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HOW TO IMPROVE STUDENTS' ENVIRONMENTAL LITERACY ON PLASTIC WASTE ISSUES: PROBLEM-BASED FLIPPED CLASSROOM

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ABSTRACT

The research aimed to enhance students' comprehension of plastic waste concerns by implementing problem-based flipped classrooms, focusing on environmental literacy. Carried out on a cohort of 32 students using a one-group pre–test–post–test design, the study employed various data collection methods, including observation sheets, performance assessment rubrics, and environmental literacy assessment tools. The findings unveiled a commendable overall student engagement level, with a 95% activity rate, signifying a highly positive interpretation. Notably, students' environmental literacy exhibited advancements across knowledge, cognitive skills, and actionable behaviors. The calculated N-Gain value of 0.64 reflected substantial growth, falling within the medium interpretation range. Concerning the attitude facet, students garnered an average score of 80, with 79% expressing alignment with the prescribed attitudes, positioning them within the fairly good category. This underscores the students' positive stance toward environmental concerns. Significantly, implementing the problem-based flipped classroom model targeting plastic waste topics effectively enhanced students' environmental literacy, fostering a more comprehensive understanding of these critical issues.

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INTRODUCTION

The prevailing ecological issues linked to plastic waste predominantly stem from human activities that lack environmental consciousness [1]. Plastic, categorized as inorganic waste, comprises synthetic polymers formed by connecting recurring molecular units known as monomers [2]. Plastic has many advantages, like versatility, affordability, and durability, but plastic also has the disadvantage of being unable to decompose naturally. Plastics can break down into tiny particles called microplastics, which can end up in water bodies, soil, and even air [3]. Plastic takes 300-500 years to decompose naturally, so that plastic can cause damage to ecosystems in the future [4].

While plastic boasts advantages such as versatility, affordability, and longevity, its drawback lies in its inability to biodegrade naturally. Plastic materials can disintegrate into minute fragments called microplastics, disseminating into water bodies, soil, and even the atmosphere [3]. The natural decomposition of plastic requires an extensive 300-500 years, thus posing the potential to inflict ecological harm in the future [4].

The generation of plastic waste escalates nearly every year. In Indonesia alone, plastic waste quantities amounted to 804 tons/day in 2013 [5]. This surge in plastic waste production is attributed to population expansion and rapid economic growth. The upsurge in the global populace begets augmented demands for goods and services, often associated with plastic packaging, products, and materials [6].

Given their status as the forthcoming generation and future leaders, students are pivotal in tackling environmental issues, particularly plastic waste. Students' mindfulness can pave the way for a more sustainable tomorrow. Their enthusiasm, vigor, and commitment wield significant potential in addressing worldwide environmental dilemmas [7]. To harness awareness for tangible student actions concerning environmental challenges, environmental education must integrate practical measures, fostering behavioral transformations. Innovative learning models can optimize students' grasp of conceptual knowledge and environmental literacy regarding environmental concerns [8].

Environmental literacy is the ability of individuals to understand, interpret, and critically evaluate environmental issues, as well as to make informed and responsible decisions concerning the environment [9]. People can have good environmental literacy if they have the knowledge, skills, ability to prevent environmental problems, and a strong commitment to maintaining and improving environmental quality for future generations [10]. Therefore, environmental literacy needs to be integrated into the curriculum in schools to help students develop a well-rounded understanding of the environment, its challenges, and the importance of sustainable practices [11]

The attitude of caring for the environment can grow if students have knowledge related to human life. Polymers are chemistry concepts closely related to environmental issues [12]. However, in its application, the topic of polymer is considered a difficult topic for students to learn because learning about polymerization reactions and mechanisms can involve complex chemical concepts. Hence, students can apply the topic of polymer in daily life [7].

Therefore, a chemistry teacher must innovate in the learning process, including using a learning model that connects real-life problems with chemistry concepts so students can be directly involved in finding solutions to given environmental issues [13]. By directly observing environmental phenomena that occur in real life and focusing on making the subject matter relatable, teachers can help students overcome the perception that polymers are complex concepts to learn [14].

Problem-based learning is one of the learning models that can help improve students' environmental literacy. It has the advantage of learning focused on students by raising phenomena from human life, such as plastic waste [15]. The problem-based learning model has the characteristic of making problems a starting point for learning [16]. This model also provides an innovation because the problems presented are very close to students' lives, so students can easily find concepts and construct their knowledge [17].

The problem-based learning model can be combined with the flipped classroom method known as the problem-based flipped classroom (PBFC). Flipped classroom is a learning strategy that will encourage students to actively learn because the advantages of this method are not limited by space and time [18]. Problem-based learning will make students solve problems in class, and flipped classrooms will encourage students to study independently by creating a learning environment according to their style to motivate them to study optimally [19]. In a flipped classroom, students can participate in activities inside and outside the classroom, such as understanding the concept and studying, and in-class activities, such as completing assignments, discussing the concept that has not been understood, and solving problems [20].

