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Research Article

The Influence of Green Chemistry Activities on Students' Environmental Care Attitudes

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Abstract
This study aims to investigate the effect of green chemistry activities on students' environmental care attitudes. A quasi-experimental with a pretest-posttest control group design was used in this study. The participants were 44 eleventh-grade students at a public school in West Java, Indonesia. Two intact classes were randomly assigned to the control group (n=19) and the experimental group (n=25). Control group students carried out traditional experiments, while experimental group students carried out green chemistry experiments. The data obtained were analyzed using independent samples t-test and paired samples t-test. The results of the independent samples t-test (α=5%) show that the p values obtained for the pretest and posttest scores are 0.189 and 0.037, respectively. In addition, the results of the paired samples t-test indicated that the p-values for the control and experimental groups were 0.349 and 0.000, respectively. This shows that there is a significant difference in the environmental care attitude score between the two groups in favor of the experimental group. The experimental group also showed a greater increase in scores than the control class after treatment. It can be concluded that green chemistry experiments and activities are effective in promoting the environmental care attitudes of eleventh-grade students on the topic of acids and bases. It is suggested to teachers use the green chemistry curriculum on other topics to improve student learning.

Keywords: Acid-base titrations, environmental care attitudes, green chemistry experiments

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1. INTRODUCTION

Chemicals are extensively utilized across various sectors of daily life, including industry, agriculture, and households. The use of pesticides, cleaning products, and other chemicals is unavoidable. However, this widespread use can lead to environmental issues such as ozone depletion, pollution, climate change, and contamination of water, soil, and air (Rockström et al., 2009). These environmental problems are further aggravated by the general public's low level of environmental awareness. Environmental care is defined as actions that consistently prioritize the prevention and repair of environmental damage (Asmani, 2013). The Ministry of Environment (Kamilah, 2013) stated that the results of calculations regarding the concern of the Indonesian people for the environment were only 57%. Previous studies (e.g., Fitriati et al. 2019; Hafida & Wahid, 2018; Rohweder, 2004) also stated that students' environmental awareness tended to be low.

Various environmental problems that occur today are mostly caused by human intervention, so natural improvements alone will not be able to solve environmental problems. Thus, the character in humans must be improved to prevent environmental problems and natural damage. Instilling an attitude of caring for the environment must be emphasized again so that future generations can still feel the benefits provided by nature (Priyanto et al., 2013). Therefore, it is necessary to apply an effective method to increase environmental care attitudes and reduce environmental problems.

United Nations (1992) mentioned in Agenda 21, that formal and non-formal education is a very important medium in promoting public awareness in overcoming environmental problems. Education is considered to be able to instill an attitude of environmental awareness. Marshall et al. (2017) stated that education can foster behavior that shows awareness of the environment in each individual. Koulougliotis et al. (2021) also stated that integrating the principles of green chemistry into the curriculum can contribute to promoting awareness of the environment in students so that an environmentally responsible society is formed.

Green chemistry in education is a learning approach that prioritizes human safety and environmental sustainability, guided by 12 principles that are expected to be a solution to various environmental problems as well as occupational safety and security (Wahyuningsih & Rohmah, 2017). The purpose of implementing green chemistry in education focuses on forming people into responsible individuals (Haack & Hutchison, 2016). According to Wardencki et al. (2005), green chemistry is an appropriate medium for explaining and promoting sustainable development that can be carried out in the classroom. This is because in teaching green chemistry, it is explained the relationship between the material being studied and everyday life (Braun et al., 2006), green chemistry provides space for students to deal with environmental problems and global environmental problems (Levy et al., 2005).

Chemistry learning is closely related to experimental activities. However, chemical experiments are seen as something dangerous and have a risk to work safety (Imamkhasani, 1990). The use of hazardous chemicals not only threatens the safety of its users, but also the surrounding environment. The use of these hazardous chemicals is certainly unavoidable when conducting chemical experiments (Subamia et al., 2019). Some chemicals can cause harmful effects directly or in a single exposure, such as nitric acid which is corrosive, while other chemicals can cause harmful effects in the future or after continuous long-term exposure, such as chloromethyl, dichloromethane, and other chemicals that are carcinogenic (Suharto, 2013).

