IJORER : International Journal of Recent Educational Research
Homepage : https://journal.ia-education.com/index.php/ijorer
Email : ijorer@ia-education.com

p-ISSN : 2721-852X ; e-ISSN : 2721-7965
IJORER, Vol. 2, No. 3, May 2021 : 342-353

The Effectiveness of Science Learning Tools Based on Education Sustainable Development (ESD) to Improve Problem-Solving Skills

Dwita Dana Pradipta[1], Madlazim[2], Eko Hariyono[3]
[1,2,3]State University of Surabaya, Surabaya, Indonesia

DOI : https://doi.org/10.46245/ijorer.v2i3.113

Sections Info

Article history:
Submitted: April 19, 2021
Final Revised: May 8, 2021
Accepted: May 17, 2021
Published Online: May 31, 2021

Keywords:
Development
Education sustainable development
Problem solving skills
Science learning tools

ABSTRACT

This study aims to determine the effectiveness of practicing problem-solving skills from ESD-based science learning tools. This research is development research with the ADDIE development model and a one-group pre-test post-test design. Data collection methods using validation and tests. Learning tools in all aspects are stated to be very valid so that they can be implemented. The pre-test average score was 52.96 and the post-test score was 79.84 with an N-gain score of 0.67 in the moderate category. This shows that students can be improve in problem-solving skills with ESD-based learning. Students can improved problem-solving skills in the Lapindo mud phenomenon by integrating the liquid pressure material (Archimedes Law and Bernoulli's Law) with the ESD concept (social, ecological, and economic). In terms of ecology, Lapindo mudflow can be overcome by applying Bernoulli's Law. In the economic sector, the overflowing Lapindo mud can be used as a building material. This is studied in the material of Archimedes Law. In the social point, students can communicate the results of problem-solving with the concept of ESD to the surrounding community.

PENDAHULUAN

Sustainable Development Goals (SDGs) are 17 goals with 169 measurable achievements and have a deadline set by the United Nations as a world development agenda for the benefit of humans and the planet until 2030. The concept of sustainable development is based on the concept of social and economic development in line with environmental constraints, the concept of necessity with redistribution of resources to ensure the quality of life, the concept of future generations (Danneberg, 2016).

Sustainable development goals which are the 21st-century agenda delegate part of the action to develop education. Sustainable education is believed to ensure that all people acquire knowledge, values , and skills for a better life and society in a sustainable way (Klarin, 2018). This Program called ESD (Education Sustainable Development). The purpose of ESD is to provide a balance of well-being between humans, the economy, and cultural traditions as well as to give honor to the universe (Parello-Marin, 2018). Particularly, the initial goal of ESD was the incorporation of ecological, economic, and social aspects throughout learnig process (Kolleck, 2017). These aspects are adjusted to the learning material and environmental problems that occur around them. ESD also reflects complexity by adopting multiple perspectives on education for inclusiveness (UNESCO, 2012). ESD has been seen as a generation of student competencies related to collaboration through critical thinking, decision making based on problem-solving, increased communication skills, collaboration, conflict management, and planning (Parello-Marin, 2018). Thus ESD-based learning results in a paradigm shift to build new learning perspectives based on the inclusion of students in

the entire learning process. Responsible behavior towards a global future in ecological, economic and social aspects is an attitude involved in ESD (Lozano, 2015).

The main objective of ESD is to equip students through interdisciplinarity in student-centered sustainable competencies and democratic pluralistic learning synergies (Locke, 2012). environmental problems and sustainable development cannot be separated, therefore the learning process with the earth context as part of the human resource development process and the supervision of the educational environment to create a responsible society must be emphasized in learning (Hariyono, 2018). ESD is more focused on developing attitudes and skills to lighten life as well as find relevant findings on a problem (Danneberg, 2016). ESD is also competence-based which encourages innovative abilities that integrate skills, knowledge, attitudes, and values with the relationship between student competencies and the needs of the job market. (Lambrechts, 2016).