Problem-based flipped classrooms can encourage more active student involvement in the learning process. In a flipped classroom, students take a greater role in independent learning, while in PBL, they have to collaborate in groups to solve complex problems [21]. Combining these two approaches can help build students' motivation and sense of responsibility for their learning [22]. This model makes it easy for students to access content at any time and helps students learn phenomena or problems in real life [23].

Based on Nurhakim's research stated that students' environmental literacy increased after learning using flipped classrooms on the impact of burning hydrocarbons [24]. Other studies have been conducted by Arnata et al., and the results show that applying the problem-based flipped classroom model can increase students' learning outcomes [25]. Other research shows increased environmental literacy and knowledge after applying problem-based learning models to environmental pollution material [26]. Based on the explanation above, the problem-based flipped classroom is expected to help students increase environmental literacy in all aspects, not just in knowledge aspects of material plastic waste issues.

METHOD

1. Research Design

The research employed a pre-experimental approach with a one-group pretest-posttest design. This type of design utilizes a single group for pretest and posttest evaluations without a control group [27]. This method focuses on assessing students' environmental literacy before and after treatment. In this case, the treatment involves implementing a problem-based flipped classroom to address plastic waste issues. This method is particularly suited for evaluating changes in environmental literacy within a single group context.

2. Participants

The study included 32 students from an Islamic school in Purwakarta. The sample selection utilized purposive sampling due to the presence of a class that hadn't undergone the topic of polymer instruction. This approach facilitated the selection of participants with relevant characteristics for the research, specifically those who hadn't received the polymer concept.

3. Research Instruments

The research employed learning descriptions and assessment instruments. Learning descriptions guided the problem-based flipped classroom activities and procedures throughout the research. Students followed these descriptions, and their activities were documented on an activity observation sheet. Assessment instruments included activity observation sheets, environmental literacy tests (pretest-posttest), questionnaires, and assessment rubrics. Rubrics were utilized to evaluate student activities during both in-class and out-of-class phases.

4. Validation and Reliability

Expert validation of the research instruments involved three Chemistry Education lecturers. The results demonstrated instrument readiness, albeit with slight adjustments needed in the pretest-posttest questions. Further recommendations were made to align questionnaire inquiries with environmental literacy aspects. After validation, the ecological literacy test components underwent reliability and validity testing. The test questions comprised 15 adapted multiple-choice questions, while the questionnaire contained 10 positive statements. Validity testing revealed ten valid and five invalid items within the test questions. Questionnaire validity was confirmed for all 10 statement items. Both test questions and questionnaires exhibited strong reliability with values of 0.784 and 0.933, respectively.

5. Data Analysis

Data analysis encompassed student activity observation and environmental literacy evaluation. Student activity sheets were scrutinized to gauge their involvement during the learning process. Scores of 1 were assigned for executed activities, while 0 denoted unperformed tasks. Cumulative scores were then converted to percentages. Environmental literacy analysis entailed t-test (paired samples) hypothesis testing, N-gain analysis, and questionnaire assessments. The paired sample t-test, facilitated by SPSS 29.0, compared environmental literacy before and after treatment within the same sample. N-gain analysis further examined literacy enhancement in various aspects. The environmental literacy questionnaire scores were derived by aggregating statement item scores, which were then averaged for each respondent and calculated for sub-indicators in the attitude aspect.

RESULTS AND DISCUSSION

1. Description of Student Activities

Learning with the problem-based flipped classroom model is carried out in five stages: problem orientation, organizing, guiding, developing and presenting results, analyzing and evaluating [23]. This learning stage occurs in three modified sessions: pre-class, in-class, and out-class [28]. In pre-class sessions, students will be directed to study independently, assisted by online learning media. In-class sessions will be more effective because students only need to discuss to solve the given problems. At the out-class session, students' learning abilities will be evaluated through group projects after the class.

During the problem initiation phase, students are instructed to engage in online learning using WhatsApp as a communication medium. The initial step involves students joining a designated WhatsApp group. Upon group enrollment, they are prompted to complete an online pretest to assess their existing knowledge. Following the pretest, students are given three videos and tasked with crafting summaries.

Table 1. Recapitulation of Connected Activities and Environmental Literacy

No.	Learning Stage Problem-Based Flipped Classroom		Environmental Literacy Aspect	Assessment Aspect (%)		Achievement
				Activity	Environmental Literacy	
1.	Problem Orientation	*Pre-Class*	Knowledge	94	87	Very good
2.	Organize	*In-Class*	Knowledge	100	84	Very good
3.	Guide		Cognitive Skills	100	81	Very good
4.	Developing and Presenting Results		Cognitive Skills	100	95	Very good
5.	Analyze and Evaluate	*Out-Class*	Attitudes and Actions	92	84	Very good

In the organizational phase, classroom-based learning occurs, wherein students gather for in-person sessions. As the learning process commences, students are grouped and directed to discuss the identified problems. In the initial discussion, students delve into a discourse regarding plastic waste, actively participating in conversations about the hazards posed by plastic waste and brainstorming diverse solutions.

In the guidance phase, students are instructed to scrutinize product images featuring plastic resin codes within a worksheet. They are guided to populate an observation table with details such as the item's name, plastic type, and suitability for food or beverage containers. Students respond to worksheet queries using various sources while observing products carrying plastic resin codes.