In Indonesia, chemical experiments that are usually carried out at the high school level currently use many materials that are not environmentally friendly, such as experiments on the law of conservation of mass and chemical equilibrium using $Pb(NO_3)_2$, KI, $FeCl_3$, and KSCN (Redhana, 2014). These materials can have negative effects on the health of teachers and students, as well as the environment. Thus, applying the principles of green chemistry to chemical experiments can be a good solution to create safer experimental conditions, compared to the traditional experimental atmosphere (Burmeister et al., 2012). Green chemistry experiments aim to reduce hazardous waste by substituting dangerous materials with safer alternatives for both humans and the environment (Mohammed & Errayes, 2020). These experiments are conducted as part of green chemistry, which seeks to minimize waste and reduce the use of harmful chemicals. Essentially, green chemistry focuses on the efficient creation and utilization of chemical products to ensure safety and environmental sustainability (Redhana et al., 2020). The principles of green chemistry are highly relevant and effective in promoting pro-environmental attitudes (Karpudewan et al., 2012b). Therefore, by integrating green chemistry principles into chemical experiments, it is hoped that students will develop a greater sense of environmental care, contributing to a more sustainable future (Eilks & Rauch, 2012).

In its application, experiments that apply the principles of green chemistry generally use materials that are safe, inexpensive, and easy to obtain in everyday life. For example, betadine is used to treat wounds and vitamin C is used as a supplement (Redhana et al., 2020; Lestari & Diana, 2018). The use of safe and environmentally friendly materials during lab activities is reported to be able to increase awareness and action in environmental preservation (Taha et al., 2019), increase understanding of relevant chemical concepts, attitudes, motivation, and pro-environmental values (Karpudewan et al., 2012a), and in turn increases students' self-efficacy, task scores, and interest in learning chemistry (Karpudewan et al., 2013), promotes learning motivation (Lokteva, 2018), and improves critical thinking skills (Sudarmin et al., 2019). Apart from being safe for teachers and students when used in experiments, these materials are also environmentally friendly so they do not cause environmental problems such as pollution (Merta, 2020).

Acids and bases are one of the main topics in chemistry. Acid-base titration experiments that are usually carried out in schools use synthesis indicators such as phenolphthalein (PP). Synthesis indicators such as PP, methyl orange, and phenol red are quite expensive. This indicator turns out to be not only dangerous for the health of its users but also for the environment because this indicator is a pollutant (Lavanya et al., 2018). In accordance with the principles of green chemistry, the use of synthetic indicators can be replaced with natural indicators because they are cheaper and not harmful to the environment and users (Abugri et al., 2012). In addition, students are expected to be more enthusiastic in participating in experiments because they use natural materials that can be found around them.

Natural indicators can be made by extracting natural ingredients. Compounds that can be used as indicators in acid-base titrations are compounds that can give different color changes at various pHs. The use of natural materials for titration indicators is based on the content of color pigments found in plants. Color pigments or anthocyanins can change color due to changes in the degree of acidity (pH). Anthocyanins tend to be colorless in neutral conditions and change color to red in acidic conditions ($pH<3$), whereas in alkaline conditions ($pH>10$) they will change color to green (Astuti & Wiyantoko, 2018). Examples of plants that contain anthocyanins are butterfly pea flowers and Dayak onions.

The butterfly pea flower (*Clitoria ternatea L*) is a plant that contains anthocyanin which gives purple color to the flower crown. According to Astuti and Wiyantoko (2018), butterfly pea flower extract can be used as a natural indicator of acid-base titrations because it shows color changes in acidic and basic conditions. Butterfly pea flower extract has a similar pH trajectory with phenolphthalein (PP) so it can be used as a substitute for PP indicators. In this study, it was found that the extract of the butterfly pea flower tends to have a purplish-blue color in acidic conditions, whereas in alkaline conditions the extract tends to have a green color. In addition, the Dayak onion (*Eleutherine americana Merr.*) is a typical plant originating from West Kalimantan, Indonesia. According to a study conducted by Rahmalia et al. (2020), Dayak onion extract contains flavonoids, phenolics, and anthocyanins. The stability of the color of the Dayak onion extract is influenced by several factors such as temperature, pH, and storage conditions. In this study, it was found that Dayak onion extract tends to be colorless to yellowish in acidic conditions, whereas in alkaline conditions Dayak onion extract tends to have a brownish-red color.

