JIPI (Jurnal IPA dan Pembelajaran IPA) 7(1), p.40-55, (2023)
p_ISSN: 2614-0500 e_ISSN: 2620-553X
URL: http://jurnal.unsyiah.ac.id/JIPI/index DOI: dx.doi.org/**10.24815/jipi.v6i4.29199**

Education for Sustainable Development Oriented Didactic Design in A Bioplastic Context in Overcoming Barriers to Learning and Developing Attitude and Environmental Awareness

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Article History:
Received date: November 27, 2022
Received in revised from: March 23, 2023
Accepted date: March 25, 2023
Available online: March 30, 2023

Citation:
Pratiwi, A.J., Hernani., & Anwar, B. 2023. Education for Sustainable Development Oriented Didactic Design in A Bioplastic Context in Overcoming Barriers to Learning and Developing Attitude and Environmental Awareness. *JIPI (Jurnal IPA dan Pembelajaran IPA)*, 7(1):40-55

Abstract. Human ignorance in conserving, managing, and protecting the environment makes plastic pollution a real problem for the world's health and environment. Therefore, this study aims to develop environmental attitudes and awareness as well as mastery of pre-service teachers' concepts through ESD-oriented didactic design in the context of bioplastics. This study used a Didactical Design Research (DDR) with 27 pre-service teachers. The instruments used in this study were tests, questionnaires, validation sheets, and transcripts. Based on the results of the analysis, it was found that there are attitudes and awareness of pre-service teachers that need to be developed, the results of preconception data analysis of pre-service teachers experienced learning barriers in content (1) classification of biodegradable biopolymers (2) starch decomposition process (3) benefits of biopolymers in various fields (4) and the environment (5) bioplastic dilemma (6) function of materials in the manufacture of bioplastics. The validation results indicate that improvements are needed in the learning objectives and some improvements in sentence redaction in didactic situations. After the learning was applied, it was found that most of the responses that emerged from the pre-service teacher were in accordance with what was designed by the educator, and after the percentage analysis was carried out there was a development of attitudes and awareness and mastery of concepts of the pre-service teacher.
Keywords: Didactic Design, Bioplastic, Environmental Attitude and Awareness, Preconception, pre-service teachers

Introduction

Environmental problems in the 21st century are very serious problems, especially the massive use of petrochemical plastics has become a real problem for the health and environment of the world (Azmin et al., 2020) which urgently requires social, environmental and engineering solutions (Jordyn et al., 2022). This is also in accordance with what was stated by Wahyuningtyas & Suryanto (2017) that Indonesia is the second largest country after China as a contributor to plastic waste. According to the latest data provided by Inaplas (Indonesian Olefin Aromatic Plastic Industry Association) in 2019, the annual consumption of plastic in Indonesia reached 9.52 million tons, as a result of which

there were various environmental problems such as the accumulation of plastic waste, water pollution by microplastics (Zoungranan et al., 2020).

The above problems do not escape the fact that knowledge and human behavior are factors that greatly affect the quality of the environment. One of them is human ignorance in preserving, managing, and protecting the environment (Purba & Yunita, 2017). To provide a healthier and safer environment for future generations, it becomes mandatory for us to increase attitudes and awareness about issues related to environmental issues (Eren & Yaqub, 2015). According to Unesco (1977) in Mahat et al. (2019) environmental attitudes refer to the feeling of concern for the environment, while environmental awareness is basic knowledge and perceptions of problems that occur in the environment (Dolenc & Kovač, 2021). Therefore, the United Nations as a world organization introduces education for sustainable development (ESD) as an approach that is expected to overcome problems and contribute to environmental welfare (Kotaman, et al. 2022).

ESD is a learning approach based on the principle of sustainability (Mochtar et al., 2014) which is designed to develop knowledge, skills (Ali, 2017) attitudes to maintain the environment so that it can support the needs of future generations (Wilujeng et al., 2019). ESD can be implemented through the implementation of learning in tertiary institutions (PT) (Mkumbachi et al., 2020) because it can become an arena for meetings between individuals and significant sustainability with critical thinking, provocative questions, and alternative ideas to find a better environment (Ferguson et al., 2022). especially in chemistry study programs, according to Burmeister et al. (2012), chemistry is considered to have a central role in ESD.

There are several studies that have been carried out in applying the ESD approach through learning designs with certain models, including the Aksan & Çelikler (2020) research conducted on 30 prospective science teachers regarding the application of sustainable learning in the context of waste recycling. The results showed that after conducting a 10-week study, there was an increase in knowledge and awareness in 30 pre-service teachers. Other research results according to Balakrishnan et al. (2020) sustainable development study programs offered at University A, Japan, and University B, Malaysia have developed positive attitudes and perceptions about environmental and social sustainability issues. The results of another study conducted on students according to Ahel, et al. (2023) there are differences in learning outcomes between conventional Research-based learning (RBL) models and RBL models integrated with ESD. Student learning outcomes through integrated learning with ESD resulted in a higher ranking.

