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Sustainability Development-Based Agroindustry in Chemistry Learning to Improve the Preservice Chemistry Teachers' Competence

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Abstract: This research aims to integrate agroindustry and sustainability development into chemistry learning through the Project-Based Learning model (PjBL) to improve the competence of preservice chemistry teachers. This research employed the qualitative method. The Summer Course program was held collaboratively by Universitas Negeri Jakarta, Institut Pertanian Bogor, and Villanova University. The program was implemented online within six weeks due to the COVID-19 pandemic. The participants consisted of 25 students. The data had been collected through interviews, questionnaires, observations, student portfolios, and reflection journals. Based on the analysis, several projects developed by preservice chemistry teachers increased the application to solve sustainability problems in the agroindustry field. Furthermore, the project was expected to be developed into a natural product that can increase the agroindustry value for coffee farmers. The findings also foster the preservice chemistry teachers to improve their creative thinking, collaboration, higher-order thinking skills, and problem-solving skills. Besides, they developed their communication and collaboration after participating in the program. The paper outline is a project development learning experience in a sustainable field and would be a good resource for student-teacher involvement in teacher education.

INTRODUCTION

The global era demand students to possess 21st-century skills and good environmental insight. Environmental insight is essential to foster a sense of responsibility towards the environment. The concept that can be applied to increase ecological awareness is Education for Sustainability Development (ESD). The ESD concept has three pillars: environmental, economic, and social (Svanström et al., 2008). This concept expects students to be more responsible in deciding issues related to the economy and society closely related to the environment (Jegstad & Sinnes, 2015). Sustainability development (SD) is described as development that meets the needs without compromising the ability of future generations to meet their own needs. ESD aims to promote education as an essential tool to prepare today's young age to become responsible future citizens, so that future generations can form a sustainable society. All levels and domains involved in education can contribute to ESD, including chemistry education (Burmeister et al., 2012).

Chemical education plays a vital role in sustainable development because the chemical industry lies at the heart of every industrial society. Industry boosts

the economy. A good economy improves social activities so that a suitable living environment will be more desirable. Likewise, chemical-based products in the process of running the industry can be found everywhere in our lives (Portal et al., 2005). Therefore, chemistry is expected to be a greener industry (Anastas & Kirchhoff, 2002) to achieve more sustainable production, processes, and products. However, industry and chemistry have a very negative image (Hartings & Fahy, 2011). From this point of view, chemistry learning should better improve students' ability to understand the role of chemistry in society (Hofstein & Kesner, 2006). Based on social education point of view, chemistry education should improve students' ability to evaluate businesses related to technology and products that are multidimensional, balanced, and reflect prudence in their implementation (Hofstein et al., 2011). From the ESD point of view, the perspective that must be instilled is how chemistry can affect the future, positively contribute to designing a sustainable community, assist in the proper management of natural resources, promote a sustainable economy, and overcome the opposing sides of globalization (Wheeler & Harvey, 2000). As one of the agents of change, chemistry teachers should understand their roles before engaging in the world of work practices by instilling, developing, and evaluating sustainable values to students. Therefore, the purpose of this research is to develop the sustainable competencies of preservice chemistry teachers.

In developing the preservice chemistry teachers' competencies, they must be facilitated with a supportive learning process. The Project-Based Learning model (PjBL) is one of the student-centred learning models, where students are enabled to learn independently to build their learning experience (Fletcher et al., 2000). PjBL is one of the relevant learning models for ESD (Singh-Pillay, 2020). Through PjBL, the concept of ESD is included as a theme discussed through the development of an ESD-oriented project. Several studies have shown that the PjBL model can improve science process skills in learning (Gofur et al., 2016; zer & zkan, 2013; Tias & Octaviani, 2018). Project-Based learning provides students with better critical thinking skills than conventional learning models (Sastrika et al., 2013). Also, PjBL can develop students' 21st-century skills and develop teachers' professional abilities in learning and assessing (Ravitz et al., 2012). The PjBL enables students to work independently in real-world contexts while honing their abilities in different degrees, namely high-level academic and professional skills such as leadership, collaboration, design, and problem-solving (Ghobrini, 2020). Devkota et al. (2017) state that the PjBL can increase learning motivation and student involvement in learning by changing listeners into colleagues and active learners. Education is more focused on complex tasks based on challenging problems, which involve designing, solving problems, making decisions, investigations, and allowing students to work independently for a certain period. PjBL has several characteristics that direct students to investigate essential ideas with an inquiry process according to their needs. The projects can be the result of individual work or group work.