1.1 Purpose of the Study

Based on the problems described above, this study aims to determine the effect of green chemistry experiments on students' environmental care attitudes. The research questions (RQs) posed in this study were:

RQ1. Is there a difference in scores of environmental care attitudes between students in the control and experimental groups before and after treatment?

RQ2. Is there an increase in the scores of students' environmental care in the control and experimental groups after the treatment?

2. METHODS

2.1 Research Design

In this study, we employed a quasi-experimental design with a pretest-posttest control group format. According to Creswell (2012), a quasi-experimental design is used to test an idea, whether it be a procedure or practice, to determine its effect on the outcomes or the dependent variable. Experimental research is utilized to identify the causal relationship between the independent and dependent variables in a controlled environment (Creswell, 2012). For this study, two intact groups were recruited: an experimental group and a control group, which were randomly assigned. Both groups were given a pretest before treatment and a posttest after treatment (Creswell, 2012). This research was carried out in the 2021/2022 academic year after obtaining approval from the Institutional Ethics Committee. The official decision was numbered 3335/UN39.12/KM/2022 on 23 March 2022.

2.2 Participants

A total of 44 grade 11 students at a public school in West Java, Indonesia, were included in the current study. A class of 19 students (8 females and 11 males) was selected as the control group, and another class of 25 students (15 females and 10 males) was selected as the experimental group. Students in the control group carried out traditional experiments, while students in the experimental group carried out green chemistry experiments.

2.3 Treatment in Control and Experimental Groups

In the control group, students were asked to do a questionnaire as a pretest first, after which the teacher explained briefly about the experimental concept that would be carried out so that students had initial knowledge. Then, they carried out traditional experiments. After completing the experiment students were asked to fill out the questionnaire again as a posttest. The experiments carried out were acid-base titration experiments. This experiment was carried out by preparing the necessary tools such as burettes, statives, clamps, and Erlenmeyer as well as materials, namely HCl solution, NaOH solution, and PP indicator. After that, the students carried out the titration with the PP indicator. Students then observed the changes that occurred.

In the experimental group, students were asked to complete a questionnaire as a pretest. After that, the teacher explained briefly about the experiment to be carried out. Students then conducted green chemistry experiments. The difference in the experiments carried out by the control and experimental groups was in the indicators used. The control group used PP indicators, while the experimental group used natural indicators, namely extracts of butterfly pea flowers and Dayak onions. After completing the experiment, students were asked to fill out the questionnaire again as a posttest. This experiment was carried out by preparing the necessary tools such as burettes, statives, clamps, and Erlenmeyer as well as materials, namely HCl solution, NaOH solution, and natural indicators from extracts of Dayak onion and butterfly pea flowers. After that, students carried out titrations with extracts of natural ingredients. Then, students were asked to observe the changes that occurred and recorded the results.

2.4 Instrument

In this study, the Environmental Care Attitude Questionnaire (ECAQ) was developed to measure students' environmental care attitudes. The ECAQ was designed based on a literature review of previous studies (Anastas & Warner, 1998; Eilks & Rauch, 2012; Mirzaei et al., 2019; Wardencki et al., 2005). The research instrument consisted of 4 subscales, namely pollution prevention, reduction of hazardous waste, reaction efficiency, and the importance of green chemistry. The reliability coefficient of ECAQ was found to be 0.837. This instrument covered 17 items using a 5-point Likert scale; strongly agree (5), agree, neutral, disagree, and strongly disagree (1). The minimum and maximum scores students could get were 17 and 85. The estimated time needed to complete the instrument was approximately 15 minutes.