However, according to Suryadi (2011) developing didactic situations in learning plans, usually does not consider the diversity of student responses so it can cause learning activities to be less than optimal. This is because some of the responses of students to didactic situations that are developed outside the scope of the educator's thinking or are not explored so that the learning difficulties that arise vary are not responded to by educators appropriately or not responded to at all. In contrast to the research developed by Suryadi (2011) in developing didactic designs, it strongly considers the diversity of student responses which is reflected in learning planning. Therefore, to overcome the shortcomings of the learning design, the effort that can be made is to develop an ESD-oriented didactic learning design.

ESD-oriented didactic design is a learning design that focuses on developing the learning activity process (Andersen & Munksby, 2018) through the principle of sustainability (Mochtar et al., 2014). There are many previous studies that suggest that didactic design development is able to develop certain knowledge or skills in chemistry learning, one of which is Mustikasari's research (2019) on the development of didactic designs in the context of ionic fluids, the results of research obtained that didactic design also has the potential to overcome learning difficulties and can develop VNOST. Another research was conducted by Hashemi (2022) regarding the development of didactic design

strategies, based on the results of the analysis it is proven that design provides space for the development of shared and collaborative knowledge involving students. However, there has been no research that develops an ESD-oriented didactic design.

ESD-oriented didactic design is very suitable to be developed through biopolymer lecture materials because it can make bioplastics an alternative context for sustainability from problems caused by plastic waste (Burmeister & Eilks, 2012). In addition, based on the results of previous studies, there are learning barriers experienced by preservice teachers in biopolymer content (Sha et al., 2021). Based on the background that has been presented, the purpose of this study is to develop environmental attitudes and awareness as well as mastery of pre-service teachers' concept through ESD-oriented didactic design in the context of bioplastics.

Methods

This research focuses on designing the didactic design of education for sustainable development (ESD) oriented learning with the aim of developing the attitudes and environmental awareness of preservice teachers in the bioplastic context and overcoming the learning barriers experienced by preservice teachers in studying biopolymer content. This study used didactical design research (DDR) developed by Suryadi (2011). The design of this study has three stages, namely 1) Didactic situation analysis 2) Metapedadiactical analysis or learning implementation analysis, and 3) Retrospective analysis. The method used in this study is a mixed method with an intervention mixed methods design (Creswell, 2018). The following are the stages of research design using the DDR framework adjusted to intervention mixed methods design (Figure 1).

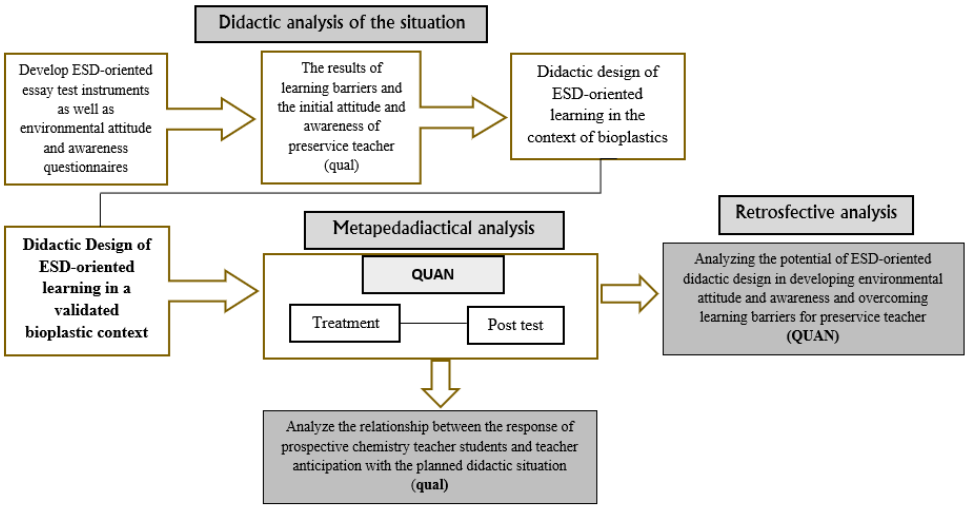


Figure 1. The stages of design preparation are didactic using the mixed method with the intervention mixed methods design

The subjects of this study consisted of 27 preservice teachers in one of the Chemistry Education study programs, State Universities in West Java, and 5 lecturers of chemistry education experts at one of the State Universities of West Java and Aceh. The sampling technique was carried out through purposive sampling. The following are the instruments and data processing steps of each stage of learning, which are shown in Table 1.