In the UK, there is a significant focus on research in education for sustainable development and global citizenship education (McNaughton, 2012). The research resulted in critical reflection on teachers to adopt education for sustainable development and global civic education that was centered on students and teachers benefiting from and participating in these activities. ESD is the backbone of NQCFs (National Qualification and Credit Framework), critical pedagogy provides an adequate instrument to develop sustainable competence in the 21st century that is embedded into the curriculum as a result of learning (Gookol-Ramdoo, 2016).

The 2015 Survey For International Student Assesment (PISA) problem-solving framework recommends solving student problems, it should not only focus on the final solution, but on the process and understanding of student's concepts in determining suiTable strategies to find solutions (OECD, 2016). Learning that is relevant and needed in real / contextual life is learning to develop students' problem skills in problems, meaning that it can be applied by implementing learning strategies that adhere to several principles in the 21st century. (Glaze, 2018). In science learning, problem-solving skills are the main skills that students must train (Chaudhry N G and Rasool G, 2012). Problem-solving skills are very important to be trained in students because through these skills students learn to be more independent and can train higher-order thinking (Mashlulah, 2018). Problem-solving skills are also very much needed in science learning, especially when doing experimental activities. Several studies argue the problem-solving physics is important goal in learning physics (Rojas, 2012; Gok, 2015; Hung et al., 2012; Doctor, 2015) because it is a students cognitive processes activity to building physics knowledge (Bogard et al. ., 2013; Docktor, 2016).

The ESD program is an innovation and has the potential to be implemented in Indonesia. The ability of students in developing lesson plans is good, especially about the relevance of lesson plans with environmental problems, but the accuracy of choosing the appropriate learning strategy tends to be low (Hariyoo, 2018). This proves that students do not understand the characteristics of learning strategies to accommodate problem-solving skills, students have embraced a rigid learning model, prioritizing the scientific assessment of theoretical process skills, and have not focused on problem-solving skills. Most teachers admit that lesson plans determine the quality of education (Nisari, 2014) and become one of the basic indicators of professional teachers. Danneberg's (2016) presentation in Education for Sustainable Development for Transformation states that the competencies that must be achieved in ESD can be

integrated with problem-solving skill indicators, so that problem solving used is viewed from social, economic, and environmental aspects.

Five steps in helping students develop problem-solving skills, namely (i) identifying known conceptions, (ii) providing more than two possible solutions, (iii) evaluating solutions, (iv) presenting experiments according to the most suiTable design, and (v) challenge the evidence-based explanation following the results obtained (Cheng, 2018). Solutions in problem-solving are presented in four phases, namely: (i) understanding the problem, (ii) planning a solution, (iii) implementing a problem-solving plan, (iv) reinterpreting the results (Polya, 1957). The stages of solving these problems are related to the competencies possessed by ESD, the stages and competencies are integrated as follows in Table 1.

Table 1. Integration of ESD competencies with problem-solving stages.

Key competence (OECD)	Components	Stages of Solving Problems
Interactive use of tools and media	• Integrate new perspectives and a global view in knowledge generation • Interadisciplination • Anticipation in thinking and acting • Identify and assess risk and uncertainties	Udestanding the problem
		Planning a solution
Co-operate in groups marked by diversity	• Act and plan in cooperation • Participate in decision-making processes • Motivate others to act in sustainable way	Carry out a problem-solving plan
Act independently	• Reflect one's own principles as well as those of others • Act and plan different and divergent notions of justice • Show and feel empathy and solidarity	Reinterpret the result

The environmental problem faced around Sidoarjo is the Lapindo mud problem which has not been resolved until now. Apart from the unstoppable mudflow, there is also a problem with the air environment. The gas containing methane has a very disturbing odor to residents. Through this environmental phenomenon by linking to the learning material of liquid pressure, students are expected to be able to provide ideas for problem-solving with the concept of ESD. In the liquid pressure material, students learn the content of sludge through the concept of the density of an object, so that it has economic value and is useful for the affected environment. According to Wiryasa (2009), the content of sludge can be used as a substitute for cement in the manufacture of solid concrete with an ideal mix composition in terms of compressive strength and water absorption. As well as some ideas from students to stop the mudflow after studying Bernoulli's Law.