2.5 Data Analysis

Inferential statistics were employed for quantitative data analysis. The Kolmogorov–Smirnov test was used to assess the normality of the data distribution, and Levene's test was calculated to verify the homogeneity of variances within the tested groups. The results of both the Kolmogorov–Smirnov and Levene's tests for the pre-test and post-test of the two groups (p-values for each cohort were greater than 0.05) indicated that the data were normally distributed and homogeneous. An independent sample t-test was utilized to determine whether there was a significant difference between the experimental and control groups in their pre-test and post-test scores. A paired samples t-test was conducted to compare the pretest and posttest scores within each group. To measure the effect size, Cohen's d index was calculated, with criteria as follows: d greater than 0.2 and less than 0.5 indicates a small effect, d greater than 0.5 but less than 0.8 indicates a moderate effect, and d greater than 0.8 indicates a large effect (Cohen, 1992). Data analysis was performed using SPSS 25 software, and the significance level was set at 0.05.

3. FINDINGS

The results of the independent samples t-test for the pretest and posttest scores of the control and experimental groups are presented in Tables 1 and 2. Additionally, the results of the paired samples t-test for the pretest and posttest scores within each group are summarized in Table 3.

According to Table 1, the independent samples t-test results indicate that the p-value for each subscale is greater than 0.05. This suggests that there is no significant difference in the pretest scores between the control and experimental groups for each subscale. Specifically, the overall p-value for the independent samples t-test on the pretest scores of the control and experimental groups was 0.189.

Table 1. The Results of T-test for the Pretest of the Groups

Subscales	Group	Mean	SD	*t*	*p*
Pollution Prevention	Control	10.58	2.116	0.632	0.531
	Experimental	10.08	2.900		
Hazardous Waste Reduction	Control	16.16	2.754	1.615	0.114
	Experimental	14.64	3.315		
Reaction Efficiency	Control	18.89	2.923	1.232	0.225
	Experimental	17.76	3.099		
The Importance of Green Chemistry	Control	18.42	2.631	0.746	0.460
	Experimental	17.80	2.814		
All Subscales	Control	64.05	8.409	1.334	0.189
	Experimental	60.28	9.897		

This indicates that the p-value is greater than 0.05, confirming no significant difference in the pretest scores between the control and experimental groups. Thus, it demonstrates that students in both classes had similar initial attitudes.

Table 2. The Results of T-test for the Posttest of the Groups

Subscales	Group	Mean	SD	*t*	*p*
Pollution Prevention	Control	10.68	2.136	0.886	0.381
	Experimental	11.28	2.264		
Hazardous Waste Reduction	Control	14.63	2.891	2.559	0.014
	Experimental	16.96	3.062		
Reaction Efficiency	Control	18.53	2.894	2.083	0.043
	Experimental	20.12	2.186		
The Importance of Green Chemistry	Control	18.68	2.868	1.288	0.205
	Experimental	19.72	2.458		
All Subscales	Control	62.53	8.605	2.157	0.037
	Experimental	68.08	8.346		

As seen in Table 2, the results of the independent samples t-test reveal that the p-values for the pollution prevention subscale and the importance of green chemistry subscale are greater than 0.05. This indicates no significant difference in the posttest scores between the control and experimental groups for these two subscales. However, for the subscales of hazardous waste reduction and reaction efficiency, the p-values are less than 0.05, indicating a significant difference in the posttest scores between the control and experimental groups. Overall, the p-value obtained was 0.037 ($p<0.05$), reflecting a significant difference in the posttest scores between the control and experimental groups. This suggests that the green chemistry experiments had a significant impact on students' environmental care attitudes.

Based on the results of the paired samples t-test for the experimental group's pretest and posttest scores (see Table 3), the p-value for each subscale is below 0.05, indicating a significant increase in posttest scores in the experimental group. Overall, the result of the paired samples t-test for the experimental group was 0.000, showing significant differences between the pretest and posttest scores. Additionally, the Cohen's d value for all subscales is 1.161, indicating that green chemistry experiments have a substantial impact on students' environmental care attitudes.