Table 1. Research and Data Processing Instruments

No	Instruments	Data obtained	Data Processing
1	Test questions on biopolymer content as well as attitude and environmental awareness questionnaire sheets	Preconceptions as learning barriers as well as initial attitudes and awareness experienced by preservice teachers.	Percentage Interpretation of % (Mendenhall, et al, 2013) and Qualitative analysis (Creswell, 2009)
	Expert Validation Sheet, related to didactic design design	Suggested improvements on the didactic design validation sheet	Qualitative Analysis (Creswell, 2009)
2	video recording transcript analysis sheet	The transcript results of the learning video recording are in the form of learning obstacles and the relationship between the response of preservice teachers to didactic situations and educators' anticipation of the learning process.	Qualitative Analysis (Creswell, 2009)
3	Test questions on biopolymer content as well as attitude and environmental awareness questionnaire sheets	The test results of preservice teachers as well as the attitudes and environmental awareness of students who are preservice teachers.	Percentage % change before and after learning (Mendenhall, et al, 2013)

Results and Discussion

Didactic Situation Analysis Stage Before Learning

Preconceptions of preservice teachers on Chemistry Content through the Bioplastic Context

One of the basics of didactic design development is the consideration of preconceptions from students (Suryadi, 2011). Preconception is an integral part of learning that provides a framework for assimilating new knowledge into existing cognitive structures (Van Tinonas & Diaz, 2019a). It is very important to identify the initial knowledge of the student before teaching some new content to direct the learning process (Yang et al., 2021). This is in line with what Van Tinonas & Diaz (2019b) stated, good learning design is a learning design that considers the preconceptions of students who are preservice teachers.

In this study, the preconceptions of pre-service teachers were measured by a validated test instrument consisting of 12 questions. Questions are arranged based on the learning objectives to be achieved in the biopolymer content. These questions include the meaning, classification, benefits, development, and manufacture and function of materials in the manufacture of starch-based bioplastics. After the instrument was tested, an analysis of the results of the answers of preservice teachers was carried out, and it was obtained that students experienced learning obstacles in most of the sub-materials (Table 2).

Table 2. Percentage of Student Preconceptions Question

No	Question	Student Preconceptions %			
		-	+	++	+++
1.	Question 1	0	56	33	11
2	Question 2	19	52	26	4
3	Question 3	19	48	26	7
4	Question 4	19	59	22	0
5	Question 5	4	48	48	0
6	Question 6	4	48	44	4
7	Question 7	30	48	22	0
8	Question 8	52	48	0	0
9	Question 9	59	30	11	0
10	Question 10	81	19	0	0
11	Question 11	33	30	37	0
12	Question 12	52	44	4	0
	Total	31	44	23	2

Desc: (-) = Bad (+) = Enough (++) = Good (+++) = Very Good

The results of the data analysis obtained a total percentage of preconceptions in each category. If ranked from the largest, then overall it was identified that 44% of preservice teachers had preconceptions with sufficient categories, 31% of preservice teachers with bad categories, 23% of preservice teachers with good categories, and 2% of preservice teachers had preconceptions with very good categories.

The results of the preconception analysis resulted in very varied answers. This is an important point that supports the fact of the importance of preconception assessment to find out variations between students (Hailikari et al., 2008). Based on the results of the analysis of student preconception data with a bad category and sufficient from the 12 questions that have been presented, preservice teachers were identified as experiencing the most learning obstacles in the sub-discussion, including (1) classification of biodegradable biopolymers (2) the process of decomposition of starch (3) the benefits of biopolymers in various fields (4) the benefits of bioplastics for the environment (5) the dilemma of bioplastic sustainability issues (6) the function of materials in making bioplastics.

The learning barriers experienced by pre-service teachers in studying biopolymer content through the bioplastic context are influenced by several factors, including that pre-service teachers do not fully understand prerequisite concepts, such as biobased and biodegradable concepts so pre-service teachers experience learning barriers when studying biopolymer classification. This is in line with what was stated by Van Tinonas & Diaz (2019b) about previous knowledge is a stepping stone for pre-service teachers to be able to continue other topics of discussion. The second factor is the lack of information about bioplastics among students. This is in line with the results of research proposed by Soesanto et al. (2016) in Indonesia bioplastics are still at the niche level and bioplastics only have a small market share in Indonesia. Then the third factor is that pre-service teachers do not understand the concept of ESD and the relationship between bioplastics and sustainable aspects (environmental, economic, and socio-cultural). This is in line with the results of research on the application of ESD in Indonesia conducted by Sutanto (2017) regarding the achievement of ESD in NTB is considered still difficult to achieve because there is not optimal cooperation between local governments, educational institutions, and community elements.