The subsequent phase involves developing and presenting outcomes, during which the entire group showcases the results derived from their worksheets. Active participation characterizes this stage, as all students proffer insights and respond to their peers' presentations. In the analysis and evaluation phase, students collaborate in groups to produce a video campaign themed around "plastic waste management." The video submission deadline is one week after the in-class learning activities. This phase occurs beyond classroom hours, as students create videos and share them on Instagram. After completing the video task, students are guided to undertake online post-test assessments and questionnaires.

Based on the results of observations at each stage of learning with the problem-based flipped classroom model, the percentage of student activity at all stages is 95%, with a very good interpretation. The average value of environmental literacy in working on student worksheets is 86, with a very good interpretation. The recapitulation of the connectedness of student activities and environmental literacy values at each stage of problem-based flipped classroom learning is described in Table 1.

2. Environmental Literacy Improvement Analysis

The improvement in students' environmental literacy can be seen from pretest-posttest questions and questionnaires. Improvement in environmental literacy was analyzed by testing the instrument hypotheses on environmental literacy test questions and calculating the N-gain value. Hypothesis testing was carried out using SPSS 29.0 software. Before testing the hypothesis, a normality test was carried out on the pretest and posttest. We can test with a paired samples t-test if the data is normal. We use a non-parametric test like the Wilcoxon test if the data is abnormal. The normality test chosen is the Kolmogorov-Smirnov test because this test is considered to have a good power to determine the distribution of data and is more efficient to use.

Table 2. Recapitulation of Normality Test Results

	Kolmogorov-Smirnov		
	Statistics	dF	Sig.
Pretest Environmental Literacy	0.141	32	0.105
Posttest Environmental Literacy	0.140	32	0.114

Table 2 shows that the pretest and posttest data are normally distributed based on the Kolmogorov-Smirnov normality test. The pretest significance value is 0.105 > 0.05. The posttest significance value is 0.141 > 0.05. Both data are normally distributed so that the hypothesis can be tested with the t-test. The chosen t-test is the paired sample t-test because this test is suitable for comparing the differences in environmental literacy in the same subject before and after being given treatment.

Table 3. Recapitulation of T-Test Results

	Paired Samples Test							
	Means	std. Deviation	std. Error Means	95% Confidence Interval of the Difference		t	dF	Sig. (2-tailed)
				Lower	Upper			
Pretest-Posttest	-20,313	4,741	0.838	-22,022	-18,603	-24,23	31	0.000

Table 3 shows that the significance value is 0.000 < 0.05. Then H_0 is rejected, and H_a is accepted. So, it can be concluded that there is an increase in students' environmental literacy after implementing a problem-based flipped classroom on plastic waste issues. The improvement in environmental literacy can be measured using the N-gain calculation. Interpretations of the N-gain score are presented in Table 4.

Table 4. Interpretation of N-Gain Score

Limitation	Interpretation
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

In determining the N-gain score, students are divided into three groups according to their initial abilities. The group will make it easier to observe an improvement in environmental literacy in each group. Students' environmental literacy significantly increases if they get an N-gain score of more than 0.7. The results of the calculation of N-gain on the environmental literacy test are presented in Table 5.

Table 5. The Calculation Results N-Gains

Students' Group	Pretest Average Score	Posttest Average Score	N-Gains	Interpretation
Upper	80	96	0.79	High
Middle	65	86	0.60	Medium
Lower	50	75	0.50	Medium
Average			0.64	Medium

Based on Table 5, the environmental literacy of all groups has increased with medium interpretation. This is shown by the N-gain value of 0.64. The increase in environmental literacy in each aspect of environmental literacy can be seen from calculating the N-gain value for each aspect. The results of the N-gain calculation for each environmental literacy aspect are presented in Table 6. Students' attitudes are measured using an environmental literacy questionnaire. The results of the assessment of the average student attitude value on each attitude aspect are presented in Table 7.

Table 6. The Calculation Results N-Gain Environmental Literacy Aspect

Environmental Literacy Aspect	N-Gains Students' Group			Average *N-Gains*	Interpretation
	Upper	Middle	Lower		
Knowledge	0.90	0.63	0.30	0.61	Medium
Cognitive Skills	0.50	0.57	0.75	0.61	Medium
Action	1.00	0.58	0.50	0.69	Medium
Average				0.64	Medium

Table 7. Results of Environmental Literacy Attitudes Questionnaire Assessment

Environmental Literacy (Attitude Aspect)	Group Attitude Value			Average Attitude Score	Interpretation
	Upper	Middle	Lower		
Environmental Care	81	81	88	83	Very good
Aware of Environmental Sustainability	88	84	83	82	Very good
Actions Against the Environment	74	73	75	75	Good
Average				80	Very good

3. Improvement in Knowledge Aspect

Based on Table 6, the improvement in knowledge aspect that occurred in the upper and middle groups was higher than the lower group because of activities in pre-class sessions, such as watching videos and making resumes that could provide space for students to learn according to their learning styles. According to Chang et al., learning using a combination of online and offline classes can create fun learning so students never feel bored with traditional methods [29].