Table 3. The Results of Paired Samples T-test for the Experimental and Control Groups' Pretest and Posttest

Subscales	Group	Paired Differences		*t*	*p*	Cohen's *d*
		Mean	SD			
Pollution Prevention	Experimental	1.200	2.739	2.191	0.038	0.438
	Control	0.105	2.079	0.221	0.828	0.051

Subscales	Group	Paired Differences		*t*	*p*	Cohen's *d*
		Mean	SD			
Hazardous Waste Reduction	Experimental	2.320	2.968	3.908	0.001	0.782
	Control	1.526	2.547	2.612	0.018	0.599
Reaction Efficiency	Experimental	2.360	2.691	4.385	0.000	0.887
	Control	0.368	2.338	0.687	0.501	0.157
The Importance of Green Chemistry	Experimental	1.920	2.515	3.817	0.001	0.763
	Control	0.263	2.841	0.403	0.692	0.093
All Subscales	Experimental	7.800	6.721	5.803	0.000	1.161
	Control	1.526	6.915	0.962	0.349	0.221

4. DISCUSSION AND CONCLUSION

This research delved into how conducting green chemistry experiments impacts the environmental attitudes of eleventh-grade students focusing on acid-base titration. The findings revealed no notable disparity in pretest scores between the control and experimental groups, indicating similar initial attitudes. This similarity stemmed from both groups previously engaging in conventional experiments. Consequently, this uniformity likely led to no significant difference in attitude scores between the two groups.

Following the intervention, a significant gap emerged in the posttest scores of the control and experimental groups, with the experimental group exhibiting stronger inclinations across all facets. The divergence in posttest scores can be attributed to the disparate treatments administered to the groups. While the experimental group was exposed to green chemistry principles through experimentation, the control group adhered to conventional laboratory procedures outlined in recipe books. This discrepancy in approach resulted in divergent mindsets, thus reflecting in the significant difference in posttest scores.

This outcome aligns with prior studies, such as that of Sari et al. (2015), which underscored how mindset influences attitudes and behaviors. Similarly, Taha et al. (2019) found a notable variance in environmental awareness between control and experimental groups, favoring the latter. The experimental group demonstrated heightened environmental consciousness compared to the control.

Moreover, the experimental group's paired t-test revealed a significant surge in environmental care scores post green chemistry experimentation. This uptick signifies the impact of exposure to green chemistry principles, prompting students to critically evaluate their environmental footprint and fostering a greater sense of environmental concern.

These findings corroborate studies like that of Karpudewan (2012a), indicating the positive influence of green chemistry experiments on attitudes and motivation toward environmentally friendly actions. Additionally, Koulougliotis et al. (2021) advocate for integrating green chemistry principles into curricula to bolster environmental awareness and cultivate an environmentally responsible populace.

This study underscores the efficacy of green chemistry experiments over traditional methods in enhancing student learning and attitudes. Nonetheless, certain limitations merit consideration. Firstly, the quasi-experimental design and limited sample size necessitate broader future studies involving diverse participants across multiple schools. Secondly, future research could explore the impact of green chemistry curricula on various chemistry topics or additional variables like critical thinking and problem-solving skills. Lastly, qualitative inquiries could enrich our understanding of the effects of green chemistry activities on student learning.

Conflict of Interest

The authors declared that they have no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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REFERENCES

Abugri, D., Apea, O., & Pritchett, G. (2012). Investigation of a simple and cheap source of a natural indicator for Acid-Base titration: Effects of system conditions on natural indicators. *Green and Sustainable Chemistry, 2*(3), 117–122.

Anastas P. T. & Warner J. C. (1998). *Green chemistry: theory and practice.* Oxford University Press.

Asmani, J. M. (2013). *Buku panduan internalisasi pendidikan karakter di sekolah.* Yogyakarta: DIVA Press.

Astuti, & Wiyantoko, B. (2018). Ekstrak (Clitoria ternatea L.) sebagai indikator pengujian titrasi asam basa. *Indonesian Journal of Chemical Analysis, 1*(1), 1–8.