The science teacher in Sidoarjo stated that ESD-based learning is important to apply to liquid pressure material because ESD-based learning students not only learn about the lesson but acquire the skills needed to face future challenges, namely Lapindo mud (Pradipta, 2020). However, more than 70% of science teachers did not implement ESD

learning for various reasons, that are (1) they had not mastered the ESD concept and (2) the teacher had difficulty relating the material to the ESD concept. This study aims to determine the effectiveness of ESD-based science learning tools to improve problem-solving skills. Improve problem solving skills are problem solvig skills that are integrated into the ESD concept, manely ecological, economic, and social aspects of the liquid pressure material with the lapindo mud phenomenon.

RESEARCH METHOD

This study aims to determine the effectiveness of ESD-based science learning tools to improve problem-solving skills. This type of research is development research using the ADDIE research model (*Analysis, Design, Development, Implementation, and Evaluation*) (Branch, 2009).

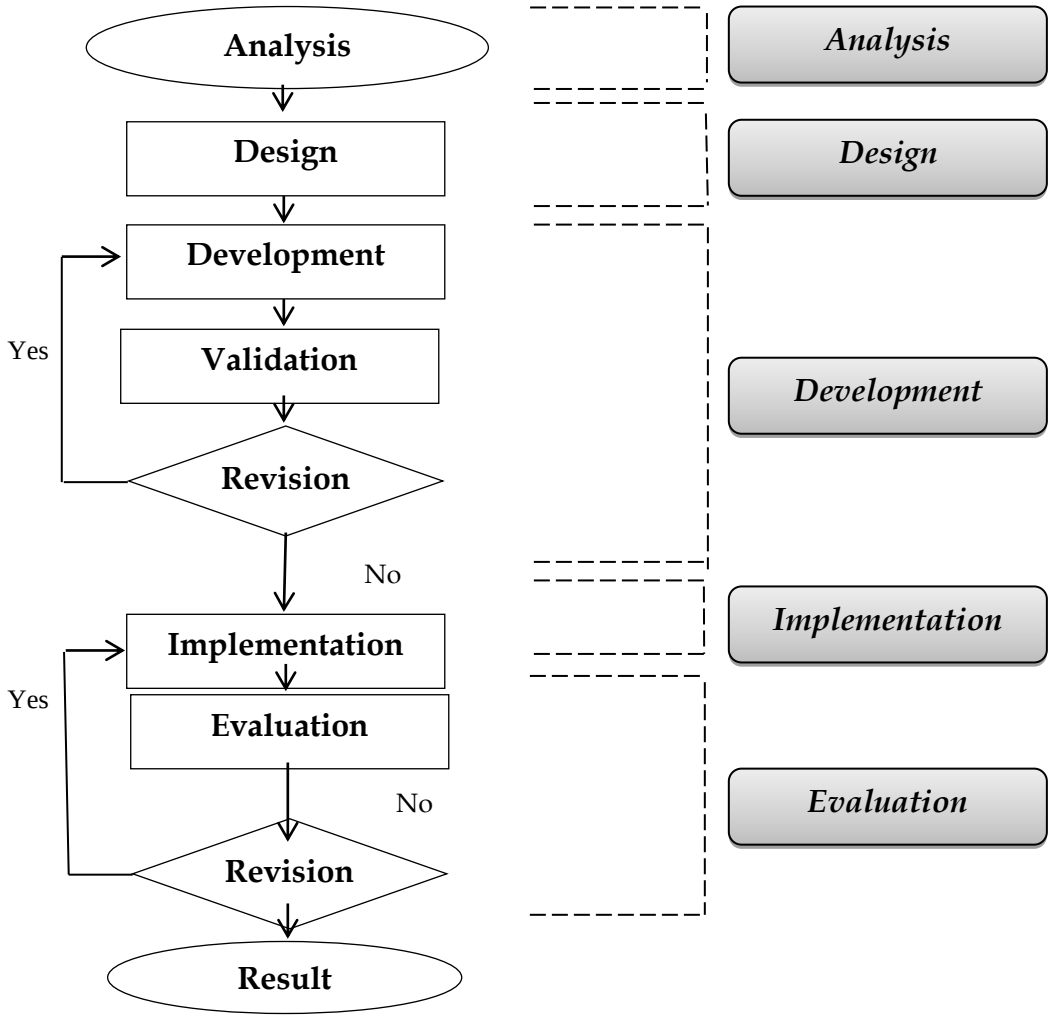

Figure 1. Flowchat of research.

This study used a one-group pretest and posttest research design. The study population was 16 middle-class students in junior high school in Sidoarjo. Before the ESD-based science learning tools was implemented, students were given a test problem-solving problem related to the material of liquid pressure. At the second, third, and fourth meetings students were given ESD-based learning. Then, at the fifth meeting

students were given a test, as a result of ESD-based learning. The test questions used are the same as the questions before being given ESD-based learning.

Analysis of Validation

After the implementation stage is carried out, the collected data is generated, then an analysis is carried out to describe the results of the research. Data analysis to determine the effectiveness of ESD-based learning tools is presented as follows: Measuring problem-solving abilities using descriptive analysis according to Setyono (2016).

Table 2. Rating of problem-solving skills.

Score interval	Percentage	Category
0 – 25	0 – 25	Very Low
26 – 49	21 – 40	Low
59 – 73	41 – 60	Enough
74 – 98	61 – 80	High
99 – 122	81 - 100	Very high

(Setyono, 2016)

Data were analyzed to determine the effect of ESD on problem-solving skills in the following details:

a. Normality test with followig hypotesis:

