International Journal of Learning, Teaching and Educational Research
Vol. 22, No. 1, pp. 406-433, January 2023
https://doi.org/10.26803/ijlter.22.1.23
Received Oct 24, 2022; Revised Jan 23, 2023; Accepted Jan 27, 2023

Embedding Sustainable Development Goals to Support Curriculum *Merdeka* Using Projects in Biotechnology

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Abstract. The lack of practices of Curriculum *Merdeka* cause science teachers to worry about the results, especially related to environmental awareness. As such, this study aimed at exploring the role of biotechnology learning with embedded sustainable development goals (SDGs) to accomplish the academic purposes of the curriculum. In doing so, Pre-service Science Teachers (PSTs) were required to develop projects in biotechnology as well as problem-solving skills to be induced into their teaching competencies. This study used one-group pre-test and post-test design and involved twenty PSTs as participants. The parameters were perception, knowledge, and development of scientific projects. The instruments consisted of questionnaire, paper-pencil test, and rubrics. The data were then analysed in a descriptive manner. The results showed that most students perceived that biotechnology learning provides access to sustainability in human life. Also, there is a significant increase of student knowledge about innovating science with P-value of 0.00<0.05. For scientific projects, students in groups successfully created five titles in relation to SDGs issues, such as food nutrients, agricultural pests, fish-pond management, dengue fever control, and water quality. In terms of learning outcomes and themes, the contents within PSTs projects are relevant to two learning outcomes and four different project themes of Curriculum *Merdeka*, including lifestyle for sustainability, technology to support Indonesia, entrepreneurship, and local wisdom. Therefore, there is potential to bring PSTs projects to practice Curriculum *Merdeka*.

Keywords: biotechnology; curriculum *Merdeka*; SDGs

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1. Introduction

The curriculum plays a vital role in education for sharpening and forming not only student knowledge, but also attitudes in line with the development of science and technology (Almutairi et al., 2014; Hubers et al., 2022; Ring-Whalen et al., 2018). Following the rapid changes in science and technology, Indonesia, through the Ministry of Education, Culture, Research, and Technology, launched the latest curriculum, Curriculum *Merdeka* [Independent Curriculum]. In the industrial era, they believe the curriculum can accommodate multiple perspectives of knowledge (Nanggala & Suryadi, 2022), enjoyment of learning, student potentials, and attitudes to achieve 21st century skills (Maipita et al., 2021; Restu et al., 2022).

In fact, however, the implementation of Curriculum *Merdeka* has caused teachers to worry about the results of the learning process. Zakiyyah et al. (2021) found that teachers still perceived themselves as the source of information rather than a facilitator of learning; therefore, making them unsure as to whether they already provide sufficient learning or not. Others showed that school facilities do not meet the requirements for projects in Curriculum *Merdeka* (Yudhawasthi & Christiani, 2022) and still need some innovation to realise the projects (Rahayu et al., 2022; Supriati et al., 2022). However, innovation is typically hindered by cultural workload in schools and limited access to communication with other academic staff (Davis, 2003; Marx et al., 1994). Moreover, such burden is increasing along with the use of technology that requires fast innovation capabilities (Fernández-Batanero et al., 2021). Observation proved that there are two factors influencing the success of implementation of Curriculum *Merdeka*: learning atmosphere and independent learners (Restu et al., 2022), supported by the system within institutions (Maipita et al., 2021).

To solve the problems, teachers should use multidisciplinary subjects which entail multiple perspectives of knowledge. One of which is biotechnology, which requires various disciplines such as botany, zoology, and ecology. In the light of research, biotechnology can elevate student participation and actively induce positive attitude while learning (Aqil et al., 2020; Ketpichainarong et al., 2010; Klop et al., 2010). Teachers can also freely modify the lesson by incorporating experiments for making products (Aqil et al., 2020), introducing aspects whereby students can learn to manipulate variables and get closer to real-world problems (Marklin Reynolds & Hancock, 2010; Membrillo-Hernandez et al., 2019). Moreover, according to Limson (2021), biotechnology affords opportunities for teachers to make modifications in their learning tools since it offers debatable issues such as cloning, genetic modification, and stem cells for health treatment. This ultimate point benefits schools which have lack of laboratories. Moreover, environment issues become prominent in biotechnology due to its significance in leveraging the quality of human life, which depends on sustainability, emphasising both societal and natural aspects (Asveld et al., 2019; Cornelissen et al., 2021; Fröhling & Hiete, 2020; Matthews et al., 2019).

Considering the aforementioned findings, learning biotechnology is relevant for realising the essence of Curriculum *Merdeka*. Not only does it provide opportunities for teachers to innovate their teaching and learning materials and processes, but it also deals with the issues of sustainability. The latter is in line with two of the seven themes of projects in the curriculum, namely, lifestyle with sustainability and innovating technology to develop a better future for Indonesia. These projects also are in scope of the sustainable development goals (SDGs) which are of significant concern today because all countries face the same ecological problems, such as deforestation, fire, and climate change, which potentially increase the risk of diseases (Frumkin & Haines, 2019; Ryan et al., 2019; Zinsstag et al., 2018) and failure in farm productivity (Khan et al., 2020; Malhi et al., 2021). Since its launch in 2021, few studies have talked about these connections, with most describing the conception of the curriculum (Maipita et al., 2021; Sopiansyah et al., 2021; Suryaman, 2020; Yulianto, 2022), the school readiness in terms of facilities and teacher competencies to employ student mastery of concepts and the learning process (Baharullah, 2022; Rozi et al., 2021). However, this study focuses not only on the interconnection between teaching competencies and projects, but also proposes SDGs as a central evaluation of projects as well. By incorporating SDGs into the teaching and learning processes of Curriculum *Merdeka* it will result in strengthening knowledge, attitude, and awareness of environmental problems (Hogan & O'Flaherty, 2021).

As this study worked with pre-service science teachers (PSTs), this article provides an analysis of to what extent learning biotechnology with embedded SDGs can assist PSTs to initially develop innovative teaching material for Curriculum *Merdeka* through scientific projects. The research questions of this study are 1) to what extent biotechnology learning with embedded SDGs affects PSTs perception and knowledge of science innovation as a foundation of Curriculum *Merdeka*? and 2) What is the alignment of PSTs scientific projects to support an initial effort to design teaching materials for Curriculum *Merdeka*?

2. Literature Review

2.1 Curriculum *Merdeka*

Currently Indonesia has developed a new curriculum, known as Curriculum *Merdeka* [Independent Curriculum] (Kusumastuti, et al., 2021; Neina & Qomariyah, 2021) which gives students freedom of thought and encourages teachers to be able to shift their educational paradigm from a traditional to contemporary one (Telaumbanua et al., 2022). The Indonesian government promotes the idea of "*Merdeka*" as an effort to achieve independence in students to be creative, critical, and collaborative (Yulianto et al., 2021). In addition, the Curriculum *Merdeka* differs from the previous curriculum in terms of projects, introducing issues of sustainability, local wisdom, ideology, Indonesian spirit, democracy, innovating technology, and entrepreneurship (Tjaija, 2022). Through these projects, students are expected to achieve 21st century skills in line with the uniqueness of the country. In practice, teachers must choose three themes of the projects in a year and dedicate 30% of their teaching to completion of the projects.