The developed project is an agroindustry product, namely coffee. The coffee agroindustry has a promising opportunity to be developed in Indonesia because it has excellent prospects in the domestic and international markets. Novita et al. (2012) state that coffee commodity as part of agroindustry that contains sustainable development. The development, processing, production, and distribution process comprises three pillars of sustainable development: economic, social, and ecological (environment). This research focused on

developing the competence of preservice chemistry teachers through Project-Based Learning. The research activities were integrated into the Summer Course 2020 program to equip students with sustainable development knowledge related to chemistry. Participants learned from hands-on experience on product development by adding value to environmentally friendly products, systems, and management. The researchers analyzed the competency development of the preservice chemistry teachers during and after the program. The researchers also reviewed the projects developed by the participants on how the project increased the value of agroindustry products and their sustainable value.

METHOD

This research was qualitative research with an analysis of the actual situation. It was not experimental research; instead, it looked at the research context. This qualitative research adopted the theories by Creswell and Creswell (2017), who define a case study as "an in-depth exploration of a bound system such as an activity, event, process, or individual". The paradigm used in this study was the interpretivism paradigm.

Preservice chemistry teachers who took part in the Summer Course registered themselves via the link https://bit.ly/SCAgroindustry2020. The participants consisted of 25 students from the Universitas Negeri Jakarta, precisely ten students from the Chemistry Study Program and the rest from the Chemistry Education Study Program with an age range of 21-22 years. The Summer Course program run from October 5 to November 14, 2020. The program was held online through Zoom, Google Classroom, and YouTube. The steps of this research can be seen in Figure 1.

This program was started by observing the knowledge of preservice chemistry teachers on the concepts of ESD and PjBL. Then, there was a presentation of sustainable development materials in general. After that, a more detailed explanation of sustainable development in the agroindustry was delivered. Also, there was a business discussion of the sustainable agriculture industry with practitioners or entrepreneurs of the coffee industry. Furthermore, there was a virtual visit to coffee plantations so that the preservice chemistry teachers could better understand the authentic atmosphere and conditions in the agroindustry sector. From this whole series of activities, it was hoped that the preservice chemistry teachers could have ideas and innovations to develop integrated projects with the sustainable coffee farming industry business.

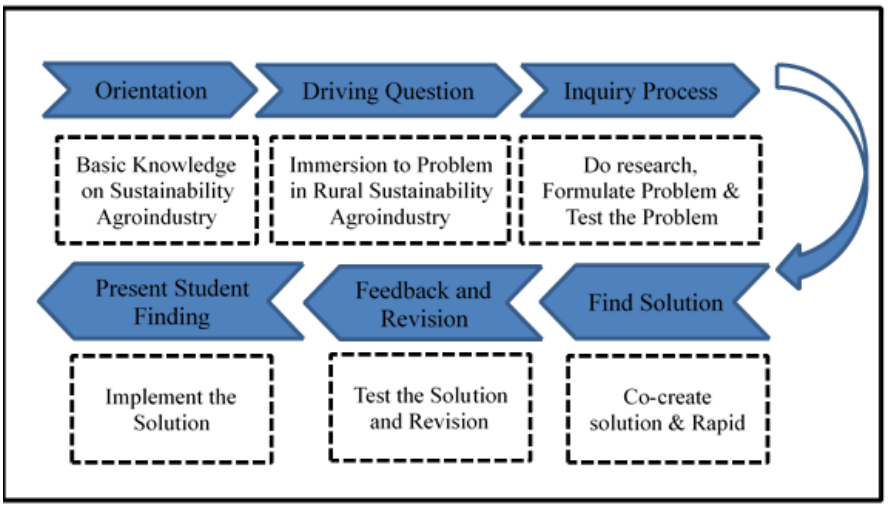

Figure 1. Research Design.