Braun, B., Charney R., Clarens A., Farrugia J., Kitchens C., Lisowski C., Naistat D., & O'Neil A. (2006). Completing our education. *Journal of Chemical Education, 83*(8), 1126–1129.

Burmeister, M., Rauch, F., & Eilks, I. (2012). Education for sustainable development (ESD) and chemistry education. *Chemistry Education Research and Practice, 13*(2), 59–68.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed). Boston, MA: Pearson.

Eilks, I., & Rauch, F. (2012). Sustainable development and green chemistry in chemistry education. *Chemistry Education Research and Practice, 13*, 57–58. doi:10.1039/c2rp90003c

Fitriati, M., Sapura, R., Lestari, I. (2019). Pengaruh pembelajaran berbasis lingkungan terhadap sikap peduli lingkungan pada materi pencemaran lingkugan. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa, 8*(1), 1–8.

Haack, J. A., & Hutchison, J. E. (2016). Green chemistry education: 25 years of progress and 25 years ahead. *ACS Sustainable Chemistry & Engineering, 4*(11), 5889–5896. doi:10.1021/acssuschemeng.6b02069

Hafida, N., Wahid, A. H. (2019). Pembentukan karakter peduli dan berbudaya lingkungan bagi peserta didik di madrasah melalui program adiwiyata. *Jurnal Pendidikan dan Manajemen Islam, 8*(2), 951–971.

Imamkhasani, S. (1990). *Keselamatan kerja dalam laboratorium kimia.* Bandung: Gramedia.

Kamilah, E. (2013). 57 persen masyarakat peduli lingkungan. Retrieved from https://kbr.id/nasional/03-2013/57-persen-masyarakat-peduli-lingkungan/20757.html

Karpudewan, M., Ismail, Z., & Roth, W. M. (2012a). Ensuring sustainability of tomorrow through green chemistry integrated with sustainable development concepts (SDCs). *Chemistry Education Research and Practice, 13*(2), 120–127. doi:10.1039/c1rp90066h

Karpudewan, M., Ismail, Z., & Roth, W. M. (2012b). Promoting pro-environmental attitudes and reported behaviors of Malaysian pre-service teachers using green chemistry experiments. *Environmental Education Research, 18*(3), 375–389. doi:10.1080/13504622.2011.622841

Karpudewan, M., Roth, W. M., & Ismail, Z. (2013). The effects of "green chemistry" on secondary school students' understanding and motivation. *Asia-Pacific Education Researcher, 24*(1), 35– 43. doi:10.1007/s40299-013-0156-z

Koulougliotis, D., Antonoglou, L., & Salta, K. (2021). Probing greek secondary school students' awareness of green chemistry principles infused in context-based projects related to socio- scientific issues. *International Journal of Science Education, 43*(2), 298–313. doi:10.1080/09500693.2020.1867327

Lavanya, D., Guna, G., Purushothom, A., & Pallavi, A. (2018). Green chemistry: a study on acid- base indicator property of various flower pigments. *International Journal of Research and Development in Pharmacy & Life Sciences, 7*, 3155–3163.

Lestari, M. Y., & Diana, N. (2018). Keterampilan proses sains (KPS) pada pelaksanaan praktikum fisika dasar I. *Indonesian Journal of Science and Mathematics Education, 1*(1), 49–54. doi:10.24042/ijsme.v1i1.2474

Levy, I. J., Haack, J. A., Hutchison, J. E., & Kirchhoff, M. M. (2005). Going green: Lecture assignments and lab experiences for the college curriculum. *Journal of Chemical Education, 82*(7), 974–976. doi:10.1021/ed082p974

Lokteva, E. (2018). How to motivate students to use green chemistry approaches in everyday research work: Lomonosov Moscow State University, Russia. *Current Opinion in Green and Sustainable Chemistry, 13*, 81–85. doi:10.1016/j.cogsc.2018.04.021

Marshall, G. R., Hine, D. W., & East, M. J. (2017). Can community-based governance strengthen citizenship in support of climate change adaptation? Testing insights from Self-Determination Theory. *Environmental Science & Policy, 72*, 1–9. doi:10.1016/j.envsci.2017.02.010.