Unlike the previous curriculum, Curriculum 2013, Curriculum *Merdeka* attempts to filter the essential contents and, therefore, students can deepen their understanding and strengthen their competencies (Nurani et al., 2022). To implement the curriculum, The Ministry of Education, Culture, Research, and Higher Education categorises three statuses for schools, that is, *Mandiri Belajar* [Independent Learning], *Mandiri Berubah* [Independent Change] and Mandiri Berbagi [Independent Sharing] (Nurani et al., 2022). Each different status determines the implementation of Curriculum *Merdeka*. *Mandiri Belajar* still uses Curriculum 2013; *Mandiri Berubah* partly practises Curriculum *Merdeka* by employing a learning package from the school unit; and *Mandiri Berbagi* conducts a self-modified learning package to implement Curriculum *Merdeka* (Inayati, 2022). This last part requires teachers to be creative and skilled in creating teaching materials and projects independently. In the *Merdeka* curriculum, the completeness of learning outcomes is no longer measured by the KKM [Completeness Criteria Minimum] in the form of a quantitative value. Formative assessment of learning is done to identify the achievement of learning objectives. Teachers are given the freedom to determine criteria achievement of learning objectives in accordance with the characteristics of competence on learning objectives and learning activity. In addition, students can continue to the class above it according to their achievement of the learning objectives (Purwananto, 2022).

2.2 Sustainable Development Goals in Indonesia

The Sustainable Development Goals (SDGs) are a substantial development framework to encourage development in a global context (Akanle et al., 2022). Seventeen SDGs are targeted for acquisition to support the implementation of the 2030 development agenda (Anderson et al., 2017) and Indonesia is committed to successfully implementing SDGs by achieving such agenda (Bappenas, 2019). The SDGs were established by the UN General Assembly in 2015 (Zeng et al., 2020) to achieve environmental and human development (Czvetko et al., 2021). The objectives of the SDGs are in line with the challenges of primary, secondary, and tertiary education. Research in Indonesia about SDGs shows a tendency towards the energy sector (Santika et al., 2020); improving quality of sanitation, cleanliness and availability of clean water (Chalil et al., 2018); and capacity for health. Thus, educational institutions are required to be able to integrate a variety of key issues of sustainable development in the learning process, one of which is through multidisciplinary lessons, such as biotechnology.

2.3 Biotechnology Learning

Biotechnology is the application of technologies that use biological systems, living beings or their derivatives, to create or modify products or processes for special use without neglecting the ethics (Savova et al., 2014; Thieman & Palladino, 2013). Others define biotechnology as the process of increasing human life quality using biological agents (Crawford, 2018). In other words, biotechnological practices fall within the scope of what people need to escalate and make their life easier without disregarding health issues. For instance, biotechnology has been used to improve nutrients in various foods to overcome malnutrition worldwide (Lee et al., 2013). The development of biotechnology reflects the rapid changes in scientific research, progress of technology (Yeh et al., 2012), and economic growth (Chabalengula et al., 2011). Indonesia participates in the OECD's work programme on biotechnology and biosafety (OECD, 2018) as a form of participation in the international arena. In line with this, applying biotechnology is then one of the main agendas in 2020 to create a variety of sustainable products (Mohamed et al., 2014). Nevertheless, biotechnology has also been criticised for its application and its unknown impact on human health and the environment (Amin et al., 2011).

2.4 Pre-service Science Teachers (PSTs)

Pre-service Science Teachers (PSTs) are university students that become prospective science teachers in junior high school. During the study, they learn pedagogical courses such as Curriculum, Assessment, Learning Theories, and Innovative Teaching. In the context of science, they link those courses to the study of environment, animals, and plants from physical, chemical, and biological perspectives. In terms of level of cognition, they need to master 21st century skills and bring them to their teaching capabilities. Thus, preparing these skills is the key to reform education (Heinrichs, 2016). Also, they are considered as an agent for change in some of the current global trends and challenges in the field of science education, including scientific literacy (UNESCO, 2017b), standards for science teachers (NSTA, 2012), STEM education (UNESCO, 2017a), and survival skills. At university level, PSTs are considered able to demonstrate competencies in terms of applying theoretical and practical skills in science teaching and doing critical and analytical thinking, which, according to the ASEAN Qualification Reference Framework, are in the sixth level. For instance, when conducting teaching practices, they can analyse the learning model alongside with learning theories and make an appropriate assessment.

3. Methods

3.1 Research Design and Procedures

This study was carried out using the one-group pre-test and post-test. It is relevant to one group of participants which was not equal to the other groups. The design identifies the effect of treatment from the difference of pre-test and post-test (Fraenkel et al., 2012): if there is difference between pre-test and post-test, it will conclude that the result is due to the treatment. This study was conducted in four meetings. At the first meeting, the lecturer administered the pre-test. Following this, PSTs were then introduced to the video of how different wavelengths elevate the sweetness of fruits https://www.youtube.com/watch?v=-rxM2QnZqQc. From this activity, PSTs are asked six questions about 1) the topic of the video, 2) where the research takes place, 3) why the research is conducted, 4) how the research is done, 5) what the research contribution is, and 6) what makes the research unique. Afterwards, PSTs and the lecturer had a discussion to narrow and sharpen the answer to the questions. In the second meeting, PSTs in groups of four were given the second worksheet by which they had to formulate their own ideas of scientific projects. Five aspects adapted from Heath and Heath (2008) were addressed to assist PSTs, namely, simplicity, uniqueness, urgency, applicability, and credibility. The third meeting required PSTs to present their scientific ideas in the form of both oral and written posters. The lecturer gave his feedback, whereas the other PSTs stuck their comments on the posters. The PSTs who presented their projects collected and analysed the feedback from the others. In the final meeting, the group wrote down the revision in the form of a summary of their projects based on the feedback of the other PSTs and lecturer and did the post-test.