The evaluation was carried out to see the development of participants' abilities in developing agroindustry projects. The evaluation was carried out at the end of the program by distributing an online questionnaire.

The data collection was performed by distributing a questionnaire at the beginning of the program to determine the participants' motives in joining the program. Then, another questionnaire was distributed at the end of the program for evaluation. The questionnaire contained knowledge and understanding of sustainability development (SD), PjBL, and the relationship between SD and the field of chemistry education. Besides, semi-structured interviews were conducted at the end of the program session by asking semi-open questions about project development, sustainable development, and participants' competencies before and after the program. The questions can be seen in Table 1.

Table 1. Open-Ended Interview.

	Subtheme	Questions
A.	***Sustainability Development (SD)***	A1. What do you think about sustainability development (SD)? A2. Should SD be integrated into chemistry learning? A3. Does SD give an impression on your life?
B.	**Project Development**	B1. What projects are you developing? Can you explain the process? B2. What impressions do you feel in the project planning process? B3. How about teamwork? Does it give you a chance to argue? B3. Who plays a role in making decisions?
C.	**Multicultural Environment**	C1. What do you think about working with foreigners? C2. How about working, discussing, and collaboration with people you just met?
D.	**Online Class**	D1. What do you think about this online class?

The portfolio of preservice chemistry teachers was collected when the program has finished. The participants also filled out an online reflective journal dis-tributed at the middle and end of the pro-gram. The indicators of the reflection jour-nal are sustainability development, project development, multicultural environment, and online learning. The data analysis technique of this research consisted of da-ta reduction, data display, and conclusion and verification. Data reduction and data display are helpful to see the overall picture of the research results. The results of data reduction and data display were used to interpret and analyze the data to conclude the development of the competence of preservice chemistry teachers. The data was displayed in interview excerpts, pho-tos of activities, statements in reflective journals, the answers on the worksheets, and the activity sheets during the training process. The interview data were validated using the member check technique by providing transcript data to the preservice chemistry teachers containing interview transcript data and then asked whether the data were correct or not. The following is the documentation of the Summer Course Program on sustainability development in the agroindustry sector.

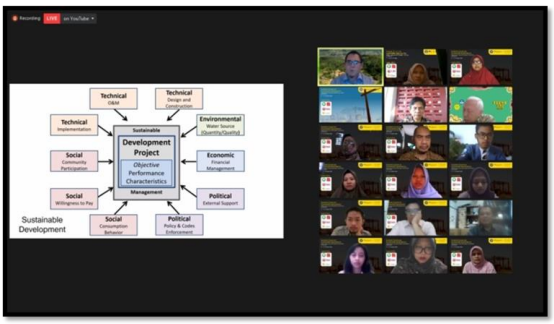

Figure 2. The Summer Course Program.

RESULT AND DISCUSSION

At the observation stage, the participants were given a questionnaire

regarding their understanding of sustainability development (ESD) and project-based learning (PjBL). The results of the questionnaire can be seen in Figure 3 and Figure 4.

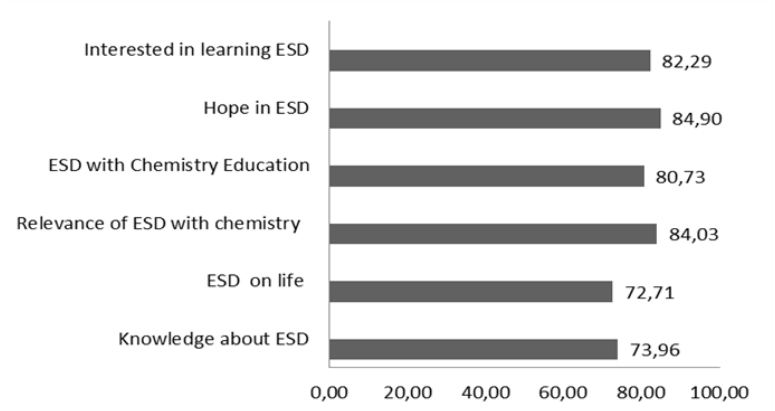

Figure 1. Participants' Questionnaire Response on Education for Sustainability Development (ESD).