Videos are packaged with a short duration using YouTube media to make it easier for students to understand the concept provided [30]. Learning videos containing environmental problems effectively increases students' environmental knowledge [31]. Animation videos enable the teachers to interact with students in reviewing the learning subjects and aim to develop more active, interactive, and quality learning, such as providing students with a more complete and more flexible learning environment to be able to build students' motivation and can increase student's knowledge [32].

The limited knowledge among the lower-performing group is purportedly attributed to their struggles in comprehending the learning materials, which consequently reflected in their post-test scores. A deficiency in motivation to engage with the learning process may further contribute to the restrained growth in their knowledge. Scholars have indicated that students' motivation wanes when not actively participating in dynamic learning activities [33]. This underscores the significance of fostering an interactive and engaging learning environment to bolster understanding and motivation among students, particularly those encountering difficulties [33].

Overall, students' knowledge increased after being given problem-based flipped classroom learning. This is in line with the results of Siddiq et al. that learning by using a problem-based learning model affects environmental literacy, especially in knowledge, because of the convenience and interest of students in learning the content provided [26]. In addition, using technology also affects increasing students' knowledge because using the right technology will increase knowledge to solve environmental problems [34]. According to Garcia Martinez & Torregrosa, flipped classrooms are suitable for chemistry lessons because students' knowledge will be developed before learning begins. So, teachers must execute learning in class more deeply [35].

4. Improvement in the Cognitive Skills Aspect

Based on Table 6, the cognitive skills of the upper and middle groups increased with medium interpretation because some students already had skills in analyzing, so the comparison of pretest and posttest scores in the upper and medium groups did not show a high increase as in the lower group. This shows that students in the upper and middle groups have used their critical thinking skills to analyze environmental problems. When students can critically analyze the information, they are more likely to develop a deeper understanding of the topic. Saputra et al. said that solving environmental problems requires critical thinking skills such as analyzing and evaluating [36]. Critical thinking enables students in upper and middle groups to break down complex problems into smaller components, analyze the causes and effects, and understand the relationships between different factors contributing to the issue.

The cognitive aptitude of students in the lower tier demonstrated a marked improvement, evident from the test outcomes displaying enhanced skills among previously less proficient students. The introduction of problem-centric learning methodologies, wherein students directly engage with presented challenges, played a pivotal role in this augmentation. This approach, encouraging active involvement in problem identification and analysis, was an effective strategy in heightening students' motivation to learn. Literature posits that interactive learning experiences, particularly those addressing real-world environmental issues, can substantially enhance students' grasp of environmental literacy [37].

Furthermore, integrating genuine problems into the learning process has been acknowledged as a means to cultivate valuable skills [38]. Additionally, incorporating discussion activities during the learning planning and guidance phases notably impacted cognitive skill enhancement. Group discussions served to steer students toward more active cognitive engagement [39]. Employing a problem-based learning framework empowered students to think critically, thus fostering the capacity to formulate answers and solutions to intricate problems. This approach also facilitated experiential learning, fostering connections that offer potential solutions to anticipated challenges [40]. The amalgamation of interactive learning, real-world challenges, and discussions collectively contributed to the cognitive skill progression observed among the lower-performing students.

After partaking in the problem-based flipped classroom approach, evident enhancement was observed in students' cognitive capabilities, marking a moderate level of interpretation. Nonetheless, this increase in cognitive skills might not have been as pronounced due to several factors. As previously highlighted, students' pre-existing understanding of environmental issues might not have been effectively translated into adept problem-solving abilities [41].

Building on this premise, the significance of knowledge in bolstering students' proficiency in addressing environmental challenges has been underscored [42]. This underscores the importance of educators fostering activities that can elevate students' cognitive skills, which in turn could improve their practical problem-solving aptitude. This notion aligns with the observation that the problem-based flipped classroom model can potentially encourage students to participate in problem-solving endeavors actively. The students' existing knowledge base, acquired through instructional videos, is a valuable resource. [43].

5. Improvement in Action Aspect

The action facet correlates closely with knowledge and cognitive skills. A notable advancement in students' knowledge and aptitude often translates into a propensity for active environmental involvement. As highlighted by prior research, an elevated cognitive understanding aligns with positive behavioral inclinations. Individuals with robust cognitive knowledge and competencies tend to grasp environmental sustainability's significance inherently. This comprehension, in turn, propels them toward concrete actions aimed at preserving and safeguarding the environment. This symbiotic relationship underscores the integral role that enhanced comprehension and proficiency in environmental matters play in motivating individuals to engage meaningfully in endeavors geared toward environmental conservation and protection [44].

Knowledge provides an important basis for developing skills and taking effective action. Without a good understanding of environmental problems, it is difficult for students to identify the right solutions or take the right actions. Skills enable students to take more effective and informed action. Skills in analyzing data, planning solutions, and communicating enable students to make real changes in their behavior and drive positive change in the environment. Through real action in the environment, students gain practical experience that can strengthen their knowledge and skills. This action can motivate students to continue learning and increase their understanding of environmental issues.