The results of the analysis of learning barriers can be used as a reference in developing didactic situations in didactic design (Table 3).

Table 3. Results of the Planned Didactic Situation Draft

No	Question Items	Planned Didactic Situation
1	Classification of *biodegradable biopolymers*	Educators can make effort by displaying a graph of the 2021 bioplastic production capacity in order to provide pre-service teachers with an overview of examples and classifications of biopolymers.
2	The process of decomposition of starch	Educators can display tables of names of decomposing enzymes from several biopolymer compounds, as well as infographics related to the biopolymer decomposition process so that pre-service teachers can describe the biodegradation process of each biopolymer properly and correctly.
3	Benefits of biopolymers in various fields	Educators need to provide some overview of examples of bioplastics in everyday life, then educators direct pre-service teachers to group them in the right field.
4	Benefits of bioplastics for the environment	Educators can direct pre-service teachers to think about biobased bioplastics can overcome the shortcomings of petroleum-based materials or educators can ask questions related to how examples of environmental problems caused by non-biodegradable plastic waste can be overcome by biodegradable plastics. (Connect with cases of water pollution and soil pollution).
5	The dilemma of bioplastic sustainability issues	Educators can make efforts by displaying a graph of the distribution of bioplastic production costs (economic aspects) as well as displaying graphs of bioplastic production capacity 2021-2026 (socio-cultural aspects), then educators direct pre-service teachers to compare it with the annual production amount of petrochemical plastics.
6	The function of materials in the manufacture of bioplastics	Educators can make efforts by showing learning videos related to the function of materials in making bioplastics so that students can gain knowledge properly and correctly.

Attitudes and Initial Environmental Awareness of Preservice Teachers

The results of this study aim to determine the initial environmental attitudes and awareness of pre-service teachers. The results obtained are used as a reference in the stages of preparing the didactic design. The instrument used was a questionnaire of attitudes and environmental awareness adapted from Özden (2008). This questionnaire consists of two types of statements, namely positive statements and negative statements which consist of 24 statements with four sub-categories namely Awareness of environmental problems (1,5,9,13,17,21) Awareness of individual responsibility (2,6,10,14,18,22) general attitudes towards environmental solutions (3,7,11,15,19,23) and general attitudes towards environmental problems (4,8,12,16,20,24).

The following are the results of the analysis of the initial environmental attitudes and awareness of preservice teachers in the four sub-categories that have been grouped through five assessment scales. (STS, TS, N, S, SS) (Table 4).

Table 4. Results of Initial Environmental Attitude and Awareness Analysis

Subcategories	Statement Number	Assessment Scale					%	Average (%)	Cate-gory
		SS	S	N	TS	STS			
Awareness of an Environmental Problem	Statement 1	25	1	0	0	1	96	79,8	High
	Statement 5	0	2	5	11	9	80		
	Statement 9	11	11	4	1	0	84		
	Statement 13	1	6	6	10	4	67		
	Statement 17	1	3	4	12	7	76		
	Statement 21	1	2	6	11	7	76		
Awareness of Individual Respon-sibility	Statement 2	22	5	0	0	0	96	88,2	Very High
	Statement 6	0	0	1	8	18	93		
	Statement 10	13	14	0	0	0	90		
	Statement 14	0	4	14	8	1	64		
	Statement 18	18	8	1	0	0	93		
	Statement 22	18	9	0	0	0	93		
General Attitudes Towards Environ-mental Solutions	Statement 3	21	6	0	0	0	95	88,8	Very Positive
	Statement 7	9	16	1	1	0	85		
	Statement 11	0	1	0	8	18	92		
	Statement 15	12	14	1	0	0	88		
	Statement 19	0	1	3	13	10	84		
	Statement 23	15	11	1	0	0	90		
General Attitudes Towards Environ-mental Problems	Statement 4	3	11	10	3	0	70	79,7	Positive
	Statement 8	4	10	11	2	0	78		
	Statement 12	10	16	1	0	0	87		
	Statement 16	14	13	0	0	0	90		
	Statement 20	0	0	5	16	6	81		
	Statement 24	0	4	11	4	8	72		
	DESC:	Negative statement			Positive statement				

Based on the results of the analysis in the first sub-category, the lowest percentage is found in statement 13 with an average of 67%, so it can be concluded that there are pre-service teachers who are not aware of environmental problems caused by plastic waste is a very serious and worrying problem. In fact, the use of petrochemical plastics has become a real problem for the health and environment of the world (Azmin et al., 2020a). To make pre-service teachers aware of the impact of these problems, a learning design is needed that presents a video of the phenomenon of environmental damage by plastic waste and is expected to make pre-service teachers aware of the seriousness of environmental problems.

