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Improving Water Saving Behaviors: The Role of STEM-EDP Education for Future Physics Teachers

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Abstract

In a global context, water quality issues have become a major environmental issue affecting many countries, including Indonesia, especially in the East Kalimantan region. This research aims to determine the difference and increase in water saving behavior (WSB) of pre-service physics teachers after being involved in learning with the Science - Technology - Engineering - Mathematics (STEM) - Engineering Design Process (EDP) model. The research method used was pre-experimental research using a one-group pretest-posttest design with a quantitative approach. The sampling technique in this research was purposive sampling, involving 31 pre-service physics teachers. A questionnaire that had been adapted from previous research was used as an instrument in this research. The learning was carried out by giving 4 STEM-EDP worksheets with a total of 6 offline meetings. The results showed that there was a difference and increase in WSB after learning with the STEM-EDP with moderate criteria overall. The results of this research indicate that the STEM-EDP learning model may improve positive behavior toward the environment.

Keywords: Pre-Service Physics Teacher, STEM-EDP, Water Saving Behavior,

Abstrak

Dalam konteks global, masalah kualitas air telah menjadi isu lingkungan utama yang melanda banyak negara, termasuk Indonesia, khususnya di wilayah Kalimantan Timur. Penelitian ini bertujuan untuk mengetahui perbedaan dan peningkatan perilaku hemat air (Water Saving Behavior/WSB) *mahasiswa calon guru fisika setelah mengikuti pembelajaran dengan model* Science - Technology - Engineering - Mathematics (STEM) - Engineering Design Process (EDP). *Metode penelitian yang digunakan adalah penelitian pra-eksperimental dengan menggunakan desain one-group pretest-posttest design dengan pendekatan kuantitatif. Teknik pengambilan sampel dalam penelitian ini adalah purposive sampling, dengan melibatkan 31 guru fisika calon guru. Kuesioner yang telah diadaptasi dari penelitian sebelumnya digunakan sebagai instrumen dalam penelitian ini. Pembelajaran dilakukan dengan memberikan 4 lembar kerja* STEM-EDP *dengan total 6 kali pertemuan secara offline. Hasil penelitian menunjukkan bahwa terdapat perbedaan dan peningkatan* WSB *setelah dilakukan pembelajaran dengan* STEM-EDP *dengan kriteria sedang secara keseluruhan. Hasil penelitian ini menunjukkan bahwa model pembelajaran STEM-EDP dapat meningkatkan perilaku positif terhadap lingkungan.*

***Kata kunci**: Calon Guru Fisika, Perilaku Hemat Air,* STEM-EDP

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INTRODUCTION

Poor water and air quality are the most important environmental problems around the world (Alimissis et al., 2018) (Farhan et al., 2023). Indonesia also suffers from poor water and air quality, especially East Kalimantan (Subagiyo et al., 2019). Indonesia as a member of the United Nations (UN) must take part in overcoming global problems to fulfill the government's commitment in the implementation of achieving the Sustainable Development Goals (SGDs) (Indonesian, 2017). The SDGs focus on 17 goals, with 4 pillars (Adiyoso, 2022), one of which is the environmental development pillar. The environmental development pillar is one of the 4 major pillar categories of the SDGs that focuses on improving environmental quality, especially water issues by promoting water-saving behavior (WSB) which is connected to the 6th SDGs goal, namely clean water and sanitation. Human behavior is one of the factors that play a role in the occurrence of problems on water issues which actually causes a lot of clean water to turn into dirty water (Rayma, 2020). These behaviors include disposing of liquid waste and solid waste into clean water pools, such as rivers, lakes, and seas (Kospa & Rahmadi, 2019).

Environmental education has evolved from a view of the environment to knowledge and action, emphasizing the dynamic and complex relationships between surrounding ecosystems that influence habits and education received in daily life (Marcinkowski & Reid, 2019). One of the subjects that teach about the environment is Natural Science (IPA). In the Learning Outcomes of Phase D Science Subjects for SMP/MTs/Package B Programs in the Merdeka Curriculum published by the Ministry of Education and Culture in 2022, it is stated that one of the learning outcomes of students who must be developed in accordance with the profile of Pancasila students is to play an active role in maintaining, maintaining, preserving the natural environment, managing natural resources and the environment wisely (Kemendikbudristek, 2022).