Based on Table 6, the average N-gain value for knowledge, cognitive skills, and action aspects is 0.64 with a medium interpretation. This shows that students' environmental literacy has increased quite well after being given learning using the problem-based flipped classroom model. This is also found in the research by Anggraini et al., which shows that the knowledge and skills of students increase in the medium category [34].

The hypothesis test results also evidence the improvement of environmental literacy. Based on the hypothesis test, it was found that students' environmental literacy increased after learning with the problem-based flipped classroom model. It was proven from the hypothesis test results, which stated that H_o was rejected and H_a was accepted. Arnata et al. said combining problem-based learning with flipped classrooms can improve student learning outcomes [25].

6. Improvement in Attitude Aspect

The questionnaire results showed that students' positive attitudes had begun to be instilled in each student, although some students still had difficulty reducing plastic use. This is shown from the score of student responses, which agreed to 10 positive statement points by 79%. Table 7 shows that students already have an attitude of caring for the environment and being aware of environmental sustainability. Some students cannot take concrete action to overcome the problem of plastic waste, especially in reducing the use of plastic because plastic is always attached to humans, and the reduction of plastic must be done in stages so that students can get used to reducing plastic use.

Hence, the cultivation of positive behavior remains pivotal in daily life. Active participation allows students to witness firsthand the ramifications of their actions on the environment and the challenges it faces. This direct involvement has the potential to ignite empathy and foster a comprehensive comprehension of the significance of conservation and sustainable practices. Correspondingly, previous research by scholars has highlighted that engaging students directly in environmental care activities serves to amplify positive behavior [45]. This notion aligns with other research findings, suggesting that direct exposure to environmental problems during learning can significantly shape and enhance students' constructive attitudes. In essence, this underscores the potency of experiential learning in shaping an affirmative perspective toward environmental issues [46].

7. Synthesis Of Findings

The research outcomes reveal distinct N-gain scores for each achievement group, corresponding to diverse interpretations across various environmental literacy aspects. These findings underscore the potential of the problem-based flipped-classroom approach to elevate environmental literacy for the entire cohort. The model's efficacy in enhancing environmental literacy across all facets is attributed to its capacity to capture students' curiosity and drive to learn. These outcomes harmonize with previous studies, demonstrating that the amalgamation of problem-based learning and flipped classroom methodologies stimulates students to engage with chemical concepts beyond classroom hours. This dynamic approach prompts active discussions, fostering an engaging and enjoyable learning environment [25].

Correspondingly, previous research has shown that a flipped classroom approach can enhance environmental literacy due to its ability to inject dynamism and reduce monotony in the learning process [24]. The outcomes of the questionnaire assessment substantiate that the problem-based flipped classroom method not only enhances students' environmental literacy in terms of knowledge and skills but also cultivates positive attitudes and actionable behaviors towards the environment. Interestingly, these results diverge from another study's findings, which suggest that the impacts of the problem-based learning model predominantly influence the knowledge aspect of environmental literacy [26].

Enhancing environmental literacy necessitates a constructivist approach to learning, such as problem-based learning, which empowers students to construct their knowledge by actively engaging with real-world issues [47]. Consequently, through direct observation and interaction with authentic environmental challenges, students are poised to augment their knowledge and foster positive attitudes toward environmental concerns. This approach is rooted in the premise that practical encounters with real-life environmental problems can profoundly enrich students' understanding and perspectives related to the environment [48].

CONCLUSION

Based on the results and data analysis, it was found that the average percentage of student activity implementation was 95%, with a very good interpretation. These results indicate that students can take part in learning with the problem-based flipped classroom model very well. The environmental literacy of students after being given learning using the problem-based flipped classroom model has increased significantly. Overall, environmental literacy increases with a medium interpretation with an N-gain value of 0.64. The environmental literacy attitude aspect gets an average score of 80 with a very good interpretation, and the percentage of students' attitudes that agree is 79%. Internalized attitudes and actions towards the environment are suggested through programs or projects to overcome the problem of plastic waste by using other learning models and need to be carried out by students continuously so that they become part of good character for students. For further research, it is hoped that we can apply the problem-based flipped classroom model to other chemical concepts and develop this model into higher-order thinking skills.

REFERENCES

[1] Segara, "*Education for Sustainable Development* (ESD) Sebuah Upaya Mewujudkan Kelestarian Lingkungan," *SOSIO Didakt. Soc. Sci. Educ. J.*, vol. 2, no. 1, pp. 22–30, 2015, doi: 10.15408/sd.v2i1.1349.

[2] A. N. Shofi and F. D. Anindita, "Efektivitas Degradasi Plastik Oleh *Aspergillus Terreus*," in *Proceeding Seminar Nasional IPA XII*, pp. 127-133, 2022.

[3] L. Astriani, Mulyanto, Bahfen, and Dityaningsih, "Meningkatkan Ekonomi Masyarakat Melalui Produk Kreatif dari Pengolahan Sampah Plastik," *Proc. Inst. Civ. Eng. Resour. Manag.*, vol. 1, no. 1, pp. 15–28, 2021.