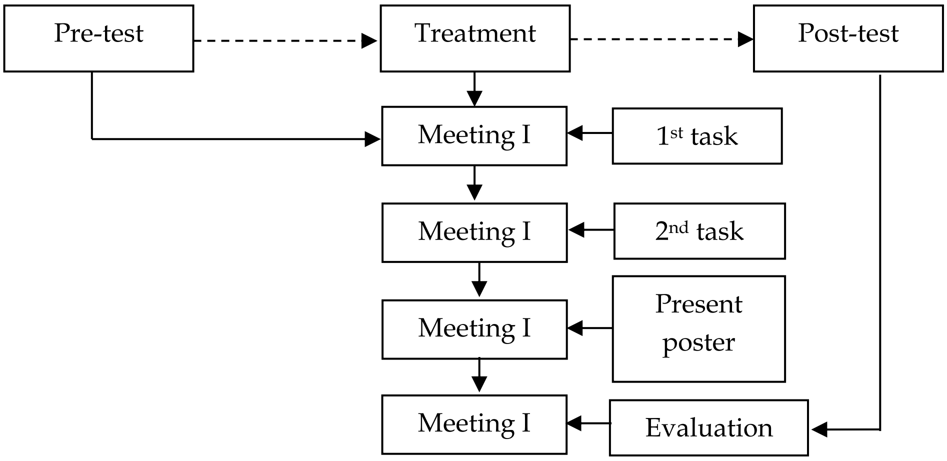


Figure 1: A flowchart of research

3.2 Participants

The participants of this research were selected using purposive sampling. Twenty PSTs from "Kelas Unggulan" (the class where the lecturers use English as language of instruction), who took the biotechnology course in Department of Science, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, academic year of 2022/2023 were involved. To be a member of this class, the PSTs must pass the prerequisite in terms of competencies of English and GPA, and, therefore, the PSTs have similar level of knowledge and skills. The reason of selecting this class as the group of participants is that all the members have equal competencies and mostly outperform students from the other classes. In other words, what they did can be examples for the other students. The participants consisted of seventeen females and three males aged between 20 to 21 years old. The PSTs had never experienced writing any scientific proposal before biotechnology learning took place. They also come from a similar province, East Java, and thus, have no different cultural background. In this study, economic background was disregarded because the students are in the same category of paying tuition fees.

3.3 Research Instruments

This study developed three instruments: questionnaire, paper-pencil test, and rubric to measure perception, knowledge of innovation, and scientific projects, respectively. Adapted from Afroz and Ilham (2020), the questionnaire consisted of ten items asking about student perception towards the integration of biotechnology in society such as vaccine, food processing, PCR, gene transfer, and stem cells to support sustainability in human life. The items were organised from the least to the most familiar. Gutmann scale was applied to observe strong preferences from participants (Niemi & Weisberg, 1974) and eliminate the possibility that participants will misuse the midpoint (Chyung et al., 2017). To make the items understandable for participants, the items were translated to Indonesian language and the content of biotechnology was inserted to the items.

Paper-pencil test comprised twenty items with five indicators, namely, 1) linking the role of biotechnology to support food supply, 2) identifying the benefits of biotechnology to improve environmental hygiene, 3) analysing relevant biotechnology projects to be applied to problems in Indonesia, 4) explaining the direction of SDGs in Indonesia through biotechnology, and 5) applying the principles of bioethics used in biotechnology to support the SDGs. These indicators were formulated to be relevant to the role of PSTs in the future as science teachers; they need to understand the phenomenon and use it to facilitate student learning. Paper-pencil test was carried out as pre-test and post-test to measure PSTs' knowledge of innovation. Before use, paper-pencil test was validated by three experts. The comments and assessment of each expert can be seen in Table 1 and Table 2.

Table 1: Validators' comments for biotechnology pre-test and post-test questions

Experts	Comments
I	1. Question No 1: The options, B, C, and D, are homogeneous, but choice A is less homogeneous because it is not in accordance with the SDGs aspect, namely Clean Water and Sanitation. 2. Problem No 2: The stimulus presented must function properly, namely the fermentation technique should be presented simply with pictures, no need to use long illustrations. 3. Problem No. 20: Questions that lead to the form of negation should be avoided.
II	1. The question grid is needed to make it easier for readers to know the categorisation of the cognitive domain and the suitability of the indicators with the questions. 2. The sentence should be written concisely, for questions no. 2 and 3.
III	For question number 4, improvement in the content needs to be done in the case of a person (illustrated model) who wants to solve problems through thinking of biotechnology concepts.

Table 2: Validator assessment results on biotechnology pre- and post-test questions

Experts	Aspects		
	Material	Construction	Language
I	3	3	4
II	3	4	4
III	3	3	4
Modus	3	3	4

Table 1 and Table 2 illustrate that the instrument was valid based on expert judgements. However, some revisions were conducted in terms of homogeneity of answer option, function of question stimulus, length of questions, and content.

A rubric of scientific projects was developed to measure to what extent the scientific projects meet the requirements for innovation. Five aspects of observation consisting of simplicity, uniqueness, urgency, applicability, and credibility were used to describe the innovation of the projects. Likert scale entailed the determination of the quality of each aspect, ranging from a score of 1 to 4. Criteria for each scale were made by considering total relevant keywords which appeared in the posters and summaries.

3.4 Data Collection Technique and Analysis

The data were collected before, after, and during the learning process. Paper-pencil test was in the form of pre-test and post-test. PSTs were given forty minutes to do each test. The test was printed and was administered to PSTs one by one. Before the test, the PSTs were randomly assigned to different seats to reduce cheating. Unlike the paper-pencil test, a questionnaire was given in the second meeting in which students partly learnt about the concept of biotechnology, and, therefore, were ready to give their perception. Online format was used for the questionnaire to produce faster responses. Scientific projects were scored during and after PSTs presentation using rubric. Keywords were noted and underlined for more precise measurement.

After data collection, the researchers analysed pre-test and post-test data descriptively and reconfirmed the results of the statistical calculation with the help of Minitab version 21.2 to see the significance of student knowledge acquisition before and after biotechnology learning with SDGs. This helps the researcher to ensure that the result is due to the treatment (Creswell, 2012). Questionnaire data were presented in the form of mean with standard deviation. On the other hand, scientific projects data were analysed using both content analysis and the score of rubrics.

4. Results

This part describes findings alongside both quantitative and qualitative analysis regarding the role of biotechnology learning with SDGs to influence PSTs in formulating scientific projects for their teaching practices in the implementation of Curriculum *Merdeka*. The subheadings follow the research questions under the respective sections.

4.1 PSTs' Perception

According to Table 3, PSTs gave various responses to each item in the questionnaire. The absolute preference of perception is determined by more than 80% of PSTs who selected "yes" answer or mean 8.0. The two strongest preferences of the perception include consumption of processed food and aspect of SDGs (mean ± SD = 1.00 ± 0.00), which means PSTs absolutely agree that biotechnology can help to reduce hunger. The knowledge of food security contributes to the absolute belief that biotechnology can sustain food availability using food fermentation and gene transfer, as stated in items number 5 and 8 with a mean ± SD of 8.5 ± 0.40. Likewise, PSTs perceive that biotechnology assists in providing clean energy and maintaining health. However, PSTs show weak perception in the use of PCR technique to prevent the spread of viruses and the production of methane to achieving SDGs through managing sanitation with a lower mean than 0.8. In this sense, PSTs seem to have lack of knowledge of the way the PCR helps in identifying genetic molecules of viruses and how bacteria change faeces into methane in anaerobic pathways.