Merta, L. M. (2020). Model pembelajaran penemuan menggunakan praktikum kimia hijau untuk meningkatkan hasil belajar siswa. *Journal for Lesson and Learning Studies, 3*(3), 461–468.

Mirzaei, S., Firooz, A. A., & Mirzaie, R. A. (2019). The effect of green chemistry education based on practical activity on learning and attitude of pre-service chemistry teachers. *Technology of Education Journal, 13*(1), 213–225.

Mohammed, W., & Errayes, A. (2020). Green chemistry: principles, applications, and disadvantages. *Chemical Methodologies, 4*(4), 408–423. doi:10.33945/sami/chemm.2020.4.4

Priyanto, Y., Djati, M. S., Soemarno., Fanani, Z. (2013). Pendidikan berperspektif lingkungan menuju pembangunan berkelanjutan. *Wacana, 16*(1), 41–51.

Rahmalia, W., Santi, & Syahbanu, I. (2020). Karakterisasi ekstrak zat warna umbi bawang dayak (Eleutherine americana Merr.). *Jurnal Kimia Khatulistiwa, 8*(4), 5–12

Redhana, I. W. (2014). *Menghijaukan" kurikulum kimia untuk mencapai pembangunan berkelanjutan.* Orasi ilmiah disampaikan pada sidang terbuka senat Universitas Pendidikan Ganesha. Singaraja: Universitas Pendidikan Ganesha.

Redhana, I. W., Suardana, I. N., Selamat, I. N., & Merta, L. M. (2020). Pengaruh praktikum kimia hijau pada sikap siswa terhadap kimia. *Edusains, 12*(2), 154–165. doi:10.15408/es.v12i2.13156

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., . . . Foley, J. A. (2009). A safe operating space for humanity. *Nature, 461*(7263), 472–475. doi:10.1038/461472a.

Sari, P.R., Holilullah., Yanzi, H. (2015). Faktor-faktor yang mempengaruhi pola pikir masyarakat terhadap pentingnya pendidikan di Desa Cugung. *Jurnal Kultur Demokrasi, 3*(7), 1–12.

Subamia, I. D. P., Wahyuni, I. G. A. N. S., Widiasih, N. W. (2019). Analisis resiko bahan kimia berbahaya di laboratorium kimia organik. *Wahana Matematika dan Sains, 13*(1), 49–70.

Sudarmin, S., Zahro, L., Pujiastuti, S. E., Asyhar, R., Zaenur, Z., & Rosita, A. (2019). The development of PBL-based worksheets integrated with green chemistry and ethnoscience to improve students‟ thinking skills. *Jurnal Pendidikan IPA Indonesia, 8*(4), 492–499. doi:10.15294/jpii.v8i4.17546.

Suharto, F. R. (2013). Bekerja dengan bahan kimia melalui manajemen bahan kimia dan manajemen kesehatan dan keselamatan kerja (K3) di laboratorium kimia. *Jurnal Info Kesehatan, 11*(2), 441–451.

Taha, H., Suppiah, V., Khoo, Y. Y., Yahaya, A., Lee, T. T., & Muhamad Damanhuri, M. I. (2019). Impact of student-initiated green chemistry experiments on their knowledge, awareness and practices of environmental sustainability. *Journal of Physics: Conference Series, 1156*(1), 1–8. doi:10.1088/1742-6596/1156/1/012022

United Nations. (1992). *United nations conference on environment & development: AGENDA 21*. Rio de Janerio, Brazil.

Wahyuningsih, S.A., & Rohmah, J. (2017). Pengembangan modul praktikum kimia dasar berbasis green chemistry untuk mahasiswa calon guru IPA. *Jurnal Pena Sains, 4*(1), 43–51.

Wardencki, W., Curylo J., & Namiesnik J. (2005). Green chemistry-current and future issues. *Polish Journal of Environmental Studies, 14*(4), 389–395.