[4] A. N. C. Saputro and A. L. Ovita, "Synthesis and Characterization of Bioplastic from Chitosan-Ganyong Starch (Canna edulis)," *J. Kim. Dan Pendidik. Kim.*, vol. 2, no. 1, pp. 13–21, 2017, doi: 10.20961/jkpk.v2i1.8526.

[5] D. Rachmadena, M. Faizal, and M. Said, "Conversion of Polypropylene Plastic Waste into Liquid Fuel with Catalytic Cracking Process using Al2O3 as Catalyst," *Sci. Technol. Indones.*, vol. 8, no. 3, pp. 694–700, 2018, doi: 10.18517/ijaseit.8.3.2586.

[6] N. W. Rustiarini, I. M. Legawa, Y. Adnyana, and T. D. Setyono, "Pengolahan Sampah Plastik Menjadi Kerajinan Tangan Bernilai Ekonomi," *JURPIKAT (Jurnal Pengabdi. Kpd. Masyarakat)*, vol. 2, no. 2, pp. 10–21, 2021, doi: 10.37339/jurpikat.v2i2.502.

[7] M. Larasati, A. Fibonacci, and T. Wibowo, "Pengembangan Modul Berbasis *Problem Based Learning* Pada Materi Polimer Kelas XII SMK MA'ARIF NU 1 SUMPIUH," *J. Tadris Kim.*, vol. 3, no. 1, pp. 32–41, 2018, doi: 10.15575/jtk.v3i1.2038.

[8] S. P. W. Lubis, I. G. P. Suryadarma, Paidi, and B. E. Yanto, "The Effectiveness of Problem-Based Learning with Local Wisdom Oriented to Socio-Scientific Issues," *Int. J. Instr.*, vol. 15, no. 2, pp. 455–472, 2022, doi: 10.29333/iji.2022.15225a.

[9] M. H. Irawati, R. C. Khuluq, L. Mardiyanti1, I. Iskandar, and S. D. Rahmatus, "The Relationship Between Self-Efficacy And Environmental Literacy Of High School Students," in *AIP Conference Proceedings*, 2023, p. 2569, doi: 10.1063/5.0112740.

[10] D. Astuti and T. Aminatun, "Student's Environmental Literacy Based On Adiwiyata And Non-Adiwiyata At Senior High School In Sleman, Yogyakarta," *J. Pendidik. Biol. Indones.*, vol. 6, no. 3, pp. 375–382, 2020, doi: 10.22219/jpbi.v6i3.13629.

[11] I. Farida, Hadiansah, Mahmud, and A. Munandar, "Project-based Learning Design for Internalization of Environmental Literacy with Sslamic Values," *J. Pendidik. IPA Indones.*, vol. 6, no. 2, pp. 277–284, 2017, doi: 10.15294/jpii.v6i2.9452.

[12] F. Triani, Asrizal and Usmeldi, " Meta Analisis Pengaruh Penerapan STEM terhadap Hasil Belajar Fisika Peserta

Didik," *Jurnal Inovasi dan Pembelajaran Fisika,* vol. 9, no. 1, pp. 99-107, 2022, doi: 10.36706/jipf.v9i1.16507.

[13] Ristiyani and Bahriah, "Analisis Kesulitan Belajar Kimia di SMAN X Kota Tangerang Selatan," *Penelit. dan Pembelajaran IPA*, vol. 2, no. 1, p. 18, 2016, doi: 10.30870/jppi.v2i1.431.

[14] D. Rahmawati, A. Purwanto, and A. Rahman, "Pengembangan Modul Pembelajaran Kimia Berbasis Permasalahan Lingkungan dengan Pendekatan *Problem Based Learning* pada Materi Kelarutan dan Hasil Kali Kelarutan," *JRPK J. Ris. Pendidik. Kim.*, vol. 9, no. 2, pp. 112–121, 2019, doi: 10.21009/jrpk.092.08.

[15] R. Tyas, "Kesulitan Penerapan *Problem Based Learning* dalam Pembelajaran Matematika," *Tecnoscienza*, vol. 2, no. 1, pp. 43–52, 2017.

[16] R. S. Hanifah, N. Windayani, and I. Helsy, "Pengembangan Lembar Kerja Berbasis Masalah Pembuatan Sabun Cair Antimikroba Kulit Jeruk Lemon *(Citrus Limon)*," *Semin. Nas. Tadris Kim.*, vol. 2, pp. 391–409, 2021.

[17] M. N. Aufa, R. Iriani, P. Saadi, M. Hasbie, M. A. Fitri, and A. Yunita, "Module Development With Problem-Based Learning (PBL) Model Based On Environmental Wetland To Increase Students' Learning Outcomes," *J. Kim. Dan Pendidik. Kim.*, vol. 5, no. 2, pp. 201–210, 2020, doi: 10.20961/jkpk.v5i2.40451.

[18] K. A. Imania and S. H. Bariah, "Pengembangan *Flipped Classroom* Dalam Pembelajaran Berbasis *Mobile Learning* Pada Mata Kuliah Strategi Pembelajaran," *J. Petik*, vol. 6, no. 2, pp. 45–50, 2020, doi: 10.31980/jpetik.v6i2.859.