H_0:sig ≥ 0.05 = Data from the population are normally distributed

H_1:sig ≤ 0.05 = Data from the population are not normally distributed

b. Paired sample t-test with the following hypotesis:

H_0: $\mu_1 \geq \mu_2$ (ESD-based learning tools do not improve problem-solving skills)

H_0: $\mu_1 < \mu_2$ ((ESD-based learning tools improve in problem-solving skills)

N-Gain Score

The N-gain score shows an increase in solving skills before and after ESD-based learning is implemented. The results of the N-gain calculation obtained are converted using criteria. The N-gain score is 0.70 ≤ N-gain in the high category and 0.30 ≤ N-gain <0.70 in the medium category (Hake, 2002).

RESULTS AND DISCUSSION

Validation of Learning Tools

The results of the validation process of ESD-based learning tools by two experts can be presented as follows:

Table 3. persentage score learning material validity.

Lerning tools componen	Percentage score validity	Category
Syllabus	91	Very valid
Lesson Plan (RPP)	92	Very valid
Worksheet	93	Very valid
Textbook	97	Very valid
Problem-solving skill test	89	Very valid

Based on Table 3 the components of the learning tools get the results in a very valid category so that the learning tools can be implemented. The syllabus can be used by teachers to find out how they carry out teaching and learning activities properly,

effectively, and efficiently so that the competency standards of graduates used can be maximally achieved. The validation theory by Akbar (2013) states that teaching materials that are categorized as valid can be used in the learning process by making several revisions according to suggestions from the validator. Anggrayni's (2019) research states that geoscience teachers have made a huge contribution to making education universal by offering local science education that is relevant to a place on a topic that is very important to society. This is due to the fact that Sidoarjo region has an environmental phenomenon that has not been resolved until now. ESD learning tools raise environmental phenomena around which are solved by three ESD concepts, namely ecological, economic, and social. Moreover, to improve the quality of science teachers must plan systematic and strategic teaching, implementation, evaluation systems, and continuous improvement of the education system in Indonesia (Sukasnih, 2018). Therefore, it is necessary to reconstruct the science learning method that prioritizes the phenomena that occur in the surrounding environment.