Furthermore, based on the results of the analysis in the second sub-category, the lowest percentage is found in statement 14 with an average of 64%. The results showed that there were pre-service teachers who chose to be neutral and there were also students who did not prioritize the use of environmentally friendly plastics to protect the environment. Even so, researchers continue to strive to produce environmentally friendly plastic packaging materials (Kamsiati et al., 2017). Some studies such as Shafqat et al. (2021); Sunardi et al. (2020); Tamiogy et al. (2019) have produced a technology for manufacturing bioplastics from degradable natural materials. The factor that influences the answers of pre-service teachers s is the lack of information related to environmentally

friendly plastics so that pre-service teachers are not fully aware of their benefits to the environment, therefore a learning design is needed that can introduce bioplastics and their advantages compared to petrochemical plastics.

Based on the results of the analysis in the third sub-category, the lowest percentage is found in statement nineteen with an average of 84%. Data shows that the average pre-service teacher has a very positive attitude towards environmental solutions. However, there are also pre-service teachers who are hesitant and negative about the idea that the use of bioplastics can lead to industrial declines. Even Though, based on data from the Global Production Capacities of Bioplastics 2021-2026, Bioplastics are growing in various fields, ranging from packaging and consumer products to electronics, automotive, and textiles. To develop pre-service teachers' attitudes, a design is needed that presents a graph of the global production of bioplastics in 2021 as well as a graph of the development of bioplastics in the industrial field in the last five years so that pre-service teachers can have a broader insight into bioplastics and be more positive about various solutions to environmental problems.

Based on the results of the analysis in the fourth sub-category, the lowest percentage is found in statement four with an average of 70%. This shows that some of the pre-service teachers are hesitant or neutral, while other pre-service teachers are negative because they feel entitled to use plastic even though it can damage the environment. Even though, the government has tried various ways to overcome problems caused by plastic, one of which is urging the public to handle plastic waste through the 3R concept (reuse, reduce, recycle) (Nur et al., 2021). To develop student pre-service teachers, a learning design is needed that can present a scheme or flow of the final impact of the life of environmentally friendly plastics and conventional plastics on the environment so that pre-service teachers can realize the advantages and disadvantages of both to the environment.

Validation Results by Experts against Hypothetical Didactic Design

This didactic design was validated by 5 expert lecturers, including a lecturer in Chemistry Education at one of the Universities of West Java and Aceh. There are several things that need to be validated regarding didactic design, including (1) the suitability of the goal and the planned didactic situation. (2) the suitability of the student's response to the planned didactic situation based on that response. (3) Conformity of Prediction of students' responses with educator/scaffolding anticipation. The validation result is in the form of a "Yes" answer if some of the things assessed are appropriate. Vice versa, if there are some things that are considered inappropriate, the validator can give a "no" answer and can make suggestions in the suggestions and improvements column. Here are some validator suggestions and results of didactic design improvements hypotheses. The validation results can be seen in Table 5.

Table 5. Validation Results by Expert Lecturers

Things to Fix	Before Repair	Suggestion
Learning Objectives	Pre-service teachers are able to design a practicum for making starch-based bioplastics.	We recommend that KKO be changed to conducting experiments
	Pre-service teachers are able to explain the process of starch biodegradation in nature.	Preferably the word "in nature" abolished
	Sequencing learning objectives from the definition, biodegradation processes, and classification.	We recommend that the learning objectives be sorted by definition, classification, and biodegradation process

Didactic Situation	Educators explain that the main components of plastics are synthetic polymer compounds.	It is best to first describe plastics as an example of a grouping of polymeric compounds based on their applications other than elastomers and fibers.
Didactic Situation	This is caused because the level of degradation does not correspond to the intended service life so the accumulation of plastic waste in the environment occurs.	The meaning of the sentence is less clear. Phrasing should be revised
Didactic Situation	Educators explain that the advantages that plastic has such as its strong durability can also have a bad impact on the environment	Provide a special explanation of the advantages of plastic durability
Response prediction	- Biopolymers are *biobased* and biodegradable. - Biopolymer biobased material and non-biodegradable - Biopolymers are fossil fuel-based and are biodegradable.	Biopolymers' characteristics are not biodegradable by what please explain
Learning objectives (Pre-service teacher's worksheet)	Pre-service teachers are able to conduct experiments on making starch-based bioplastics.	It is better if the learning objectives in the LKM are associated with aspects of knowledge, skills, and attitudes.
Pre-service teachers Worksheets	Writing is only limited to the procedure for making bioplastics	Worksheets should best reflect environmental attitudes and awareness, not just knowledge.
Educator Anticipation	Directing pre-service teachers to pay attention to the polymerization reaction of polyethylene (PE) and polypropylene (PP)	It is necessary to clarify the type of polymerization reaction

Based on the inputs and suggestions that the validators gave, resulted in some improvements from the didactic design of the hypotheses that had been designed. Here is one of the revised didactic design sections shown in figure 2. (The results of the improvements are marked with writing in red).