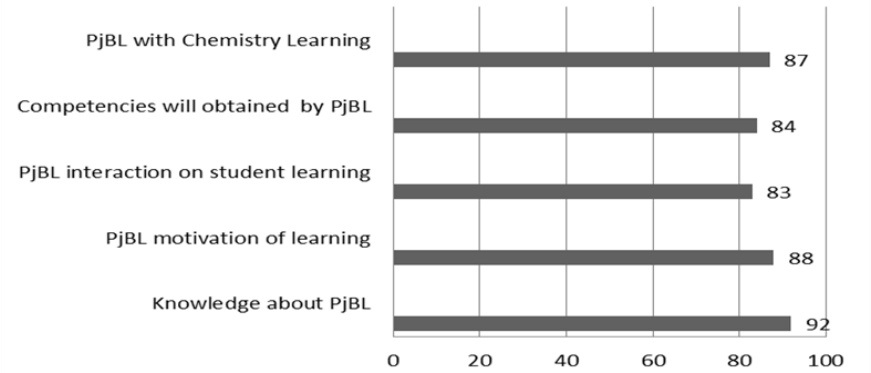

Figure *2*. Participants' Questionnaire Response on Project-Based Learning.

Based on the results of the ESD questionnaire, the participants' knowledge of ESD was at a moderate level of 73.96 %. However, the participants' interest in learning ESD was at a high level of 82.29 %. According to the participants, ESD is quite relevant if it is integrated with chemistry learning. Therefore, the preservice chemistry teachers' motivation in studying ESD during the Summer Course program was relatively high (84.03 %).

Based on the results of a questionnaire on the PjBL model, the participants' knowledge of the PjBL model was at a high level (92 %). In addition, the motivation to use PjBLmodel was also relatively high (88 %). According to the participants, the PjBL model is relevant to chemistry learning because it involves students and teachers actively participating in the learning process, so that the expected competence for PjBL was relatively high (84 %).

Table 2. The Coding Results of the Reflective Journal and Interview.

Category	Coding	Source	Respon-dent	Raw Data
Sustainability Awareness	1. Minimize industrial waste. 2. Sustainability is good for life.	Reflective Journal	P1	"…. aware of the importance of sustainability aspects in the production and development of a product. "
			P2	"Sustainability is perfect for human life……."

Category	Coding	Source	Respon-dent	Raw Data
	3. The importance of the sustainability aspect 4. Understanding		P3	Sustainability is something that benefits not only today but also the future. It presents sound effects on all aspects ranging from environmental, social, economic, political, technological and others.
			P4	"Agroindustry sustainability must be implemented because it can reduce the environmental damage caused by chemicals such as pesticides and waste."
			P11	"After carrying out the Summer Course Program, I have a new understanding of sustainable development, especially in the agricultural sector. … "
		Interview	P2	"I understand sustainability better, so I can be wiser in doing everything by minimizing things that are harmful to the earth."
Problem solving	Problem solving oriented	Reflective Journal	P5	"…The Summer Course Program and sustainable agroindustry open up insight to improve critical and creative thinking skills in solving a problem. …"
			P2	"It's great for brainstorming to find solutions to existing problems. But, also, the participants are required to conduct reliable research to construct a solution."
			P22	"...Agroindustry sustainability must be implemented because it can reduce the environmental damage caused by chemicals, such as pesticides and wastes. In agroindustry sustainability, more environmentally friendly materials were used. Agroindustry sustainability can also improve the farmers' welfare in rural areas."
		Interview	P9	"...I think problem-solving is also used based on previous research and how to solve a problem by providing an idea in the form of a project."

The participants succeeded in compiling projects for various products, both product names, appearances, materials, manufacturing methods, and branding. The products were Face Mist, COHUMA, Coffrehener, and Cascara Tea. A complete review of the projects can be seen in Table 3.

Table 3. Project Develop by Preservice Chemistry Teacher.

No.	Project Name	Product Display	Explanation
1.	**Face Mist**	 Fresh with the Waste!	Face Mist is a beauty product that utilizes coffee cherry husk waste. The method begins by extracting, filtrating, and evaporating. The process then followed by organoleptic and hedonic tests. It contains aloe vera leaf extract to moisturize the skin, coffee essential oil to brighten the skin, and vitamin C to tighten the skin. The utilization of coffee cherry husk aims to increase added value, reduce waste, and increase the income of coffee farmers.