Learning Outcomes of Problem Solving Skills

The effectiveness of ESD-based learning tools to improve problem-solving skills can be seen from the stages of problem-solving skills according to Polya (1957).

Table 4. Stages of problem-solving skills and competent achievement indicators.

Stage of problem-solving skills	Competency Indicators
Understand the problem	Identifying the phenomenon that is the problem of the Sidoarjo community, namely Lapindo mud as the concept of Archimedes Law and Bernoulli's Law
Devising a plan	Planning the right solution for the phenomenon that is a problem for the people of Sidoarjo, namely Lapindo mud by integrating the concepts of ESD (ecological, economic, and social) and the concepts of Archimedes Law and Bernoulli's Law
Caring out the plan	Carry out the plan as planned by writing the solution to the environmental problem of the Sidoarjo community, namely Lapindo mud
Looking back	Evaluating the results of solving environmental problems (Lapindo mud), then publishing it to the surrounding community

Based on the results of the implementation of ESD-based learning tools, learning outcomes are obtained, that is practicing problem-solving skills. The learning outcomes were obtained before (pretest) and after (post-test) the ESD-based learning tools were implemented.

Table 5. Pre-test and Post-test Results.

		Pretest		Posttest	
Score interval	**Percentage**	**Category**	**Amount**	**Category**	**Amount**
0 – 25	0 – 25	Very Low	0	Very Low	0
26 – 49	21 – 40	Low	2	Low	0
59 – 73	41 – 60	Enough	12	Enough	0
74 – 98	61 – 80	High	2	High	8
99 - 122	81 - 100	Very high	0	Very high	8

The pretest results showed that 100% of students did not complete the problem-solving skills competency indicator (KKM ≤ 72). The posttest results show that 100% of students complete the problem-solving skills indicator (KKM ≤ 72) in category high and very high. This shows that ESD-based learning tools can improve problem-solving skills. The results of students' problem-solving skills can publish the right solution for Lapindo mud as a phenomenon that harms the surrounding community. The solution to this problem is in the term of ecology, the Lapindo mudflow can be stopped by Bernoulli's Law. In the economic sector, an abundance of Lapindo mud can be used as a building material. This is studied in Archimedes' Law, which identifies the type of material from the density of the object. In the social term, publish these solutions in the wider community. One of the reasons students study ESD is to combine several aspects, namely environmental problems with social change and economic growth (Pauw, 2015).

Problem-solving Skills Each Indicators

The results of the student's pre-test dan post-test in term of each indicator of problem-solving skills are presented in the following diagram:

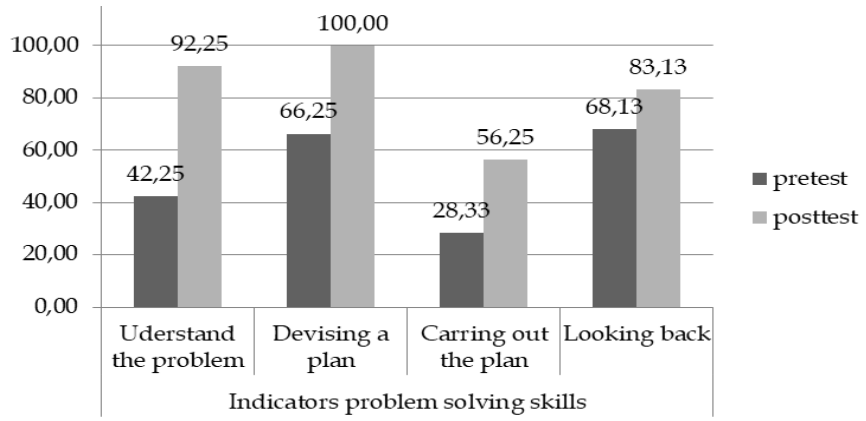

Figure 1. Problem-solving skiils of each indicators.