Considering the role of pre-service physics teachers is very important as prospective educators who will provide knowledge (Saputri, 2022) related to environmental issues, especially water issues related to water scarcity and pollution which are closely related to science subjects (Rismawati & Sya'aban, 2023), pre-service physics teachers must be prepared to be able to convey and provide problem solving to students related to attitudes that will prevent water problems in the future (Saputri, 2022), one of which is a water-saving attitude or WSB. There are several theories psychologically developed in discussing environmental behavior, one of which is the Theory of Planned Behavior (TPB). TPB is a theory that is widely used in various studies, which focuses on controlled rational choice as a factor that influences individuals to act ecologically (Nkaizirwa et al., 2021). Through the TPB formulation presented by Ajzen (2005), it results that behavior is significantly formed from intention and perceived behavior control, where intention is formed from the attitude towards the behavior and subjective norm which is controlled through perceived behavior control which is successively formed from behavior beliefs, normative beliefs, and control beliefs.

Curriculum implementation can be done through various approaches, one of which is the Science, Technology, Engineering, and Mathematics (STEM) approach. The STEM approach emphasizes the integration of science, technology, engineering, and mathematics in the learning process. The STEM approach is an integrated approach to instilling creative problem-solving techniques in students and developing future innovators (Pradana & Ngazizah, 2021). This is in line with the SDGs goals which focus on clean water and sanitation (Adiyoso, 2022). STEM education can enhance students' learning experience through the application of general principles and practices (Davidi et al., 2021). The STEM approach can be implemented through the Engineering Design Process (EDP) (Azizah et al., 2022). EDP is a process that emphasizes the design and engineering of environmentally friendly products (Hafiz & Ayop, 2019). The EDP process consists of several stages, including thinking about product goals, designing products, making products, testing products, and redesigning products (Douglas et al., 2016).

The application of the STEM-EDP approach in the learning process is expected to have an impact on the WSB of pre-service physics teachers. One of the roles of pre-service physics teachers in STEM-

EDP learning is as a facilitator or guide in the learning process. Pre-service physics teachers need to understand the concepts of STEM and EDP and be able to integrate them in learning so that students can understand and apply these concepts in solving problems (Kusumaningtyas et al., 2020). In addition, pre-service physics teachers also need to facilitate students in carrying out the EDP process, namely by helping students identify problems, design solutions, make prototypes, and test solutions that have been designed (Prismasari et al., 2019).

There is a parallel research related to behavior towards the environment that has analyzed pro-environmental behavior (PEB) towards pre-service physics teachers. The research shows that an environment-based curriculum has the potential to increase the PEB of pre-service physics teachers, both through classroom learning, and various habituation activities. In addition to the implementation of a curriculum that can strengthen the environmental knowledge of pre-service teachers, it is necessary to be equipped with student activities or habituation related to the environment (Dinurrohmah et al., 2023). However, there has not been much implementation of the STEM-EDP project in these and other studies in improving WSB as one of the components of PEB. Therefore, this study aims to determine whether or not there is an increase in the WSB of pre-service physics teachers in lectures with the STEM-EDP learning model. The results of this study are expected to provide insight into the effectiveness of the STEM-EDP approach in promoting WSB in pre-service physics teachers.

METHODS

The type of research in this study is quantitative research, where the research data presented is in the form of numbers and analyzed using statistics. The research method used is the pre-experimental type. The form of pre-experimental design used is one group pretest-postest design. According to Saat & Mania (2020), this research design uses only one group, so it does not require a control group. Before being given treatment, the experimental group was first given a pre-test, then given treatment using EDP model learning with a STEM approach and after that given a post-test.

The sampling technique in this study was carried out using a purposive sampling technique which aims to obtain a research sample that matches the criteria (Saat & Mania, 2020), namely pre-service physics teachers who are taking Integrated Science courses. The population in this study was all pre-service physics teachers at the Faculty of Teacher Training and Education Mulawarman University and the sample was represented by 3rd semester students from the Physics Education study program totaling 31 students those who take the Integrated Natural Sciences course whose understanding of the environment in terms of lecture theory is still in its infancy .

Data collection techniques were carried out through 2 stages, namely treatment and tests in the form of questionnaires. Giving treatment for 6 meetings by giving 4 worksheets. The questionnaire test was given before treatment (pre-test) and after treatment (post-test). The questionnaire used was adapted and translated into Indonesian. The following Table 1 presents the components of the questionnaire questions covering aspects of the WSB using the TPB measured using a 7-point semantic differential scale.