Table 3: Student perception towards implementation of biotechnology to support sustainability in human life

No	Items	Mean ± SD
1	I have heard of the term Sustainable Development Goals (SDGs).	1.00 ± 0.00
2	In my opinion, the use of biotechnology can reduce hunger in developing countries.	1.00 ± 0.00
3	In my opinion, vaccines are important to support human health.	0.90 ± 0.30
4	In my opinion, the concept of sustainability is the main concept in the field of biotechnology.	0.90 ± 0.30
5	In my opinion, transgenic plants can increase productivity and help to create zero hunger.	0.85 ± 0.40
6	In my opinion, the use of stem cells can maintain health of the human body.	0.95 ± 0.20
7	In my opinion, fermentation can support clean energy.	0.85 ± 0.40
8	In my opinion, the protein of Tempe is easily absorbed by human body and helps to relieve kwashiorkor.	0.90 ± 0.30
9	In my opinion, PCR can identify genetic material and is ideal to reduce initial spread of viruses.	0.70 ± 0.46
10	In my opinion, methane can be used to help achieving SDGs on sanitation.	0.65 ± 0.50

4.2 Student Knowledge of Innovation

The descriptive statistical results of student knowledge of innovation before and after the learning process and normalised gain datasets are presented in Table 4.

Table 4: Descriptive statistics of students' innovation knowledge

Parameter	Pre-test	Post-test	Normalised Gain (%)
Mean	51.00	82.25	62.99
Median	52.50	80.00	65.15
Mode	55.00	75.00	66.67
Maximum	80.00	95.00	90.91
Minimum	15.00	70.00	25.00
SD	17.29	8.34	16.07

Biotechnology project learning activities that are embedded with SDGs values indicate that they can increase students' knowledge of innovation. The students' knowledge of innovation before the treatment seems to be lacking and varied (mean ± SD = 51.00 ± 17.29). This is also reinforced by the range of values and the mode of the pre-test scores. After the treatment, students' knowledge of innovation increased significantly, and the data variation was better than the pre-test results (mean ± SD = 82.25 ± 8.34). The results of the average normalised gain also show good results, namely 62.99% ± 16.07% and in the 66.67% mode. Normalised gain for all students is at the sufficiently level. It is not enough just to use normalised gain; to measure the effectiveness of the treatment, inferential statistical tests will be used.

Prior to the inferential statistical test, it was necessary to check the normal distribution and homogeneity of the pre-test and post-test datasets. To check the distribution of the precision dataset, it is necessary to test the data outliers first. The outlier test used is the Grubbs test, as in Table 5.

Table 5: Grubbs test for outlier data

Dataset	N	G	P-value	Interpretation
Pre-test	20	2.08	0.565	No outlier data at the 5% level of significance (*P-value* > 0.05)
Post-test	20	1.58	1.000	

Based on the data in Table 5, all pre-test and post-test data are not excluded from the normal distribution checking test and the homogeneity of the pre-test and post-test datasets. The Anderson-Darling (AD) test was employed to check the distribution of the pre-test and post-test datasets. AD test results are shown in Table 6. The results of the AD test show that both datasets do not follow the normal distribution, namely post-test data (Table 6), so, for the homogeneity test of both datasets, Levene's test is used, because it is valid for various continuous distributions. The results of Levene's test on the post-test and pre-test datasets are presented in Table 7.

Table 6: Dataset normality distribution test

Dataset	AD	P-value (α = 5%)	Interpretation
Pre-test	0.175	0.911 (P-Value > 0.05)	Dataset follows normal distribution
Post-test	0.678	0.065 (P-Value < 0.05)	Dataset does not follow normal distribution

Table 7: Homogeneity of dataset's variance test

Test Statistic	*df*1	*df*2	*P-value* (a = 5%)	Interpretation
6.68	1	38	0.014	Pre-test and post-test dataset do not have equal variance (*P-value* < 0.05).

Based on the data in Table 6 and Table 7, to find out the statistical difference between the pre-test and post-test datasets, a non-parametric test was used, namely the Wilcoxon Signed Rank Test. Before this was conducted, the differences between the pre-test and post-test data for each student were first looked for. The results of the Wilcoxon Signed Rank Test of student knowledge data are presented in Table 8.

Table 8: Result of Wilcoxon Signed Rank Test

N	Wilcoxon Statistic	*P-value* (*a* = 5%)	Interpretation
20	210.00	0.000	Statistical significance between the pre-test and post-test dataset (*P-value* < 0.05)

Referring to the data in Table 8, it is concluded that the interventions carried out can increase PSTs' knowledge of innovation about biotechnology projects embedded with SDGs values. This result is also coherent with the average normalised gain in Table 4, which is also positive and is at the sufficient level.

4.3 Science Projects

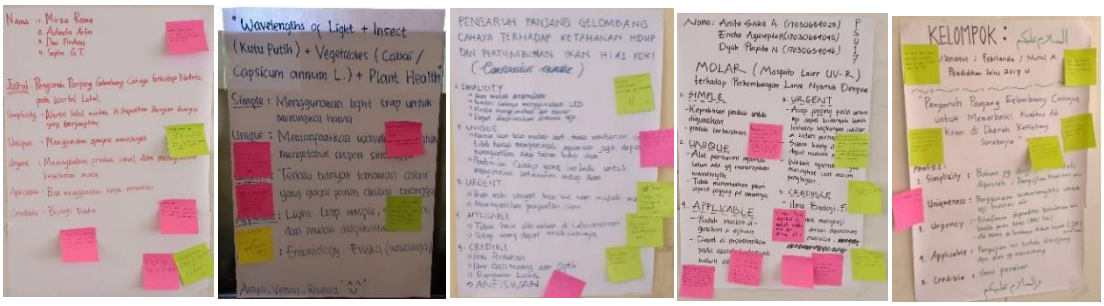
As stated in the research procedure, at the first meeting the lecturer introduced a video to PSTs talking about how different wavelengths of light can induce different sweetness in strawberries. In the science concept, strawberries have colour pigments that can capture light to further promote photosynthesis. Consequently, sugar produced during Calvin cycle increases the flavour of strawberries. PSTs then modified the variables of the research, and successfully created five project titles. The analysis of innovation is shown in Table 9.