No.	Project Name	Product Display	Explanation
2.	**COHUMA**		COHUMA utilizes coffee husks as the primary material for masks. The benefits of this project are to reduce coffee waste, increase the income of coffee farmers, and create job opportunities. This product is made by washing, drying, and grinding the coffee husk. COHUMA contains vitamin E to prevent premature ageing, fade acne scars, and reduce redness due to sunburn. Besides, coffee husk acts as an antioxidant.
3.	**Cofreshener**		Cofreshener is a natural air freshener that utilizes low-quality coffee. Cofrehener production is relatively easy, starting with sun-drying the coffee beans, roasting them for 15 minutes, and grinding them to a size of 0.5-1 cm. Put the grounded coffee in a ziplock and finally packed it with a burlap sack. The colour of the packaging indicates the type and aroma of the coffee. The red packaging contains Java Ciwidey coffee which gives the impression of a smoky aroma. The brown colour packaging is made from Sumatra Lintong coffee, which produces an earthy aroma or smells like the smell of earth being washed down by rain. The orange packaging is made from Kintamani Robusta coffee which gives a fruity aroma. The white packaging is made from Bajawa Arabica coffee which smells like nuts. The blue packaging contains robusta Toraja coffee with a chocolate-like scent.
4.	**Tea Caskara**		*Cascara* means skin in Spanish. Coffee leaves and husks rich in antioxidant compounds such as flavonoids, phenolics, chlorogenic acids, and anthocyanidins can be developed into health teas. The tea is processed by sun-drying the coffee leaves or roasting. The type of coffee variety and the drying method affect the quality of the tea.

Based on Table 3, the preservice chemistry teachers presented their projects well. The projects' ideas came from the agriculture and agroindustry problems. They intended to reduce wastes, increase the economic value of coffee residues, and increase the financial income of the farmers. The production methods were simple and did not require expensive equipment. Furthermore, the additional materials needed are also easy to obtain. The financial analysis estimated that the production costs were relatively low with high selling prices. The documentation of the presentation can be seen in Figure 5.

The four projects made by the participants showed that all participants could develop a task well. Project evaluation was based on existing problems in the coffee industry. The participants focused more on solving the coffee waste problem by making products for health, beauty, and fragrance products. Their project aimed to reduce waste, increase the economic value of waste, and

increase the financial income of coffee farmers. The production methods were simple and did not require expensive equipment, and the additional materials needed are also easy to obtain. The financial analysis estimated that the production costs were relatively low, with high selling prices that could generate coffee farmers' profits.

Figure 5. Project Presentation by Participants.

After the program ran for three weeks, the participants were asked to fill out a reflective journal provided online. Reflective journaling is a student-centred valuable activity for reflecting on their meaningful experiences, thereby increasing their desire to continue learning. (Lindroth, 2015). Finally, the results were analyzed by coding the data based on the participants' answers. From the coding results, several points were obtained based on participants' responses related to sustainability development, project-based learning, multicultural environment, and online-based learning.

Preservice Chemistry Teachers' Competency Development

From the results of semi-structured interviews, observations, and reflection journals, several keywords described the achievements of preservice chemistry teachers during the Summer Course Program, namely; 1) Perspective on sustainability; 2) Development of thinking skills; 3) Communication and collaboration.

Sustainability Development Perspective

Several important points can be discussed from the data analysis of semi-structured interviews and participant reflective journals. One of them is the perspective of preservice chemistry teachers on sustainability development (SD). Based on the results of in-depth interviews, it was found that their SD knowledge before joining this program was only at the level of chemistry because their educational background was chemistry and chemistry education. The argument can be seen in the following interview excerpt:

Table 4. Interview result

Source	Statement
Open-ended interview	"Before, I was not very aware of sustainability, especially in the field of agroindustry. This program increased my knowledge about sustainability in the field of agroindustry. I never thought that sustainability could be carried out in other fields besides chemistry." (P12011)

The interview showed that the participants did not know that agroindustry can also contribute to developing SD values. They did not know that SD is a multidisciplinary field where every field of science can be developed based on SD principles, namely socio-economic-environmental. Sleurs (2008)

states that "if the teacher has the intention to take the issue of sustainable development seriously, they will also link the issue to the economic, social, cultural and political aspects". Palmberg et al. (2017) argue that SD (hereinafter also referred to as sustainability) is a complex concept consisting of ecological (environmental), economic, social dimensions and also includes several other aspects that are complexly interrelated. The field of chemistry also does not stand alone in developing sustainable values because it is complementary with other fields of science. Therefore, the program provided a new paradigm for the participants, from not knowing to know. They could understand and then realized their essential role in contributing to sustainable development.