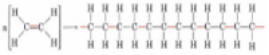
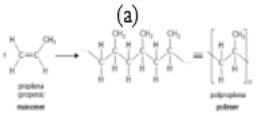
Tujuan Sikap dan Kesadaran Lingkungan	Situasi Didaktis yang Direncanakan	Prediksi Respon Mahasiswa	Antisipasi Pendidik/ Scaffolding
(1)	(2)	(3)	(4)
Mahasiswa menyadari akan permasalahan yang terjadi di lingkungan serta gagasan mereka tentang dampak masalah lingkungan dalam kehidupan	**1. PLASTIK** • Pendidik menampilkan gambar manfaat plastik dalam kehidupan Gambar. 1 kantong plastik (Sumber; Manfaat Kantong Plastik Yang Sangat Penting – Sablon Plastik Cetak Plastik (griyasablonplastik.com) • Pendidik menjelaskan plastik merupakan salah satu contoh dari pengelompokan senyawa polimer berdasarkan aplikasinya selain elastomer dan serat. • Pendidik menjelaskan bahwa komponen utama plastik adalah senyawa polimer sintetik. *(Materi yang telah dipelajari sebelumnya)* **Pertanyaan:** 1.1 Apakah yang dimaksud dengan polimer? Berdasarkan pengalaman yang anda miliki	**(1.1) Jawaban opsi 1** Polimer adalah senyawa makro-molekul yang terbentuk melalui penggabungan molekul-molekul sederhana (monomer) secara berulang. Keunggulan dari plastik dalam kehidupan sehari-hari adalah memiliki daya tahan yang kuat, elastis, ringan. **(1.1) Jawaban opsi 2** Polimer adalah senyawa makro-molekul yang terbentuk melalui monomer. Keunggulan dari plastik dalam kehidupan sehari-hari adalah memiliki daya tahan yang kuat, elastis. *(Tidak menyebutkan kalimat penggabungan molekul-molekul sederhana (monomer) secara berulang)* **(1.1) Jawaban opsi 3** Polimer adalah senyawa makro-molekul yang terbentuk melalui penggabungan molekul-molekul sederhana (monomer) secara berulang. *(Tidak menjelaskan keunggulan plastik)*	**Jika jawaban opsi 2** muncul pendidik mengarahkan mahasiswa untuk memperhatikan contoh (a) reaksi polimerisasi adisi polietena/ polietilena (PE) dan (b) polipropilena (PP) berikut ini  (a)  (b) Berdasarkan reaksi berikut coba simpulkan pengertian dari polimer. **Jika jawaban opsi 3** muncul pendidik memberikan mahasiswa contoh plastik nyata dan mengarahkan mahasiswa untuk memperhatikan sifat fisik dari plastik tersebut, lalu simpulkan berdasarkan apa yang mereka dapatkan. **Jika jawaban opsi 4** muncul pendidik mengarahkan mahasiswa untuk memahami istilah polimer secara bahasa, poli= banyak; mer= bagian/ segmen, serta memperhatikan contoh (a) reaksi polimerisasi adisi

Figure 2. Hypothesis Didactic Design Validation Results

Metapedadidactical Analysis

Metapedadidactic analysis is carried out to further examine the relationship between students and educators and the relationship between students and materials through the analysis of responses of preservice teachers after being given didactic and pedagogical actions and is able to reveal several things that can be evaluated based on findings when the learning process takes place. Learning activities using ESD-oriented didactic design are carried out in one meeting with an estimated time of 150 minutes.

After the learning activities were carried out, several discoveries were obtained that could support the development of didactic design designs. The first discovery was that preservice teachers found it difficult to understand some chemical content such as the definition of starch, the definition of biopolymers, and the process of decomposition of biopolymers through didactic situations and anticipations that had been given. This is evidenced by the response of preservice teachers when given questions when learning activities are carried out (Figure 3a) educators must guide preservice teachers to obtain the expected answers.

Furthermore, in the second discovery, preservice teachers are able to understand infographics, tables, and learning videos well so that preservice teachers are able to answer questions related to the content of benefits, challenges, and functions of materials in making bioplastics properly and correctly. This is evidenced by the preservice teacher's response when the learning activity is carried out, here is one example of an excerpt of the preservice teacher's response during learning, which is shown in (Figure 3b) Furthermore,

preservice teachers are able to communicate and conduct experiments on making bioplastics based on preservice teachers' worksheets that have been developed.