Based on Figure 1, the results of problem-solving skills are produced for each indicator. On the understand the problem indicator, students get results 42,25 for the pre-test and 92,25 for the post-test. Then the second stage in process of solving the problem, namely the indicator for devising a plan, the studens experienced an increase, the pre-test score was 66,25 and the posttest score was 100. This prove that students understand the problem and can plan solutions to solve the problem. However, the carring out the plan indicator has decreased, 28,33 for the pre-test and 6,25 for the post-test. This indicator is the stage of carrying out the plan according to the previously formulated plan. And on the looking back indicator, the pre-test and post-test result have increased 68,13 for the pre-test and 83,13 for post-test. This show that after being given ESD-based learning, students better understand the problem givenn, that is environmental problem (Lapindo mud).

Problem-solving indicators get the lowest score of all indicators, some students are still unable to solve problems. This is under Setyarini's (2020) research because some students are still confused about entering numbers in the equation. On the indikators of

understand the problem and devising a plan student get increased results, because students get guidance from the teacher. Then results decrease the carring out the plan indicators student tend not to understand what they are making. And has increased back to the looking back indicators where this indicator includes peer discussion, before the problem-solving is published to the wider community.

This learning has a very positive effect and is effective to use ESD-based learning can improve global problem-solving skills for the sustainable development agenda by 2030. This is consistent with research by Parello-Marin (2018) that ESD has been seen as a generation of student competencies related to collaboration through critical thinking, decision making based on problem-solving, increased communication skills, collaboration, conflict management, and planning. The ability of the students to integrated ESD competence in science learning is not a simple task (Hariyono, 2019). In context of teaching practice, teachers are required to have such competence to create a conducive learning atmosphere, selecting proper and suiTable learning approaches suit the individual's background and student's abilities (levels); the right selection ad utilize of the methods could become the opprtunities to actively engage students in learning process (Rauch, 2013).

Hypothesis Analysis of Influence Based Testing Result

Table 6. Normality data.

		Kolmogrov-Smirnov*		
		Statistic	**Df**	**Sig.**
Problem-solvig skills	**Pre-test**	.267	16	.003
	Post-test	.292	16	.001
a. Lilliefors Significance Correction				

Based on the critical Table of the Kormogrov-Smirnov test the statistical score should be < 0.322. The statistical score in the pre-test shows 0.267 and 0.292 post-test so that the data can be said to be normal. The t-test is carried out in pairs aims to determine the effect of ESD learning with problem-solving skills in the Lapindo mud phenomenon. Following are the results of the paired t-test in Table 6.

Table 6. T-test result.

		Paired difference			**T**	**Df**	**Sig (2-t)**
		mean	**Std-dev**	**Std.er mean**			
Pair 1	**Pre - Post**	-26.87500	8.87412	2.21853	-12.114	15	.000

The conclusion obtained from the paired t-test is that there is a significant effect on the treatment given in the pre-test and post-test, it can be seen that sig (2-t) <0.05 with the difference in the pre-test and post-test values of 26.87. The results of problem-solving skills at the pre-test and post-test scores show the N-gain score as follows in Figure 2. Based on the N-gain results from the pre-test and post-test scores in each problem-solving indicator, the results were obtained with high and moderate N-gain criteria. On understanding the problem and devising a plan indicator, the N-gain results were obtained with a high criterion, and on the caring out out the plan and looking back indicator, the N-gain results were obtained with moderate criteria. These

results prove that there is a high difference in scores between the pre-test and post-test so that learning tools can improve problem-solving skills in the Lapindo mud phenomenon. Besides, students can solve problems and be able to evaluate according to the problems given (Purnamasari, 2017).

