untuk Kesehatan

Berdasarkan peninggalan arkeologi, kacang Kacang kedelai telah dibudidayakan sejak 3500 tahun yang lalu tepatnya di daerah Asia Timur. Kacang kedelai menjad sumber utama protein nabati dan minyak nabati dunia. Berikut beberapa manfaat kacang kedelai dari segi kesehatan:

1. Menurunkan tingkat gula darah
2. Membuat kenyang lebih lama
3. Lebih sehat daripada daging
4. Aman untuk dikonsumsi untuk segala usia

Kacang kedelai menjadi sumber gizi protein nabati utama di Indonesia. Selain itu, biji kacang kedelai juga mengandung lemak dan vitamin yang dibutuhkan tubuh. Faktanya, banyak olahan makanan dan minuman yang bisa dilihat disekitar kita yang menggunakan kacang kedelai namun tidak banyak diminati oleh masyarakat. Di kalangan pemuda usia produktif, kacang kedelai bukan menjadi makanan favorit.

Sangat disayangkan bahwa kacang kedelai dengan nilai gizi yang tinggi dengan banyak manfaat Kesehatan kurang diminati masyarakat.

Tugas!
Carilah kemungkinan masalah yang terjadi di bacaan tersebut dan berikan solusi pengolahan kacang kedelai dengan menggunakan bioteknologi. Usahakan proses pengolahan setiap kelompok berbeda dengan yang lainnya.

Benefits of Soybeans for Health

Based on archaeological remains, soybeans have been cultivated for 3500 years, precisely in East Asia. Soybeans are the world's main source of vegetable protein and vegetable oil. Here are some of the benefits of soybeans in terms of health:

1. Lower blood sugar levels
2. Makes you full longer
3. Healthier than meat
4. Safe for consumption for all ages

Soybeans are the main source of vegetable protein nutrition in Indonesia. Apart from that, soybean seeds also contain fat and vitamins that the body needs. In fact, many processed foods and drinks that can be seen around us use soybeans but are not widely sought after by the public. Among young people of productive age, soybeans are not a favorite food.

It is a shame that soybeans with their high nutritional value and many health benefits are less popular with the public.

Assignment!
Look for possible problems that occur in the reading and provide solutions for processing soybeans using biotechnology. Make sure the processing process for each group is different from the others.

Appendix 2: Texts and Questions for Pre-test and Post-test (English version)

Text 1. Utilization of Microbes in Indonesian Coffee Fermentation (Adapted from https://www.itb.ac.id/berita/detail/57357/orasi-ilmiah-prof-pingkan-adiawati-pemanfaatan-mikroba-dalam-fermentasi-kopi-indonesia*)*

Task: Read the passage and answer the following four questions accordingly.

Microorganisms are one of the important natural resources that Indonesia has. However, the potential of microbes has not received special attention from various groups and is still underestimated by some people and industry. The role of microbes has been felt for a long time, and it is just that people do not know enough about the role, potential, and ways to use microbes.

Prof. Pingkan Adiawati, Professor at ITB, presented some of her research on coffee fermentation with the help of microbes. There are several studies involving microbes as examples of solving environmental problems. Microbes can act as pollutant-reducing agents, especially in bioremedies, and can act as an energy source.

Food fermentation is a food production process with the help of microorganisms as processing agents. Fermentation involves enzymatic activity that helps simplify complex components such as carbohydrates, proteins, and fats. Pingkan said that the results of simplifying these complex compounds had an impact on suppressing the growth of pathogenic microorganisms. "*Apart from that, the reduced compounds can provide new tastes, textures, and aromas in Indonesian culinary delights*," she explained.

According to Prof. Pingkan, fermentation can occur naturally and in a controlled manner. Natural fermentation is a process with the help of native (indigenous) microorganisms from the food. Examples are Sumedang tofu and shrimp paste. Meanwhile, controlled fermentation is a fermentation process that involves microorganisms from outside the food. One example is making yogurt and nata de coco.

She also explained the factors influencing the fermentation process: the basic ingredients, the microbes that play a role, environmental conditions, and the processes carried out. "*Apart from the factors above, microbes that help the fermentation process, namely bacteria, mold, and yeast, must meet several requirements. These requirements are pure, stable, superior, and not pathogenic microbes*," she said.

Coffee is one of Indonesia's leading export commodities that adds to the country's foreign exchange. Indonesia is the third-largest coffee-producing country in the world in 2010. The types of coffee produced by coffee farmers in Indonesia are robusta (73%) and arabica (27%) in 2016. However, the taste of Indonesian coffee varies from Sabang to Merauke because it is influenced by the environment in which it grows. According to her explanation, this typical Indonesian coffee fermentation makes the taste and aroma more varied. The innovation carried out by Prof. Pingkan is fermenting civet coffee with bacteria so that making civet coffee can be done independently.

"*Concerns about animal abuse of civets as production agents are a problem. "Therefore, this research was carried out by taking isolated microorganisms from the civet's digestive tract and testing them in the laboratory*," she said.