[19] M. Chris, P. Murphy, and Muntean, "Investigating Flipped Classroom and Problem-Based Learning in a Programming Module For Computing Conversion Course," *Educ. Technol. Soc.*, vol. 21, no. 4, pp. 232–247, 2018.

[20] M. Paristiowati, E. V. Nanda, N. A. P. Hasibuan, and M. Z. Ilmana, "Analysis of Students' Critical Thinking Skills by Applying Flipped Classroom Learning Model by Using Powtoon Application on the Topic of Salt Hydrolysis," *J. Kim. Dan Pendidik. Kim.*, vol. 7, no. 3, pp. 379–393, 2022, doi: 10.20961/jkpk.v7i3.67802.

[21] R. . Qader and F. . Arslan, "The Effect of Flipped Classroom Instruction in Writing: a Case Study with Iraqi EFL Learners," *Teach. English with Technol.*, vol. 19, no. 1, pp. 36–55, 2019.

[22] M. E. A. Saputra and M. Mujib, "Efektivitas Model *Flipped Classroom* Menggunakan Video Pembelajaran Matematika terhadap Pemahaman Konsep," *Desimal J. Mat.*, vol. 1, no. 2, p. 173, 2018, doi: 10.24042/djm.v1i2.2389.

[23] I. L. Kurniawati, P. Setyosari, I. W. Dasna, and H. Praherdhiono, Problem Based Flipped Classroom *Dalam Pembelajaran Sains*. Sleman: Deepublish, 2022, ISBN: 9786230238956.

[24] R. Khumairah, A. Sundaryono and D. Handayani, " Pengaruh Model Pembelajaran Flipped Classroom terhadap Hasil Belajar Kimia Siswa pada Materi Larutan Penyangga di SMAN 5 Kota Bengkulu," *Alotrop,* vol. 4, no. 2, pp. 92-97, 2020, doi: 10.33369/atp.v4i2.13832.

[25] I. W. Arnata, I. B. P. Mardana, and I. N. P. Suwindra, "Pengaruh Model Pembelajaran *Problem Based Flipped Classroom* Terhadap Keterampilan Pemecahan Masalah Siswa Kelas XI IPA," *J. Pendidik. Fis. Undiksha*, vol. 10, no. 1, p. 36, 2020, doi: 10.23887/jjpf.v10i1.26723.

[26] M. N. Siddiq, B. Supriatno, and Saefudin, "Pengaruh Penerapan *Problem Based Learning* Terhadap Literasi Lingkungan Siswa SMP pada Materi Pencemaran Lingkungan,"

Assim. Indonesia. J. Biol. Educ., vol. 3, no. 1, pp. 18–24, 2020, doi: 10.17509/aijbe.v3i1.23369.

[27] S. Arikunto, *Prosedur Penelitian Suatu Pendekatan Praktik*. Jakarta: Rineka Cipta, 2010, ISBN: 9789795180180.

[28] L. Yu, Y. Lia, Y. Lana, and H. Zheng, "Impacts Of The Flipped Classroom On Student Performance And Problem-Solving Skills In Secondary School Chemistry Courses," *Chem. Educ. Res. Pract.*, 2023, doi: 10.1039/D2RP00339B.

[29] Y.-H. Chang, Y.-C. Yan, and Y.-T. Lu, "Effects of Combining Different Collaborative Learning Strategies with Problem-Based Learning in a Flipped Classroom on Program Language Learning," *Sustainability*, vol. 14, no. 9, p. 5282, 2022, doi: 10.3390/su14095282.

[30] Rubiati and Sriwaty, "Penerapan Model Inquratif dalam Pembelajaran Menulis Tes Biografi Berbantuan Media Film," *Indones. J. Educ. Dev.*, vol. 1, no. 1, pp. 28–44, 2020, doi: 10.5281/zenodo.3760432.

[31] M. D. Agustina, K. F. Nur, and M. N. Hudha, "Pengembangan Video Pembelajaran (Animasi) Lingkungan Untuk Meningkatkan Literasi Lingkungan Siswa Tentang Topik Hemat Energi," *Exp. J. Sci. Educ.*, vol. 2, no. 1, pp. 1–10, 2022, doi: 10.18860/experiment.v2i1.13236.

[32] Marlina and Riyanto, "Developing Animation Video-Based Demonstration Experiments On The Topic Solubility And Solubility Product," *J. Kim. dan Pendidik. Kim.*, vol. 6, no. 2, pp. 163–172, 2021, doi: 10.20961/jkpk.v6i2.52044.

[33] J. Murtini, W. S. Utami, and E. Budianto, "Penerapan Model Pembelajaran *Blended Learning* Dengan Media Sway Pada Materi Peta Untuk Meningkatkan Hasil Belajar Siswa Kelas X Ilmu Sosial 1 SMA Negeri 3 Jombang Tahun Pelajaran 2018/2019," *J. Educ. Dev.*, vol. 9, no. 1, pp. 314–318, 2021.