After the participants realize that SD can be done in science, sustainable awareness can be formed. Kioupi & Voulvoulis (2019) state that SD-based learning is expected to develop students' competencies in knowledge, behaviour, and attitudes which will collectively be referred to as sustainable abilities. Participants' sustainability awareness improvement can be seen in the results of interviews and reflective journals.

Table 5. Interview Results and Participants' Reflective Journal about the Importance of Sustainability.

Source	Statement
Open-ended Interview	"I understand sustainability better, so I can be wiser in doing everything by minimizing things that are harmful to the earth" (P22211)
Reflective Journal	"After carrying out this Summer Course Program, I have a new understanding of sustainable development, especially in agriculture" (RJP231910) "One of the main things I learned was about the awareness of the importance of sustainability aspects in the production and development of a product" (RJP11910)

Based on the results of the interviews, it can be underlined that preservice chemistry teachers are increasingly aware of the importance of sustainable development, both in terms of life in general or in the field of agroindustry in particular. The sustainable development program increased participants' understanding and awareness about the importance of sustainability in life. Therefore, they can start changing their behaviour patterns.

Besides increasing awareness, the participants can be aware of the importance of protecting the environment or environment awareness. The researcher made that conclusion based on the results of in-depth interviews and reflective journals.

Table 6. Interview Results and Participants' Reflective Journals on the Importance of Protecting the Environment.

Source	Statement
Open-ended Interview	"…I can be wiser in doing everything by minimizing things that are harmful to the earth…" (P22211)
Reflective Journal	"…creating a sustainable life for the future by always paying attention to many aspects, especially the environment…" (RJP171910) "Considering that nature is getting old and waste is piling up, I think it is appropriate to start promoting sustainability". (RJP131910)

The results are in line with the statement by UNESCO (2020), which states that "ESD can help us understand the global nature of today's challenges. It provides us a concrete solution for the local living environment". Mighty et al. (2017) state that the concept of ESD issued by the United Nations can be one of the solutions to develop an environmentally sound economy and can be included in the chemistry learning process to foster and equip students with attitudes and knowledge, especially the perspective of environmental awareness. The ecological awareness of the

preservice chemistry teachers emerged after participating in this program. This program will be the forerunner for preservice chemistry teachers to be more aware of the importance of protecting the environment. It is hoped that this knowledge and experience will not stop because, in chemistry learning, many contents are closely related to ESD and the environment. Sustainability in chemistry learning is also known as green chemistry. Fibonacci (Fibonacci, 2012) states that various chemical concepts are closely linked with the environment to stimulate creativity and innovation to use chemical images to solve the environmental problem. Therefore, the preservice chemistry teachers can implement and instil sustainability values into their students at school later.

Table 7. The Results of Interviews and Reflective Journals on the Development of Thinking Skills.

Source	Statement
Open-ended Interview	"We can think of many things to create projects through online learning. This project makes students practice to think…." (P42211)
Reflective Journal	"Here we were made to rack our brains to complete a group project, and it was quite fun". (RJP221910)
	"We can think more critically and can immediately apply the lessons learned". (RJP41910)
	"This program is perfect for brainstorming to find solutions to existing problems. Also, the participants are required to conduct reliable research to construct a solution". (RJP151910)