Table 1. WSB Lifting Grid

Variables	Aspects	Items	Description
Water Saving Behavior	Behavior	1 and 2	(Kilic & Dervisoglu, 2013)
	Behavior Intention	3	
	Attitude Towards Behavior	4 and 5	
	Subjective Norm	6 and 7	
	Perceived Behavioral Control	8 and 9	
	Behavior Beliefs	10 - 14	
	Normative Beliefs	15 - 20	
	Control Beliefs	21 - 24	

The data analysis technique used in this research is paired sample t-test to know the difference and N-Gain to know the improvement of WSB of pre-service physics teachers after STEM-EDP learning

model. Using N-Gain analysis can clearly and precisely determine the increase or decrease in the data obtained (Saefullah et al., 2021).

The normality test is used to determine whether the data obtained from the research results are normally distributed or not. For the normality test and paired sample t-test, it can use the help of IBM SPSS Statistics 22 software with the Shapiro Wilk method. Researchers used this method because the data collected was <50 data. A data is said to be normally distributed if the significance level is ≥ α with the value of α is 0.05, whereas if the significance level is < α, then the data is said to be not normally distributed. This test is used to make a decision whether the research hypothesis is accepted or rejected. The hypothesis has provisions that if sig. (2-tailed) < 0.05, then H_0 is rejected and if sig. (2-tailed) > 0.05, then H_0 is accepted. The hypothesis tested Ho is that there is no significant difference in WSB after learning with the STEM-EDP learning model for pre-service physics teachers and H_1 is that there is a significant difference in WSB after learning with the STEM-EDP learning model for pre-service physics teachers.

Furthermore, knowing the increase in WSB. The increase in this study is only limited to the understanding of changes in the WSB questionnaire score of pre-service physics teachers before and after treatment which is determined based on the normalized gain score, namely the comparison of the actual gain score with the maximum gain score. The N-Gain score according to (Hake, 1999) is expressed in the following equation

$$< \square - \square\square\square\square > = \frac{< \square_{\square\square\square\square\square\square\square} - \square_{\square\square\square\square\square\square\square} >}{< S_{\square\square\square\square\square} - \square_{\square\square\square\square\square\square\square} >} \quad (1)$$

The high and low N-Gain can be classified with the N-Gain value criteria adapted from Delfita et al. (2016) presented in Table 2.

Table 2. N-Gain Criteria

Score N-Gain	Criterias
N-Gain > 0.70	High
0.30 < N-Gain ≤ 0.70	Medium
N-Gain ≤ 0.30	Low

RESULTS AND DISCUSSION

The study was conducted on pre-service physics teachers at Mulawarman University, namely physics education students from the class of 2022 who took the Integrated Science course. Data collection was carried out in the even semester of the 2022/2023 academic year, namely from November 2023 to December 2023, with a total of 31 respondents who went through 3 stages of research, namely pre-test, treatment, and post-test. The pre-test was given to determine the WSB score of pre-service physics teachers before being given the treatment. The treatment was given by providing worksheets consisting of a visit to the UNMUL Water Treatment Plant (1 meeting), identifying water sources (1 meeting), making a simple water turbidity measuring tool using a smartphone (2 meetings), and designing a water filter to reduce water turbidity (2 meetings). Providing treatment for 6 face-to-face meetings (2 × 50 minutes) and structured assignments (2 × 60 minutes) for each worksheet. After being given treatment, a post-test was then given to determine the differences and improvements in WSB scores after carrying out a series of STEM-EDP learning.

This study aims to determine whether or not there is an increase in the WSB of pre-service physics teachers in lectures with the STEM-EDP learning model. The results of this study are expected to provide insight into the effectiveness of the STEM-EDP approach in promoting WSB in pre-service physics teachers. Before being given treatment, researchers first conducted a pre-test to measure the initial score of the WSB of pre-service physics teachers before being given material using the STEM-EDP learning model. The test was given in the form of a questionnaire consisting of 8 aspects of TPB with a total of 24 questionnaire statements adapted from Kilic & Dervisoglu (2013) research entitled

Examination of Water Saving Behavior within the Framework of Theory of Planned Behavior. The number of pre-test data analyzed in this study was 31 according to the number of physics education students in class 2022. The frequency of the results of the pre-test can be seen in Table 3.

Table 3. Frequency of Pre-test Scores

No	Pre-Test score	Frequency
1	0.00 – 1.00	0
2	1.01 – 2.00	0
3	2.01 – 3.00	0
4	3.01 – 4.00	1
5	4.01 – 5.00	12
6	5.01 – 6.00	13
7	6.01 – 7.00	5

After the pre-test, treatment was given in the form of working on 4 STEM-EDP worksheets, namely a visit to the UNMUL water treatment plant, identifying water sources, making a simple water turbidity measuring instrument with the help of a smartphone, and making a water filter. After being given treatment, researchers conducted a post-test to determine the increase in the WSB score of pre-service physics teachers. The results of the post-test on pre-service physics teachers have increased. The frequency of the results of the post-test can be seen in Table 4.