Table 9: Analysis of innovation of project titles

No	Project Titles	Aspects of innovation					SDGs
		S	U	U	A	C	
A	The effect of light wavelength to nutrient level in local carrot	Local carrots are abundant.	The use of wavelength of light	To increase local commodity	The use of light with different colour	Biology and physics	Zero hunger, good health and wellbeing
B	The use of different light to attract insects and protect plants	Lamp is set up alongside with insect trap.	The use of wavelength to attract insects and change their behaviour	Many chili plants are attacked by pests.	The use of insect trap alongside with LED.	Entomology, biology, and physics	Life on land
C	The effect of light wavelength to the lifespan and growth of goldfish	Goldfish is abundant; LED can be used as a source of light.	The use of light can be used to affect the lifespan of goldfish juveniles within aquarium.	Many juveniles are not able to continue their life due to diseases.	It can be applied at home to protect juveniles from diseases.	Animal anatomy and physio-logy, biology, and physics	Life below water
D	MOLAR (Mosquito laser UV-R) to the growth of mosquito larvae of Dengue	The materials are easy to set up; easy to handle	It can help reduce the use of fogging; use different wavelength	Many cases of dengue fever and pollution due to fogging	It can be applied in endemic area but needs power supply.	Biological knowledge, mosquito life cycle, and environment	Good health and wellbeing
E	The effect of light wavelength to increase water quality in Surabaya	The water is ample.	The use of wavelength to influence bacterial growth in water	The need of clean water in dense urban	The tools are easy to modify and organise.	Knowledge of water quality	Clean water and sanitation

Indicators of innovation (SUUAC)
S: simplicity: easy access to tools and materials
U: Uniqueness: not many people use it yet
U: Urgency: urgent need
A: Applicability: ease of use of the tool
C: Credibility: knowledge need for the projects

Table 9 shows that PSTs created five different project titles in groups from a single independent variable, wavelength. The problems they raise are closely related to plantation, insects, fishing, and water quality, with which PSTs are familiar. The breakdown of the title shows aspects of innovation, including simplicity, uniqueness, urgency, applicability, and credibility. From the simplicity aspect, most of the titles are based on easiness and abundance. This benefits to the continuation of the projects. Since the idea comes from the same sources, the uniqueness of the ideas depends on the use of wavelengths, which seem to be effective in affecting small organisms and cells. Hence, the subjects PSTs use, consisting of insects, juveniles, microbes, and plants. In terms of urgency, PSTs see how useful their research ideas are to human beings, such as increasing food productivity and lowering the risk of diseases. From the table, all the ideas are applicable to solve problems and mostly involve biology and physics to deliver the ideas to scientific evidence. The scientific projects fall within different purposes of SDGs, like zero hunger, good health and wellbeing, life on land, life below water, and clean water and sanitation. To sum up, all the projects of the PSTs are successful to bring about the essence of SDGs from the perspective of what they learn.



A B C D E

Figure 2: Poster of science project ideas using wavelengths of light to A. modify the nutritional content of carrots, B. ward off garlic pests, C. modify the habitat of goldfish, D. reduce the resistance of mosquito larvae, and E. improve water quality

Figure 2 shows that each poster receives feedback from the other PSTs after presentation, leaving questions (red cards) and supports (green cards). Poster D obtains most red cards, meaning that many other PSTs are very curious towards the project about the use of wavelength to affect the life cycle of mosquitos. The second place is poster A talking about how to increase flavour as well as nutrients in local carrot. The least number of red cards is in poster E. PSTs in Department Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, were familiar with the parameter of freshwater quality when they programmed the Ecology course, including dissolved oxygen, biochemical oxygen demand, and biodiversity of plankton. This experience does not make them curious enough about project E.

Table 10: Results of review and assessment of scientific projects

No	Title	Review
A	The effect of light wavelength to nutrient level in local carrot	• The idea raised is very good to increase local commodities. • All aspects studied are in accordance with the idea.
B	The use of different light to attract insects and protect plants	• The title has not yet been formed, but the idea is very good. Insect trap with light is implemented to protect cultivated plants, namely chillies. • All aspects of SUUAC are in accordance with the idea review.
C	The effect of light wavelength to the lifespan and growth of goldfish	• The idea is good, that is, wavelengths of light are used to increase fish resistance from the aspect of algae and bacterial growth. • The SUUAC aspect has been well-analysed.
D	MOLAR (Mosquito laser UV-R) to the growth of mosquito larvae of dengue	• The title is very good. In the aspect of applicability, however, there is problem considering the light being used has a short wavelength with large energy that can harm genes. • Other aspects are appropriate.
E	The effect of light wavelength to increase water quality in Surabaya	• The idea is very good, but still limited to biological indicators. Not yet in the realm of chemistry. • Aspects of credibility should be added to the science of biology and physics. • Other aspects are appropriate.

As seen in Table 10, all scientific projects are sufficient to accommodate local issues as the source of problems. The use of wavelength as an independent variable is relevant to form influences on dependent variables. However, a few revisions should be made in terms of safety and knowledge needed for applying projects. The highest score of projects is D, whereas the lowest one is B due to not making the title (Figure 3).

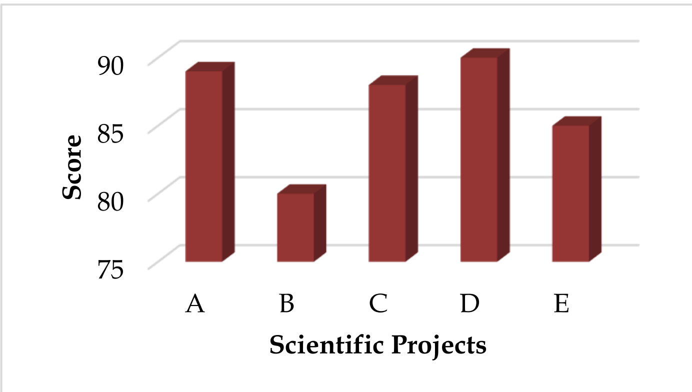


Figure 3: Score of each scientific project made by PSTs

4.4 Formulating Teaching Practices for Curriculum *Merdeka*

After conducting the presentation, students were asked to align their scientific projects to Curriculum *Merdeka*, taking into consideration learning outcomes and project themes of *Merdeka Belajar* (freedom of learning).

Table 11: Mapping projects for science learning in Curriculum *Merdeka*

No	Science Projects	Appropriate Learning Outcomes to Achieve	Relevant Project Themes for Curriculum *Merdeka*
1	The effect of light wavelength to nutrient level in local carrot	Students identify the application of biotechnology in everyday life.	Lifestyle for sustainability, technology to build Indonesia, entrepreneurship, and local wisdom
2	The use of different light to attract insects and protect plants	1. Students identify interactions between living things and their environment. 2. Students identify the application of biotechnology in everyday life.	Lifestyle for sustainability, technology to build Indonesia; local wisdom
3	The effect of light wavelength to the lifespan and growth of goldfish	Students identify the application of biotechnology in everyday life.	Lifestyle for sustainability, technology to build Indonesia; entrepreneurship
4	MOLAR (Mosquito laser UV-R) to the growth of mosquito larvae of Dengue	1. Students identify interactions between living things and their environment. 2. Students identify the application of biotechnology in everyday life.	Lifestyle for sustainability and technology to build Indonesia
5	The effect of light wavelength to increase water quality in Surabaya	1. Students identify the application of biotechnology in everyday life. 2. Students design efforts to prevent and overcome pollution and climate change.	Lifestyle for sustainability and technology to build Indonesia

Table 11 presents the alignment of science projects, learning outcomes, and project themes of Curriculum *Merdeka*. The data reveal that all projects contribute to the theme of sustainability and technology application. Only those which are close to agriculture and fishery support the theme of local wisdom and entrepreneurship. These themes are related to the value of products and how farmers plant crops using "Tumpangsari" [intercropping technique]. For learning outcomes, all scientific projects are in line with the learning outcomes of biotechnology since the projects have purposes to extend human life from the view of the use of technology to affect insect behaviour, increase nutrient and growth and quality of water from the perspective of microorganisms. By knowing this, it is helpful for teachers to prepare their teaching and learning module of Curriculum *Merdeka* using biotechnology projects. Looking at the same technique to solve different problems will help teachers innovate their teaching materials for students.