P: Sekarang perhatikan gambar yang kanan. Ini adalah salah satu contoh struktur dari biopolimer pati, ketika kita melihat struktur pati, pati terdiri dari senyawa kompleks yang tersusun dari monomer-monomer glukosa, nah dari kedua gambar ini, apa yang dimaksud dengan biopolimer?
Mhs1: (diam)
P: Kita dapat melihat biopolimer itu dari biodegradasinya, bahan bakunya lalu strukturnya, jika dihubungkan, apa yang dapat kita simpulkan tentang biopolimer? Gapapa kalau salah, kita diskusi, biopolimer adalah senyawa polimer yang bersifat.....
Mhs: Biodegradable
P: atau berbahan dasar.....
Mhs: Alam
P: atau dapat keduanya dan bagaimana dari segi strukturnya
Mhs: Kompleks
P: dari segi ikatannya gimana, jadi itu misalnya ada monomer glukosa terikat dekat glukosa melalui ikatan ...
Mhs: Glikosidik.
P: Iya, dan dia tergolong pada ikatan ion kah atau kovalen kah?
Mhs: Kovalen.
P, Mhs: Jadi dapat kita simpulkan biopolimer merupakan biopolimer merupakan senyawa polimer bersifat *biodegradable* atau yang dihasilkan dari sumber biomassa terbarukan (*biobase) atau* terdiri dari unit monomer yang terikat secara kovalen membentuk molekul besar

P: Saat ini kita berfokus pada bioplastik yang dapat terurai dan berbahan dasar alam. (Sambil menjelaskan melalui gambar) dapat mengatasi
Mhs: Permasalahan sampah plastik (sambil ragu-ragu)
P: Coba ayo sekali lagi, sudah benar tadi
Mhs: Dapat mengatasi permasalahan lingkungan.
P: Iya benar, permasalahan lingkungan apa yang dapat di atasi oleh bioplastik
Mhs: Penumpukan sampah di daratan dan dilautan
P: Benar, akan tetapi ada satu manfaat lagi yang belum disebutkan. Ketika kita menggunakan bioplastik, berarti kita dapat mengurangi penggunaan apa? Misalnya botol plastik? Terbuat dari apakah botol tersebut?
Mhs: Bahan bakar fosil
P: Nah fosil ini bahan bakar terbarukan atau tidak?
Mhs: Tidak
P: Iya benar, jadi ketika kita menggunakan bioplastik, bagaimana manfaatnya jika dari pembahasan yang saya jelaskan sebelumnya
Mhs: Dapat mengurangi penggunaan bahan bakar fosil yang merupakan sumber daya tidak terbarukan
P: Iya benar, jadi suatu saat pastinya bahan bakar fosil pasti akan habis, jadi dengan menggunakan bioplastik menjadi salah satu solusi untuk mengatasi permasalahan ini.

Figure 3. Quote Response of Preservice Teachers in Sub Discussion (a) Definition of Biopolymer (b) Benefits of Biopolymer

Retrospective Analysis

Didactic Design Potential in Developing Environmental Attitudes and Awareness

The attitudes and environmental awareness of preservice teachers in this study have generally developed. Although there are some results that are not in accordance with what was expected. The following is the result of an analysis of the development of attitudes and environmental awareness of preservice teachers in Table 6.

Table 6. Percentage of Attitudes and Environmental Awareness of Preservice Teachers Before and After Learning

Subcategories	Statement Number	% Initial Assessment	% Final Assessment	% Initial average	% Final average
Awareness of an Environmental Problem	Statement 1	96	100	79,8	85,2
	Statement 5	80	85		
	Statement 9	84	90		
	Statement 13	67	68		
	Statement 17	76	80		
	Statement 21	76	88		
Awareness of individual responsibility	Statement 2	96	97	88,2	91,2
	Statement 6	93	96		
	Statement 10	90	92		
	Statement 14	64	79		
	Statement 18	93	91		
	Statement 22	93	92		
The general attitude toward environmental solutions	Statement 3	95	96	88,8	90,7
	Statement 7	84	90		
	Statement 11	92	99		
	Statement 15	88	87		
	Statement 19	84	79		

	Statement 23	90	93		
The general attitude toward environmental problems	Statement 4	70	83	78,7	79,0
	Statement 8	72	55		
	Statement 12	87	89		
	Statement 16	90	90		
	Statement 20	81	79		
	Statement 24	72	78		

Based on the results of data analysis, overall, there is a change in the percentage of the average attitude and environmental awareness. The development of attitudes and environmental awareness experienced by preservice teachers is indicated to be derived from learning activities experienced by preservice teachers, in line with research (Aksan & Çelikler, 2020) shows that after learning activities are carried out there is an increase in the awareness of prospective science teacher students towards the environment. This is because learning activities are not only designed to increase knowledge but there are points that are emphasized by educators to develop environmental attitudes and awareness through the ESD approach. An example is by displaying videos and pictures about environmental damage so that preservice teachers feel more aware of environmental problems. Educators also convince preservice teachers to always be optimistic to carry out activities that can overcome environmental problems, one of which is by introducing bioplastics as an alternative to overcoming environmental problems. This is in line with Garcia & Luansing's (2016) research that environmental awareness can be understood through environmental education which is seen as an important way to educate preservice teachers about environmental issues and concerns. However, harder efforts are still needed in developing the attitudes and environmental awareness of preservice teachers.