Table 4. Frequency of Post-test Scores

No	Post-Test score	Frequency
1	0.00 – 1.00	0
2	1.01 – 2.00	0
3	2.01 – 3.00	0
4	3.01 – 4.00	0
5	4.01 – 5.00	1
6	5.01 – 6.00	19
7	6.01 – 7.00	11

From the pre-test and post-test data that has been obtained, a comparison graph can be made to see the comparison of the values of the pre-test and post-test which can be seen in Figure 1.

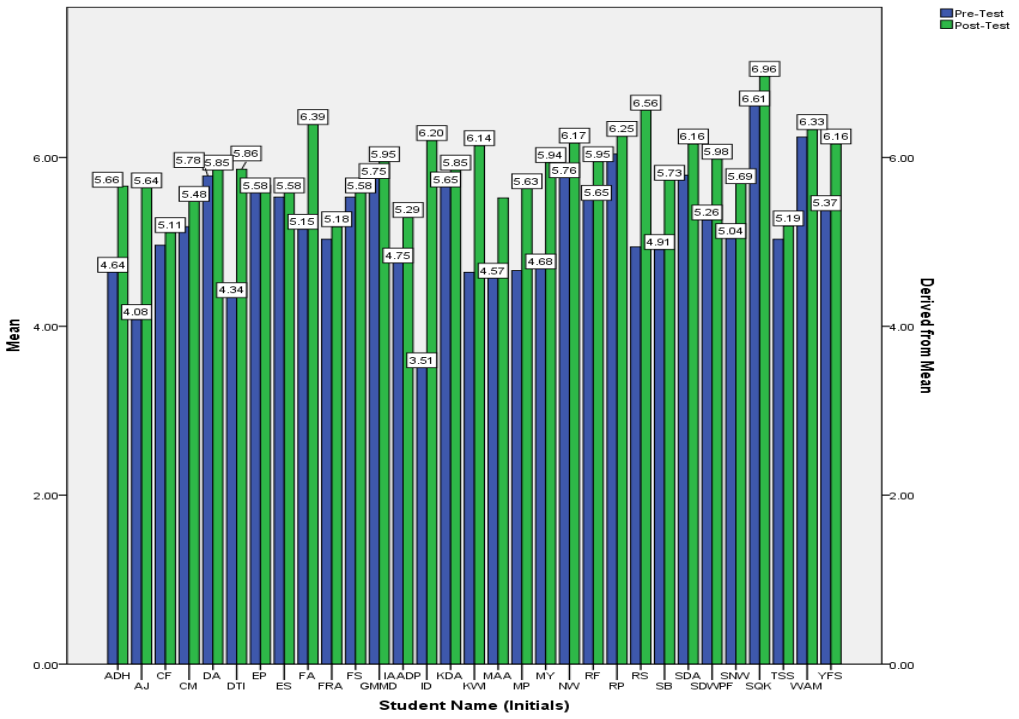

Figure 1. Comparison of pre-test and post-test scores

The data collected from the results of filling out the questionnaire, then tested for normality as a prerequisite test before conducting a different test, namely the paired sample t-test. The analysis was carried out based on predetermined analysis techniques to answer the two problem formulations, namely for differences using the paired sample t-test and to determine the increase using the N-Gain test.

The normality test in this study was conducted to determine the distribution of the research data which was then intended as a prerequisite test of the paired sample t-test. Table 5 below is the result of data normality test using IMB SPSS Statistics 22 software.

Table 5. Normality Test Results

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pre-Test	0.090	31	0.200*	0.985	31	0.932
Post-Test	0.076	31	0.200*	0.978	31	0.744

**. This is a lower bound of the significance*

[a.] Lilliefors Significance Correction

Based on the normality test conducted by researchers, it can be seen that the sig. value on the pre-test and post-test is 0.932 and 0.744 at the 0.05 level, respectively. The normality test results show that the data in this study are normally distributed, so that a parametric difference test can be carried out, namely the paired sample t-test. The results of the paired sample t-test can be seen in Table 6.