5. Discussion

The findings revealed that PSTs give their perception after experiencing learning about concepts in biotechnology (see Table 3). Ten items of the questionnaire asked about PSTs' personal opinions towards the biotechnology that supports human health and environmental cleanliness (Chalil et al., 2018), so that their perception relies on knowledge and attitudes (Dawson, 2007; Usak et al., 2009) to use biotechnology products such as vaccine, genetic modified crops (plant transgenic), processed food, and biofuel. It is not surprising then that many people positioned their positive expectation on biotechnology due to its significance to increase productivity of farming (Borlaug, 2000; Serageldin, 1999). From Table 3, eight items received more positive feedbacks from PSTs, while two of the items (item 9 and 10) had lower positive responses. However, these items are displayed on PSTs works as in Table 9, in that PSTs accommodate the role of microorganisms and cleanliness of water. In other words, what PSTs are less familiar with can be a positive construct to them in determining the decision of widening the area of learning (Figure 5). Previous research supported this finding since the perception can influence student decision-making of what to choose and what to do (Marcus & Velardi, 2022).

Regarding the knowledge of innovation, biotechnology learning offers PSTs opportunities to modify the material they learn. The statistical analysis reveals that biotechnology learning with SDGs influences PSTs to increase their knowledge of innovation (see Table 8) P-value < 0.05 ($0.000 < 0.005$). The success of this treatment is driven by the characteristics of biotechnology itself. First, as an interdisciplinary subject, biotechnology allows students to immerse themselves in the areas in which most people are interested in or feel challenged (Aqil et al., 2020; Dunham et al., 2002; Frumkin & Haines, 2019; Ketpichainarong et al., 2010). For instance, learning biotechnology integrated with technology can help to learn molecules (Daniels et al., 2020); produce products, manipulate variables (Ketpichainarong et al., 2010), and communicate ethical dilemmas (Harfouche, n.d.; Harfouche & Nakhle, 2020). Second, unlike learning other subjects in the biological field, biotechnology is central to practical activities rather than theoretical activities, so that students can have opportunities to practise scientific methods while creating projects from surrounding problems (Marklin Reynolds & Hancock, 2010; Matthews et al., 2019; Membrillo-Hernandez et al., 2019). Third, finding problems as a source of learning produces myriad impact to students as they grow with experience of facing difficulties (Corlu & Aydin, 2016; Jiménez-Cabré et al., 2019; Newman et al., 2015). Innovation often comes with a problem and a solution at the end, and, therefore, it reinforces in them that the projects they work on characterise their hard work. The acquisition of knowledge escalates what PSTs learn in modifying ideas of scientific projects by the four indicators below (see Figure 4) except the indicator about applying the principles of bioethics (below 70%) since it is not displayed explicitly in the PSTs' works (Table 9).

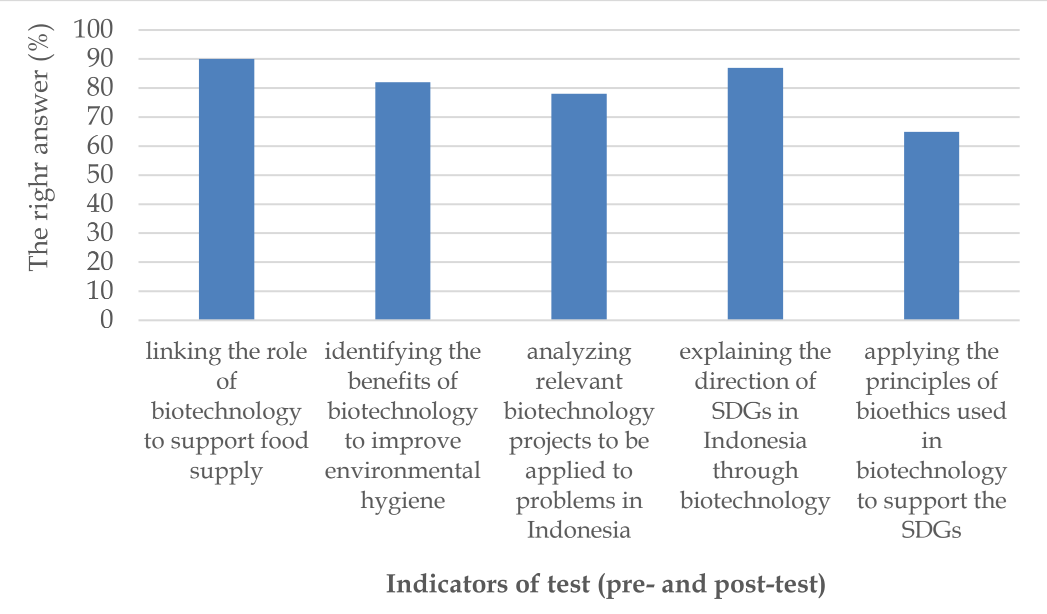


Figure 4: The percentage of right answers per indicator

The results support the effectiveness of learning biotechnology to innovate science through the aspect of SDGs, as students in groups successfully practised modification of the strawberries experiment with different wavelengths of light (see Figure 2). Every poster gets questions (curiosity) and comments that can be used to refine the ideas of projects. Presenting their own projects, asking questions, and giving feedback clearly depict activities of learning about decision-making (Helle et al., 2006; Morgan, 1983). It implies the fundamental aspects of the highest status of school of *Mandiri Berbagi* (Independent Sharing) at which teachers can innovate teaching materials (Inayati, 2022). Moreover, this benefits the PSTs when they teach, in that the innovation they produce can be used to support students where not all schools possess sufficient facilities of laboratories. Returning to the first research question, it can be implied from the results of analysis and the above explanation that learning biotechnology with embedded SDGs can effectively assist PSTs not only to have positive perception towards the use of biotechnology products and services to enhance the quality of human life, but also acquire knowledge about how to innovate or modify a single variable to generate various types of scientific projects by elaborating to different situations. This relates to Piaget's theory about assimilation and accommodation. What PSTs are familiar with can help them to raise mental processing to scientifically implement the same treatment to other occurrences, as Özgelen (2012) found in his work with sixth and seventh graders. However, what PSTs need to do for further refinement of their scientific projects (Table 10 and Figure 3) is to consider the relevancy of basic sciences to the problems and the safety for human life where it may relate to the data of Figure 4 in that some students do not successfully answer questions or problems with bioethics.