The results of his research show that fermented and roasted coffee will increase polyphenols, which are useful as antioxidants. Roasting also affects the sugar content, which will undergo caramelization, and protein, which adds bitterness. "*So basically, after the roasting process, the taste and aroma of the coffee beans are added*," she explained.

Pingkan said that there were several obstacles faced in developing farming businesses. These constraints include land resources, harvest and post-harvest aspects, and human resources. "I propose several strategies, namely improving the skills of coffee farmers with guidance from research institutions, empowering members and coffee farming business groups to increase their entrepreneurial spirit, improving business capital schemes, optimizing farming land, and assisting with product marketing.

1. What is the complete reason for necessarily fermenting Indonesian coffee?
   a. As one of the largest coffee producers, Indonesia must vary its production with various taste options. Conventional fermentation could help enhance coffee production and boost the small enterprises to do it; thus, it also assists individual coffee farmers to attain a better economy and help the country's coffee exports.
   b. Fermenting coffee must provide various coffee aromas to meet different people's tastes and demands. Individuals expect the fermentation, so complicated fermentation by manufacturers is not necessary. Moreover, fermented coffee might provide better antioxidants, which enhances its value. This further elevates local coffee farmers' business.
   c. Big manufacturers can only undertake fermentation, but with conventional biotechnology, every coffee farmer and producer can do it independently. A fermentation process must be undertaken to eliminate the polyphenols to make the coffee consumable; therefore, every person can enjoy coffee regardless of age.

d. Coffee fermentation is conducted to boost the market of Indonesian coffee because of its uniqueness. Such fermentation is an effort to improve coffee farmers' economy, and increasing demand for Indonesian coffee is achieved. Moreover, fermentation is used to reveal coffee's true taste and aroma without ever changing the textures.

2. What factors contribute to an effective fermentation process of Indonesian coffee and produce various tastes and aromas?

   a. Successful making of good fermented coffee beans that create a special taste and aroma is determined by the quality of the coffee beans, which is influenced by the surrounding planting environment, the microbes used in fermentation that should be pure, superior, and not pathogenic, the fermentation media and condition, and the fermentation process. At last, the roasting process influences the sugar content and the occurrence of bitterness.

   b. An effective fermentation process should cover three traits: determining the basic ingredients, using pathogenic microbes, and considering good fermentation media. The coffee beans should be selected to avoid bad beans, and the pathogenic microbes will help eliminate the polyphenols. The fermentation media should consider the humidity that the media creates so the microbes can work efficiently.

   c. To produce various tastes and aromas, an effective fermentation process should focus on using microbes and the roasting process. The use of microbes influences enzymatic activity that helps simplify complex components such as carbohydrates, proteins, and fats. This simplification can be controlled so it produces various coffee tastes and aromas.

   d. The effective fermentation process relies on the basic coffee beans and microbes used. The quality of the coffee beans determines how well the coffee is produced after the fermentation, whether it produces good taste, texture, and aroma. The non-pathogenic microorganism affects the success of enzymatic activities during the fermentation period.

3. How could local coffee farmers enhance the value of the coffee product?

   a. Indonesian coffee farmers can appropriately control fermentation using appropriate microbes since natural fermentation is difficult to achieve to save production times.

   b. Coffee products can be elevated through the preselection of quality coffee beans that will be unnaturally fermented and roasted to get different tastes and aromas.

   c. The farmers can determine the coffee beans with fewer polyphenols to increase the antioxidant substance and do fermentation according to the suggested process.

   d. The Indonesian coffee farmers consider the type of fermentation and use it to do enzymatic activities in producing different tastes and aromas.

4. What are the possible future eco-friendly actions related to enhancing the market of fermented Indonesian coffee?

   a. The coffee farmers can determine quality coffee seeds to get outstanding coffee beans. In addition, they should be equipped with advanced farm technology to increase their coffee production. Ultimately, the coffee product can be marketed online to reach every corner of the world.

   b. In developing a farming business, coffee farmers should look at the planting medium used and know how to reuse it so, ecologically, the land can always be productive. They also need guidance and assistance from different stakeholders in applying biotechnology, for instance, to optimize all capital and market opportunities.

   c. The coffee farmers only need an opportunity to improve their skills in conducting control fermentation since they have insufficient idea about microbe usage. Moreover, they can individually do the fermentation after the guidance, which would be the autonomous outcome.

   d. In developing farming, coffee farmers should consider using fertilized soil only in growing coffee plants. They should not consider the aspect of harvesting times and methods as long as the quality coffee beans are achieved. In addition, the production process, including the fermentation, should be considered as it determines the coffee product's eminence.

Text 2. Food Security and Biotechnology: Batan Nuclear Rice (Adapted from https://indonesia.go.id/narasi/indonesia-dalam-angka/ekonomi/menjaga-ketahanan-pangan-lewat-bioteknologi)

Task: Read the passage and answer the following four questions accordingly.