Table 6: Results of Paired Sample T-test

		Paired Differences		t	df	Sig. (2-tailed)
		Mean	**Std. Deviation**			
Pair 1	**Pre-Post**	-0.67742	0.63232	-5.965	30	0.000

Based on the significance value, sig. (2-tailed) < 0.05, then from the hypothesis that has been determined H_0 is rejected. From these results, it shows that there is a difference in WSB scores after learning with the STEM-EDP learning model for pre-service physics teachers.

In knowing the difference between the pre-test and post-test scores, the data was then tested using the paired sample t-test. The criteria for the sig value. (2-tailed) on the pre-test and post-test scores is 0.000 at the 0.05 level. Based on the paired sample t-test test, it was concluded that there was a difference in WSB after learning with the STEM-EDP learning model for pre-service physics teachers. This value indicates that there is a significant difference between the pre-test and post-test scores. In this context, the result of sig. (2-tailed) which is very low indicates that the difference observed between the paired samples is unlikely to occur by chance. This is because the treatments conducted from the first to the fourth worksheet focused on water issues which will directly impact their future knowledge and experience towards water-saving attitudes. These results are in line with research from Hashim et al. (2021) which also shows that individuals gain a high level of knowledge regarding water saving through the application of education related to water issues which allows students to have a high level of knowledge in water saving.

These results prove that learning that focuses on something, especially in this study, namely water issues, will have a significant effect on the water-saving behavior of pre-service physics teachers. The existence of this difference indicates that STEM-EDP learning related to water issues makes a significant contribution to the difference in WSB scores of pre-service physics teachers after treatment. This is in line with the results of English & King (2015)research which shows that EDP is able to develop students' ability to apply science and mathematics in solving real-world problems significantly.

It is important for campuses, especially those that will produce teachers in the future, to pay attention to issues that are and will occur in the future. Water-saving behavior will have a positive impact if it is given more attention and understanding to the community, especially to pre-service physics teachers who will become future teachers as observers of issues that will occur as learning material. Research

results from Hashim et al. (2021) showed that through WSB each pre-service physics teachers can reduce the adverse consequences of water problems to students.

N-Gain provides an overview of the increase in WSB score results between pre-test and post-test. The results of the N-Gain analysis of the STEM-EDP learning model are presented in Table 7.

Table 7. Average Results Of Pre-Test And Post-Test

Pre-test average	Post-test average	N-Gain	Criteria
5.18	5.86	0.37	Medium

Based on Table 7, the N-Gain is included in the medium criteria with a score of 0.37. Through the N-Gain analysis, it was obtained that the overall N-Gain score of the WSB questionnaire scores of pre-service physics teachers after treatment in the form of learning using the STEM-EDP learning model was in moderate criteria with an overall pre-test average score of 5.18 out of 7.00 and an overall post-test average score of 5.86 out of 7.00 so that an N-Gain score of 0.37 was obtained. From the results of the overall pre-test average score of 5.18 and the overall post-test average score of 5.86, it shows an increase from before learning even though the increase does not reach high criteria (N-Gain> 0.70). The N-Gain score of 0.37 indicates that STEM-EDP learning contributes quite well in improving the behavior of pre-service physics teachers related to WSB. The results of the analysis show that behavior cannot be changed in a short time, where researchers only conduct treatment with 4 worksheets with a total of 6 meetings. This is supported by newsletter “Changing Public Behavior” (2015) which states that a person's behavior cannot always be changed in a short time where behavior change requires a deep understanding of where the individual lives in behavior change, whether they are ready to take action or have even tried new behaviors but then stopped doing it for some reason.

In Table 8 below, it can be seen that the N-Gain results of pre-service physics teachers tend to be in the medium and low criteria.

Table 8. N-Gain Criteria Of WSB Score Of Pre-Service Physics Teachers

N-Gain Score	Criterias	Percentage	Frequency
N-Gain > 0.70	High	9.68 %	3
0.30 < N-Gain ≤ 0.70	Medium	45.16 %	14
N-Gain ≤ 0.30	Low	45.16 %	14