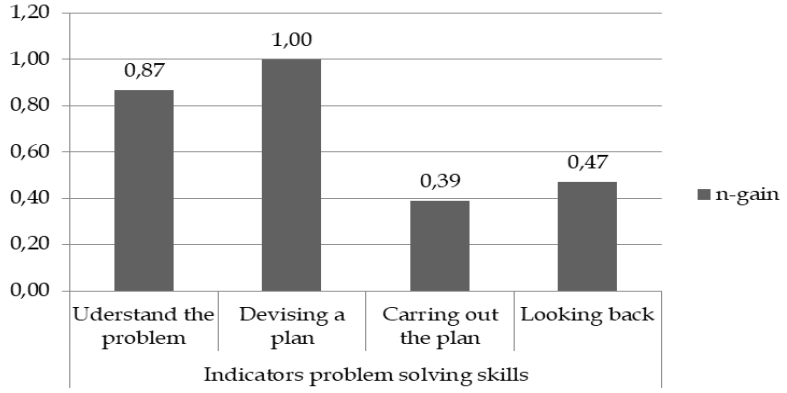

Figure 2. N-gain score problem-solving skills.

Laurie et al. (2016) suggest ESD skills contribute in many ways to quality education in primary and secondary schools. Teaching and learning change in all contexts when the curriculum includes sustainable content and ESD pedagogy promotes learning of the skills, perspectives, and values needed to foster sustainable societies. This suggests that ESD skills can effectively improve conceptual understanding and insightful problem-solving skills and environmental phenomena through science learning. To optimize the ESD program, it is necessary to develop ESD content knowledge because it is considered an important element in practice (Hudson, 2014), and it should become education priority which is in accordance with the emerging sustainable professional development (Ling, 2016). Although it has been introduced by UNESCO since 2005, the ESD program is not given serious attention to the development of science education programs in tertiary institutions. (Filho, 2018). ESD is very important to be implemented in education in Indonesia, because of natural disasters in Indonesia from geological factors and geographic location. ESD is expected to build community resilience in the face of change geographical phenomenon.

CONCLUSIONS

The effectiveness of ESD-based learning tools to improve problem-solving skills is evidenced by an increase in the score from pre-test to post-test with an N-gain of 0.68 in the moderate category. Students can improved problem-solving skills in the Lapindo mud phenomenon by integrating the liquid pressure material (Archimedes Law and Bernoulli's Law) with the ESD concept (social, ecological, and economic). In terms of ecology, Lapindo mudflow can be overcome by applying Bernoulli's Law. In the economic sector, the overflowing Lapindo mud can be used as a building material. This is studied in the material of Archimedes Law. In the social term, students can communicate the results of solving problems with the concept of ESD to the surrounding community. ESD learning tools can be used in other learning materials, provided that the material has a connection with ESD concepts (social, ecological, and economic). This ESD-based learning tool can be implemented in other sciencematerials,

provided that the materials includes evironmental phenomena releted to the concept of ESD (ecological, economic, and social). However, some teachers have not applied ESD-based learning because the teacher understands what is. ESD learning should be published in MGMP and pre-service PPG students considering that ESD is very influential on the global goals of 2030.

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***Dwita Dana Pradipta (Corresponding Author)**
State University of Surabaya
Postgraduate Programe, Continuing Program Development,
Jl. Unesa Lidah Wetan Surabaya, Indonesia
Email: dwita.18041@mhs.unesa.ac.id

Prof. Dr. Madlazim
State University of Surabaya
Postgraduate Programe, Continuing Program Development,
Jl. Unesa Lidah Wetan Surabaya, Indonesia
Email: madlazim@unesa.ac.id

Dr. Eko Hariyono
State University of Surabaya
Postgraduate Programe, Continuing Program Development,
Jl. Unesa Lidah Wetan Surabaya, Indonesia
Email: ekohariyono@unesa.ac.id