Didactic Design Potential in Overcoming Learning Barriers for Preservice Teachers

After the learning activities are carried out, educators provide test questions that aim to find out the development of knowledge of preservice teachers on biopolymer content. Based on the results of data analysis, there is a development in student knowledge of biopolymer content. This is evidenced by the average results of the percentage obtained by preservice teachers. Before the learning activities were carried out, the highest percentage was in the category of enough at 44% and bad at 31%, while after the learning activities were carried out the highest percentage of preservice teacher knowledge was in the very good category of 32% and good 30%. The results obtained are in accordance with research conducted by Wijaya (2019), the development of didactic designs in the context of artificial muscles has the potential to develop VNOST and overcome learning barriers for preservice teachers who are preservice teachers. Likewise, in Mustikasari's (2019) research on the development of didactic design in the context of ionic fluids, the results of the study obtained that didactic design also has the potential to overcome learning difficulties and can develop VNOST.

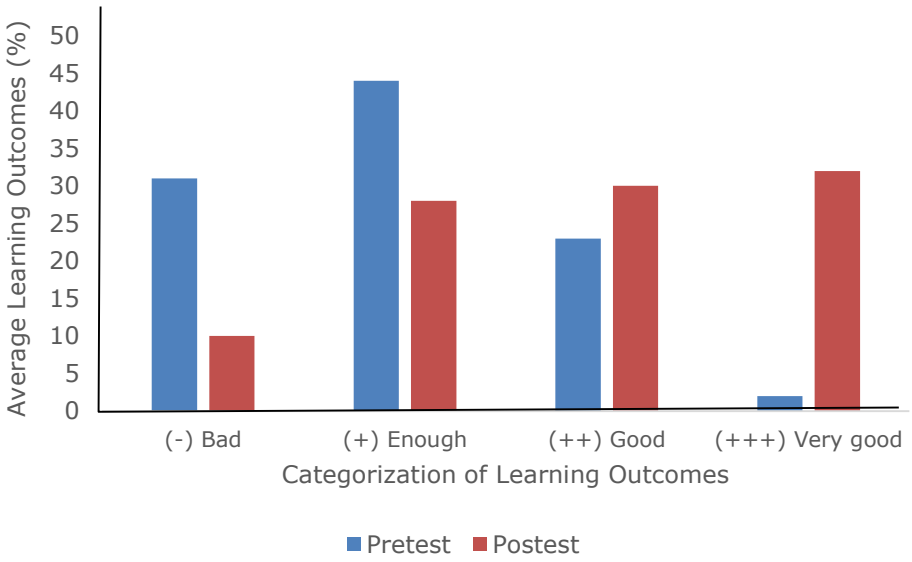


Figure 4. Graph of Knowledge Development of Concepts for Pre-service Teachers Before and After Learning Activities

The following is the development of knowledge of preservice teachers related to biopolymer content presented in figure 3. Based on the findings above, it was obtained that the development of didactic design has the potential to overcome the learning barriers of preservice teachers, so that it can also be concluded that preservice teacher experience developments in mastering concepts in biopolymer content. The findings obtained support the theory put forward by Suryadi (2011) by implementing learning through a didactical design that can overcome the learning barriers experienced by students. With more and more diverse student responses to the didactic situations that are developed, learning activities become more effective (Fauzi & Suryadi, 2020)

Conclusion

Based on the results of the research presented in the discussion, it can be concluded that the ESD-oriented didactic design that has been designed based on learning barriers, attitudes and initial environmental awareness that has been identified, is capable of developing environmental attitudes and awareness and can overcome student learning barriers to chemical content related to the context of bioplastics. This can be proven by the results of the average percentage before and after student learning activities have increased. However, in designing the didactical design, there were several suggestions for improvement given by the validator, including improving operational verbs in learning objectives, improving sentence redaction in anticipation and didactic situations, as well as improving the overall goals and content of the LKS. There were also several findings during the teaching trials using the didactic design, including: 1) appropriate didactical actions were still needed to improve students' mastery of prospective chemistry teachers 2) didactical actions were needed that could make students active in asking and answering activities.

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