To date, Curriculum *Merdeka* offers seven themes for students to choose. These vary in terms of content, namely, sustainability issue, local wisdom, ideology, diversity, citizenship, technology, and entrepreneurship. In line with the core of science, the themes selected to be used in science learning must be inherent with inquiry. Singer et al. (2010) contended that designing teaching materials in the form of projects must instruct students to formulate questions, measure or observe data, collect, and interpret data, and communicate the results. These essences remain vital to Curriculum *Merdeka* since it demands student skills to do observation, measurement, interpretation, and communication. According to Table 9, five titles of projects include the scientific method, starting from generating research problems, building hypotheses, measuring the data, analysing the results, and presenting the final products. Ika et al. (2022) found that Curriculum *Merdeka* consists of more than 80% of scientific content, which means that students are practically more familiar with the work of science. They can embed it to the themes even though they may not be directly related. In addition, the contents of Curriculum *Merdeka* are associated with the Nature of Science (NOS) in which it comprises tentativeness, subjectivity, empirical evidence, and scientific method. However, according to the results of analysis conducted by Ika et al. (2022), students in Indonesia still rely in their work on empirical evidence and scientific method. This finding also points out that PSTs' ideas of scientific projects are still consistently practising such an approach and becomes the limitation of this study by not incorporating the value of tentativeness. For subjectivity, however, since PSTs modify their scientific projects with their own ideas, it seems that they do not disregard their own point of view.

To answer the second research question, it can be seen from the data in Table 11 in which all scientific project titles are relevant to four themes of projects, that is, lifestyle for sustainability, technology to build Indonesia, entrepreneurship, and local wisdom. The relevancy comes from the content of the titles. For instance, title 1 is in line with four themes altogether. The title "The effect of light wavelength to nutrient level in local carrot" accommodates issues like increasing food productivity, the use of simple technology, and supporting traditional farming. In terms of sustainability, Head et al. (2020) found that the awareness of bringing up the ideas of SDGs into what people learn, do or work is related to the experiences and involvements towards science activities. PSTs, in this sense, as university students in response to independent learning (*Merdeka Belajar*), are regularly participating in science activities both inside and outside campus, such as lab works, scientific fairs, and community services. Therefore, it is not surprising that those experiences provide access to students to create projects which are in line with SDGs (Agirreazkuenaga, 2019) and the essence of Curriculum *Merdeka*. The following shows a flowchart of how biotechnology learning with SDGs can help PSTs align their ideas of scientific projects to the themes of Curriculum *Merdeka*.

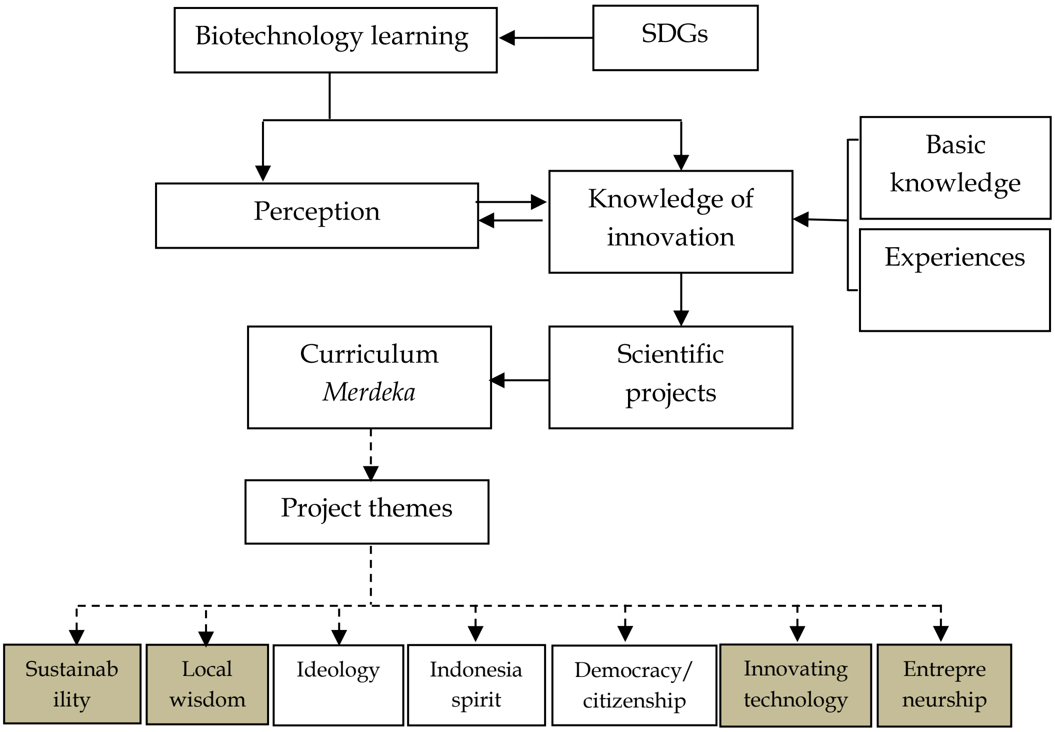


Figure 5: A flowchart of the alignment of projects towards themes of Curriculum *Merdeka*

The flowchart describes how biotechnology learning with SDGs can help PSTs align their ideas of scientific projects to the curriculum. The shaded boxes are the themes that match to the PSTs projects. According to Nugroho et al. (2018), the issues about tradition, sustainability, the use of technology, and entrepreneurship are vital aspects to sustain the development of areas in Indonesia, such as Pekalongan, Yogyakarta, and Surakarta. The boxes are matched to what Nugroho et al. (2018) found. By considering such a relevancy, PSTs can design teaching packages for students in junior high school through looking at learning outcomes in terms of understanding, science process skills, and project themes. Understanding refers to the mastery of science concepts including biology, physics and chemistry. Science process skills consist of observing phenomena, asking questions, planning and conducting experiment, analysing data, evaluating findings, and communicating the results (Kemdikbud, 2021). From these two parts of the curriculum, it can be seen the results of this study are placed at the initial effort for assisting PSTs in creating projects to plan implementation of Curriculum *Merdeka*. Project ideas fulfil understanding of science concepts and some parts of science process skills, such as observing phenomena, asking questions, and planning an experiment.

6. Conclusion

From the above explanation, it concludes that biotechnology learning effectively enhances PSTs' perception, knowledge to innovate science and create scientific projects for supporting Curriculum *Merdeka*. Most students perceive that learning biotechnology mostly relates to the issues of food and health, whereas the process of making products or services obtains a lower score of perception.