Apart from successfully developing soybeans with a fast harvest period to fulfill national food stocks and defend national food security, at the end of 2020, the National Nuclear Energy Agency (Batan) also succeeded in developing other superior agricultural crop varieties. Like LIPI, Batan has also succeeded in developing 25 superior rice varieties and other food crop products, such as green beans, peanuts, sorghum, and wheat.

Batan also developed its research to produce superior products based on nuclear radiation, namely gamma Cobalt-60 with a dose of 0.20 kilogray as a radiation unit safe for foodstuffs. Radiation can penetrate plant seeds to the chromosome layer. Radiation rays can influence the structure of chromosomes in plant seeds.

Structural changes due to radiation can cause changes in the characteristics of plants and their offspring. This phenomenon is to improve plant characteristics to obtain plant seeds with certain advantages, such as pest resistance, drought resistance, or quick harvest.

Rice produced by nuclear radiation is completely safe, and no radioactive elements are left in the product. The head of Batan, Anhar Riza Antariksawan, believes that nuclear can be useful for increasing agricultural productivity and the community's economy by creating superior plant varieties.

One of the Batan rice varieties, namely the *kahayan* and *tropiko* types, was successfully cultivated on 200 ha of land in Tugumulyo District, Musi Rawan Regency, South Sumatra, in 2019. The harvest time for nuclear rice, as farmers call it, is around 110-115 days or sooner compared to rice in general.

Head of the Agricultural Division of the Batan Isotope and Radiation Application Center, Irawan Sugoro, said that apart from being able to survive growth and development and harvest on dry land, this nuclear rice is also resistant to planthopper pests and is more resistant to lodging. Another important thing is that the production is higher; it can produce 8.6 tons of GKP or 7.38 tons of milled dry grain (GKG) per hectare.

What researchers from national research institutions have done, apart from being in line with the National Research Priorities (PRN) program, is also to realize national food security and further improve the welfare of farmers throughout Indonesia.

1. What is the problem of the given biotechnology issue?
   a. It is necessary to keep up the stock of national foods in Indonesia, where the priority is to fulfill the needs of staple foods like soybeans and rice.
   b. There is an issue of bad harvest of the staple food, so biotechnology is required.
   c. There is a need to develop the quality of staple food with biotechnology innovation to provide diverse rice tastes.
   d. There is an issue of food insecurity where many staple stocks have not met the national demands.
2. How can Batan nuclear rice be the solution to the problems?
   a. Numerous characteristics of Batan nuclear rice can alleviate the problem of food shortages. It is fully safe and unaffected by radioactivity. Because of its quick harvest, Indonesians' national staple stock might be improved inexpensively and in terms of quality.
   b. Batan nuclear rice offers an easy plantation with costless production; thus, it can be more cost-friendly for national rice farmers. Even if its quality is under rice in general, its fast harvest provides better stocks where it can fulfill the national demands rapidly.
   c. Batan nuclear rice only needs 110-115 days for harvesting, which is sooner than rice in general. Moreover, its nuclear radiation does not affect the basic structure of rice, so the rice quality is not changed. Regarding productivity, it does not need complicated materials and tools where local farmers can do it autonomously.
   d. Numerous characteristics of Batan nuclear rice offer easy, inexpensive, and effective production. Moreover, Batan nuclear rice is safe and healthier and does not contain radioactive substances. Its varieties are many, so people can choose different tastes.
3. Regarding biotechnology, what is the significant usage of gamma Cobalt-60 on Batan nuclear rice?
   a. Nuclear radiation of gamma Cobalt-60 of 0.20 kilogray can safely penetrate plant seeds to the chromosome layer and change rice structure and characteristics, i.e., insect resistance and quick harvest.
   b. The radiation of gamma Cobalt-60 determines how the rice seeds are manipulated so the rice quality can be maintained regardless of weather, farming medium, and plant vitamins.

c. The radiation of gamma Cobalt-60 is a control variable in changing rice contents and structure at more than 0.20 kilogray. Consequently, it can create radiated seeds that produce manipulated rice that is insect-resistant, drought-resistant, and quick to harvest.

d. Gamma Cobalt-60 radiation amounted to 0.20 kilogray can ferment the rice seed, change its physiological structure to produce Batan nuclear rice resistant to weather and pests and speed the harvest times.

4. What is the future significance of the Batan nuclear rice?

a. National food security can be achieved with Batan nuclear rice, which can be grown and harvested on dry land, is resistant to planthopper pests and lodging, and is high in production. The benefits help Indonesian farmers' welfare improve.

b. Batan nuclear rice might fulfill the demands of rice as a staples in Indonesia since it is fast to farm. Even though the rice quality is not good compared to general rice, it is still consumable and safe.

c. Batan nuclear rice can be the solution to food insecurity in Indonesia. Its resistance to bad weather and soil conditions makes it outstanding among general rice types. Thus, Indonesian rice farmers can meet the staple needs in Indonesia.

The national food security can be fulfilled with the Batan nuclear rice, which is easy to plant, has effective harvesting time, is resistant to pests, is adaptive to any weather, and is competitive in price. This typical rice is also healthier than general rice