Based on the results of the reflective journal interviews, the participants were trained to think about how to solve problems, find solutions, apply sustainability concepts in the projects they developed, etc. The project-based learning model (PjBL) provided an atmosphere that motivated them in higher-order thinking patterns to support sustainability-based learning (Singh-Pillay, 2020). According to Genc (2015), the PjBL model offered the preservice teacher a chance to experience the reality of their communities, as well as take ownership of the project as active participants rather than their consumers of knowledge". The PjBL model in this program encouraged the formation of a learning experience by going directly into a problem and trying to construct a solution plan by developing a project. The participants fully involved in the design of the project using coffee as the primary ingredient. They felt challenged and encouraged to think critically by racking their brains (think of many things; brainstorming) and searching for in-depth information (doing research). They felt that their abilities were honed, trained, and directed to think creatively. Instead of feeling pressured, the participants believed that this program was fun and essential to improve various abilities in the future, such as problem-solving, critical thinking, and creative thinking skills. Brundiers et al., (2021); Rieckmann, (2012); Wiek, Withycombe, & Redman, (2011) include critical thinking and problem-solving skills as one of the key competencies in sustainability. Other opinions state that they are the core competencies of sustainability (Komasinski & Ishimura, 2017). According to Wiek, Withycombe, & Redman, (2011), continuing academic education requires critical thinking skills, communication, pluralistic thinking, research, data management, and so on. Several other studies explicitly explained that necessary thinking skills are related to collective thinking and norms that apply specific criteria in making wise decisions (Glesser & Hirsh, 2016; Lambrechts et al., 2013). Problem-solving is the ability to use different frameworks in the problem-solving process by developing feasible solution options to solve complex problems on an ongoing basis (A Wiek et al., 2016). This ability is one of the skills needed to succeed in a global environment (Boix Mansilla &

Bughin, 2011). Through the ESD-based PjBL learning program, the participants can solve problems, think critically, and think creatively.

Communication and Collaboration

The results of interview and reflection journals on communication and collaboration can be seen in Table 8.

Table 8. Interview Results and Reflective Journals on Communication and Collaboration.

Source	Statement
Open-ended Interview	"…we also learned to work together in teams to work on projects. Coordination between group members went well, and they can complete the final projects. Everyone has their benefits for the team because everyone provides views according to the field studied". (P32211)
Reflective Journal	"The tasks given are group assignments so that the ability to communicate, exchange opinions, debate, cooperate, and respect one another can be built". (RFP231910) "Collaboration between members is an important aspect during project work. Although the program is virtual, it has several group assignments that can make the participant closer to one another". (RFP11910)

Based on Table 8, the participants considered that collaboration and communication are essential in working on a project. Therefore, the program encouraged participants to use their collaboration and communication skills in every activity. The data are in line with the statement that "ESD encourages collaborative learning outcomes, encourages students to work together" (UNESCO, 2020). According to Sing-Pijay (2020), PjBL allows self-introspection and work with people of different ethnicities and socioeconomic statuses that can foster participants' self-confidence, team building, tolerance, and commitment to group works. ESD-based PjBL model supports each other to create a learning atmosphere that encourages participants' communication and collaboration skills.

In some cases, collaboration is described as the ability to communicate effectively. It contains interpersonal skills to work with others and interpersonal skills (Brundiers et al., 2021; Daub et al., 2020; Glesser & Hirsh, 2016; Lambrechts et al., 2013). Several other studies have stated that collaboration is one of the key competencies in sustainability (Brundiers et al., 2021; Glesser & Hirsh, 2016; Arnim Wiek et al., 2011). Collaboration can motivate, activate, facilitate, and participate in ongoing research and problem-solving (Arnim Wiek et al., 2011). Despite experiencing some difficulties, the participants did not lose their enthusiasm in completing the projects. This program requires participants to use English in communication, so language is the biggest obstacle. However, because everyone was required to speak English, they were motivated to continue using English so that the preservice chemistry teachers can directly practice and become familiar with foreign language vocabulary about sustainability.

CONCLUSION

Based on the research results, it was found that preservice chemistry teachers could develop a project that utilized agroindustry materials (coffee) in a project of sustainable value. The development of the ESD-based project provided a new experience for the preservice chemistry teachers to have better sustainability and environmental awareness values. They can also have a caring attitude towards sustainability and the environment. The ESD-based PjBL model integrated with agroindustry developed the perspective of preservice chemistry teachers on sustainability, problem-solving, critical and creative thinking, and communication and collaboration skills.

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