[34] N. Anggraini, K. Nazip, S. Amizera, and E. Destiansari, "Penerapan Model *Problem Based Learning* Berbasis STEM Menggunakan Bahan Ajar Realitas Lokal Terhadap Literasi Lingkungan Mahasiswa," *BIOEDUSAINS J. Pendidik. Biol. dan Sains*, vol. 5, no. 1, pp. 121–129, 2022, doi: 10.31539/bioedusains.v5i1.3589.

[35] J. G. Martinez and E. S. Torregrosa, *Chemistry Education : Best Practices, Opportunities and Trends*. Germanry: Wiley-VCH, 2015, ISBN: 9783527336050.

[36] M. D. Saputra, S. Joyoatmojo, D. K. Wardani, and K. Sangka, "Developing Critical-Thinking Skills through the Collaboration of Jigsaw Model with Problem-Based Learning Model," *Int. J. Instr.*, vol. 12, no. 1, pp. 1077–1094, 2019, doi: 10.29333/iji.2019.12169a.

[37] Ozsoy, Ertepinar, and Saglam, "Can Eco-Schools Improve Elementary School Students Environmental Literacy Levels?," *Asia-Pasific Forum Sci. Learn. Teach.*, vol. 13, no. 2, pp. 1–25, 2012.

[38] I. Al-Fikry, Y. Yusrizal, and M. Syukri, "Pengaruh Model *Problem Based Learning* Terhadap Kemampuan Berpikir Kritis Peserta Didik Pada Materi Kalor," *J. Pendidik. Sains Indones.*, vol. 6, no. 1, pp. 17–23, 2018, doi: 10.24815/jpsi.v6i1.10776.

[39] A. Wang *et al.*, "Efectiveness Of A Combined Problem-Based Learning And Fipped Classroom Teaching Method In Ophthalmic Clinical Skill Training," *BMC Med. Educ.*, vol. 22, no. 1, p. 487, 2022, doi: 10.1186/s12909-022-03538-w.

[40] H. R. Widarti, D. A. Rokhim, Munzil, and N. Zakia, "The Effect Of Integrated Instagram And Tiktok Learning Media With PBL Learning Model On Increasing Student

Learning Outcomes On The Topic Of Qualitative Analysis Of Cation," *J. Kim. dan Pendidik. Kim.*, vol. 7, no. 3, pp. 394–402, 2022, doi: 10.20961/jkpk.v7i3.6703.

[41] A. N. M. Aprilianti and Suratsih, "Pengaruh Implementasi Program Adiwiyata Terhadap Literasi Lingkungan Peserta Didik SMA Negeri 10 Yogyakarta," *J. Edukasi Biol.*, vol. 9, no. 1, pp. 46–62, 2023, doi: 10.21831/edubio.v9i1.18759.

[42] Prastiwi, Daiana, and Rizhal, "Hubungan Antara Literasi Ekologi dengan Kemampuan Memecahkan Masalah Lingkungan di Sekolah Adiwiyata Kota Tangerang," *J. Pendidik. Mat. dan IPA*, vol. 11, no. 1, pp. 47–61, 2020, doi: 10.26418/jpmipa.v11i1.31593.

[43] W. F. Sinmas, C. Sundaygara, and K. B. Pranata, "Pengaruh PBL Berbasis *Flipped Class* Terhadap Prestasi," *RAINSTEK J. Terap. Sains dan Teknol.*, vol. 1, no. 3, pp. 14–20, 2019, doi: 10.21067/jtst.v1i3.3730.

[44] Zheng, Wang, and Zhang, "Effects Of Environmental Cognition And Environmental Attitude On Environmental Behavior Of Ecotourism," *Ekoloji*, vol. 27, no. 106, pp. 1743–1749, 2018.

[45] R. Yusuf and I. Fajri, "Differences In Behavior, Engagement And Environmental Knowledge On Waste Management For Science And Social Students Through The Campus Program," *Heliyon*, vol. 8, no. 2, 2022, doi: 10.1016/j.heliyon.2022.e08912.

[46] N. Anggraini and K. Nazip, "Kemampuan Literasi Lingkungan Mahasiswa Pendidikan Biologi Menggunakan Skor NELA," *J. Educ. Action Res.*, vol. 6, no. 4, pp. 552–557, 2022, doi: 10.23887/jear.v6i4.46975.

[47] W. M. Widianingsih, P. Karyanto, and B. A. Prayitno, "Pembelajaran Lingkungan melalui Pengembangan Subjek Spesifik Pedagogi Berbasis *Problem Based Learning* untuk Menguatkan Literasi Lingkungan Siswa Kelas X MIA SMA," *Proceeding Biol. Educ. Conf.*, vol. 14, no. 1, pp. 441–448, 2017.

[48] P. Rahmah, Lubis, and Festiyed, "Analisis Buku Ajar IPA SMP Kelas VIII Berdasarkan Pada Literasi Lingkungan," *Pillar Phys. Educ.*, vol. 12, no. 3, pp. 601–608, 2019, doi: 10.24036/7746171074.