The next analysis is related to the N-Gain score of pre-test and post-test scores of pre-service physics teachers totaling 31 students. From the results obtained from the N-Gain score, there were 3 pre-service physics teachers (9.68%) in the high criteria, 14 pre-service physics teachers (45.16%) were in the medium criteria, and 14 pre-service physics teachers (45.16%) were in the low criteria. It can be seen that only 3 pre-service physics teachers have N-Gain scores with high criteria, which reveals that there are variations in the level of response to learning using the STEM-EDP model in improving WSB among pre-service physics teachers. Although there are a small number of them who show a significant increase in behavior, most of them are still in the medium and even low criteria due to the initial knowledge related to water-saving behavior was quite good. This is in line with the results of research conducted by Kusumawati et al. (2022), that the response to the learning model must vary among respondents. This finding also shows that behavior change is not uniform among individuals because personality is basically a psychological and behavioral characteristic of an individual that is permanent, which distinguishes one individual from another Danandjaya (2020). Behavior can be changed according to the knowledge gained, especially in this study, namely gaining knowledge related to water issues. This is supported by the results of research by Azhar et al. (2016), which states that individuals who have good environmental knowledge will have a good attitude towards preserving the environment as well, in this case an attitude in shaping water-saving behavior.

The WSB questionnaire used the theory of planned behavior (TPB) which has 8 aspects, namely behavior, behavior intention, attitude towards behavior, subjective norm, perceived behavioral control, behavior beliefs, normative beliefs, and control beliefs. The N-Gain criteria for increasing WSB based on its aspects are shown in Table 9.

Table 9. N-Gain Criteria Of WSB Score Based On Aspects

Aspects	Pre-test average	Post-test average	N-Gain	Criterias
Behavior	4.82	5.37	0.25	Low
Behavior Intention	6.06	6.39	0.34	Medium
Attitude Towards Behavior	6.58	6.69	0.26	Low
Subjective Norm	5.03	6.10	0.54	Medium
Perceived Behavioral Control	4.98	5.40	0.21	Low
Behavior Beliefs	5.09	5.61	0.27	Low
Normative Beliefs	4.38	5.59	0.46	Medium
Control Beliefs	4.92	5.41	0.24	Low

The next analysis is related to the N-Gain score based on the aspects that make up WSB according to the theory of planned behavior (TPB). The aspect that has the highest score is a subjective norm with moderate criteria of 0.54. Subjective norm itself refers to an individual's perception of social pressure or norms perceived by others that can influence their behavior, for example someone tends to follow the behavior that is considered good by their friends, even though they themselves have a different view. The high score on the subjective norm aspect is caused by pre-service physics teachers who have expectations from parents, fellow students, and universities on the quality of their teaching, so that pre-service physics teachers feel strong pressure to meet these expectations, so that it can affect their intentions and behavior in planning and implementing physics learning. This is possible because there is a problem explanation letter on the worksheet, namely with other parties asking for help from pre-service physics teachers to help find solutions to the problems described in the problem explanation letter before pre-service physics teachers carry out a series of STEM-EDP worksheet activities. This is supported by the results of research from Kilic & Dervisoglu (2013) which states that the aspect that most influences individual behavior towards saving water is a subjective norm.

Furthermore, the aspect that has the lowest score is perceived behavioral control with low criteria of 0.21. Perceived behavioral control refers to how difficult or easy a person feels their ability to perform a behavior. The low score on the perceived behavioral control aspect is due to a lack of confidence in themselves and the circumstances of their efforts to save water which results in individuals feeling insecure about taking action to save water even though they want to do so. This is supported by the results of research from Kilic & Dervisoglu (2013) which states that individuals who have a positive attitude do not mean that they will save water, as well as individuals who have a negative attitude do not mean that they will not save water. This is possible because the tasks on the worksheet, namely sketching WTP, identifying water sources around, making a water turbidity measuring instrument, and making a water filter device are tasks that have been carried out for the first time by students, so they feel unfamiliar with the solution to the worksheet problem given. In addition, there is also a lack of signage to inform people about saving water around the campus. This is also supported by the results of Ismail (2021) research which states that learning and experience are closely related to habits that are continuously practiced or carried out, so that individuals not only know but are also able to carry out what they know easily because it has become a habit.

CONCLUSION

Based on the results of the research that has been done, it can be concluded that there is a significant difference in WSB after learning with the STEM-EDP learning model for pre-service physics teachers and an increase in WSB after learning with the STEM-EDP learning model for pre-service physics teachers with moderate criteria overall. The highest aspect of improvement is subjective norm and the lowest aspect is perceived behavioral control. The suggestions that can be given based on the research that has been done are the formation of WSB requires a more comprehensive time so that

behavioral changes can occur optimally, the participants of this study were only 31 people because they were limited to those who took Integrated Science courses in Physics Education FKIP UNMUL so that in other studies later related to WSB it is necessary to increase the number of participants in order to get generalizable results. Suggestions for pre-service physics teachers so that in STEM-EDP learning activities can be taken into consideration to be used in learning because it can increase WSB.

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