However, the items of perception which have lower scores can be used to describe what students choose to learn in creating ideas for scientific projects. This is due to the response of PSTs after receiving initial learning of biotechnology with SDGs. In terms of knowledge of innovating science, the treatment reveals significant results, 0.000 < 0.05, to effectively help students understand the area of innovation which involves concepts of wavelength of light. It is tested using Wilcoxon Signed Rank Test. This result affects PSTs to be mostly successful in generating five ideas of scientific projects. When aligned with project themes and learning outcomes, the project can be useful as an initial effort for PSTs in planning implementation of Curriculum *Merdeka*. In other words, learning biotechnology can be useful to support teaching skills, especially in preparing project themes and achieving learning outcomes, in Curriculum *Merdeka*.

Acknowledgement
We would like to thank Directorate of Research, Technology, and Community Service, Directorate General of Higher Education, Research and Technology for the research Grant under the scheme of National Competitive Basic Research (DRTPM) No. 126/E5/PG.02.00.PT/2022. Also, we thank Universitas Negeri Surabaya for providing opportunities and research facilities to complete all the procedures for this research**.**

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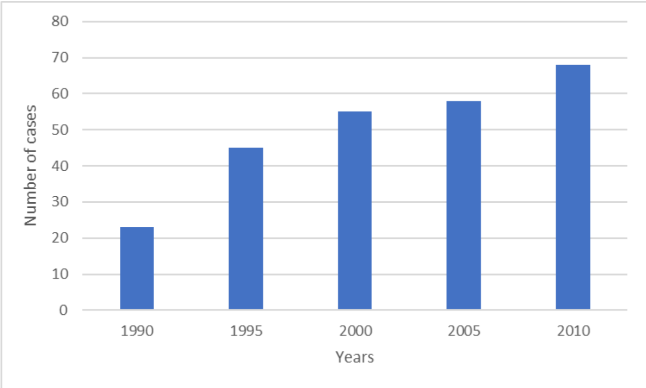
Appendix 1

Instrument of Student Perception

No	Items	Response	
		Yes	No
1	I have heard of the term Sustainable Development Goals (SDGs).		
2	In my opinion, the use of biotechnology can reduce hunger in developing countries.		
3	In my opinion, vaccines are important to support human health.		
4	In my opinion, the concept of sustainability is the main concept in the field of biotechnology.		
5	In my opinion, transgenic plants can increase productivity and help to create zero hunger.		
6	In my opinion, the use of stem cells can maintain health of the human body.		
7	In my opinion, fermentation can support clean energy.		
8	In my opinion, the protein of Tempe is easily absorbed by human body and helps to relieve kwashiorkor.		
9	In my opinion, PCR can identify genetic material and is ideal to reduce initial spread of viruses.		
10	In my opinion, methane can be used to help achieving SDGs on sanitation.		

Appendix 2
Sample of Paper-Pencil Test Items

No.	Indicators	Questions
1	Linking the role of biotechnology to support food supply.	Look at the following graph! Here is the data related to the vitamin deficiency. Most people in the country consume a little number of fruit and much amount of carbohydrate containing food.  **Figure:** a graph showing the cases of vitamin deficiency. According to the data above, the solution that is applicable is …. A. The use of gene insertion to induce the production of new nutrient. B. The use of modified pollinators to help seed production. C. The use of hydroponics with enhanced macronutrients. D. The application of biopesticides to lower the population of bugs. E. The use of organic fertilizer to enhance the nutrients in crops.
2	Identifying the benefits of biotechnology to improve environmental hygiene	Read the following title of the project below: "The use of biodiversity of bacteria on arabica dried leaves as the solution to reduce *moler* disease impact level in onion". If you want to apply the project to solve environmental issue, the strength of the title can be inferred from …. A. the dried leaves that people get rid of. B. the diseases in onion. C. the biodiversity of bacteria. D. the reduction of disease impact level.

No.	Indicators	Questions
		E. both bacteria and the dried leaves.
3	Analysing biotechnology projects to be applied to problems in Indonesia	Indonesia has focused to point out the issue of bioethics to support SDGs. The following idea that seems to be the most urgent and relevant to the statement is …. A. The effect of cengkih leaves on mice's lungs exposed to cigarettes. B. The use of multi-layered soils to induce the speed of composting. C. The use of nanoparticles from active compounds of belimbing wuluh as the indicator for mercury. D. The use of chitosan to protect fruits from decaying process. E. Instability of gene tetM which codes antibiotic resistance of *Lactobacillus casei.*
4	Explaining the direction of SDGs in Indonesia through biotechnology	Indonesia has complex issues. One of which is environmental cleanliness. The issue is already the focus of SDGs. The following aspect that best describes the relevancy of biotechnology towards SDGs is that biotechnology …. A. supports soil fertility through bioremediation. B. increases the water quality through the control of mosquitos. C. reduces water pollution through the use hydrocarbon-degrading bacteria. D. helps to reduce pollutants in soils through the application of transgenic plants. E. helps water cleanliness by using enhanced *E. coli*.
5	Applying the principles of bioethics	Indonesia has focused to point out the issue of bioethics to support SDGs. The following idea that seems to be the most urgent and relevant to the statement is …. A. The effect of cengkih leaves on mice's lungs exposed to cigarettes. B. The use of multi-layered soils to induce the speed of composting. C. The use of nanoparticles from active compounds of belimbing wuluh as the indicator for mercury. D. The use of chitosan to protect fruits from decaying process. E. Instability of gene tetM which codes antibiotic resistance of *Lactobacillus casei.*

Appendix 3

Rubric for science project ideas

Aspects	Scale			
	1 (poor)	**2 (acceptable)**	**3 (good)**	**4 (very good)**
Simplicity	The ideas are complex and incomprehensible.	The ideas are complex but still understandable.	The ideas are simple and understandable.	The ideas are simple, understandable, and easy to remember.
Uniqueness	Ideas are easy to find on google scholar, more than 8 pieces of information appeared on the front page.	Ideas are easy to find on google scholar, between 6 -7 pieces of information appeared on the front page.	Ideas are easy to find on google scholar, between 3 – 5 pieces of information on the front page.	Ideas can be found on google scholar, between 1 – 3 pieces of information appeared on the front page.
Urgency	The ideas that emerge do not have a clear urgency.	The ideas that emerge have a clear urgency but are limited to small or local scales of interest.	The ideas that emerge have a clear urgency and influence on a broader scale of interest.	The ideas that emerge have a clear urgency on a wider community, and focus on the sustainability issues.
Applicability	The idea is difficult to implement.	Ideas are potential to be implemented.	The idea created can be carried out with PSTs competencies.	The idea created can be carried out with PSTs competencies and have predictable results.
Credibility	Ideas are difficult to apply with the science knowledge of PSTs.	Ideas are applicable with at least one field of science knowledge of PSTs.	Ideas are applicable with at least two fields of science knowledge of PSTs.	Ideas are applicable with at least three fields of science knowledge of PSTs.