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The Role of Green Chemistry in Building Ethics Education

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Abstract: This is very important in growing students' environmental awareness through integrating green chemistry in learning as one of the efforts to protect the environment and reduce environmental pollution. Chemistry learning through green chemistry education has great potential in developing ethics as a method for solving environmental problems. Green chemistry has 12 principles that are expected to address pressing environmental problems such as pollution, waste management, energy shortages, and workplace safety and security. This research type is descriptive. As much as 77% of the average students in this study with a good enough category indicates that green chemistry has an important role in building chemistry ethics. Ethics is used in general to describe human attitudes towards a problem. Ethics education in chemistry with a green chemistry perspective is carried out by teaching and training integrated into courses with the hope that it will become ethical habituation that will build chemistry ethics.

Keywords: ethics education; green chemistry; learning.

Introduction

Chemistry has been a part of human life and civilization (Harari, 2017). The greatest benefits of chemistry can be felt by society and become an integral part of modern human life (Lancaster, 2002; Patil et al., 2011). However, the perception of chemistry today faces the dynamics of thinking, namely the demand for more advanced products produced by this field, and on the other hand faces bad perceptions in the form of fear and suspicion in the community (Clark & Macquarrie, 2007). This is a challenge for the development of chemistry, which is to bring benefits and be economically feasible for human life and civilization in the form of sustainable development, and on the other side does not have adverse side effects on the environment (Chen et al., 2020). For example, the production of gasoline and diesel from petroleum faces the bad perception of carbon emissions, clothing fibers made from nylon, dyes, waterproofing face the bad perception of non-biodegradable waste, and others.

Green chemistry is the answer to the statement of sustainable development that is environmentally friendly (Sheldon, 2018). Green chemistry is an innovative approach in chemistry about developing products and processes that reduce or eliminate the use of harmful substances (Ivanković, 2017; de Marco et al., 2019; Zimmerman, et al., 2020). The main principle of green chemistry is to create processes that are not only functionally effective, but also sustainable and safe for the environment and human health (Chen et al., 2020; Zimmerman et al., 2020). Therefore, green chemistry is a very important social concern. The concern aims for people to become more aware of the harmful chemicals present in everyday products and create demand for safer alternatives.

Green chemistry is a concept of chemical thinking that can be developed in the field of education to participate in the process of sustainable development (Burmeister et al., 2012; Juntunen & Aksela, 2014; M. Chen et al., 2020; Mitarlis et al., 2023). The principle of green chemistry is a chemical approach concept that is very important and needed by students as chemimstry teacher candidates. Direct understanding of environmental awareness as sustainable development to students by chemistry teacher candidates who will

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become teachers is important to do (Mitarlis et al., 2017; Listyarini et al., 2019; Idrus, et.al., 2021). Green chemistry ensures the link between learning and students' everyday environments, such as pollution, global warming, and ozone depletion (Mandler et al., 2012; Płotka-Wasylka et al., 2018). Examples of green chemistry that can be integrated into learning are the feasibility and limitations of recycling, energy efficiency, and so on.

Green chemistry was sparked in the United States in response to the Pollution Prevention Act of 1990. Green chemistry reached a symbolic peak of science when it was announced in the 2005 Nobel Prize in Chemistry (Ananstas, 1998; Murphy, 2020). The twelve principles of green chemistry can be summarized as follows: (1) prevention, (2) atomic economy, (3) synthesis of hazardous chemicals, (4) design of safer chemicals, (5) safer solvents and additives, (6) design for energy efficiency, (7) use of renewable raw materials, (8) fewer derivatives, (9) catalysis, (10) design for degradation, (11) real-time analysis for pollution prevention, and (12) inherently safer chemicals for accident prevention. (Ananstas, 1998)

Learning science, especially chemistry, has great potential in building ethics (Chowdhury, 2016; Suciati, 2018). Chemistry learning through green chemistry education is a method of solving environmental problems as a sustainable development. Green chemistry has 12 principles that are expected to address pressing environmental problems such as pollution, waste management, energy shortages, and workplace safety and security. The goal to be achieved by green chemistry is an emphasis on chemicals and products that are environmentally friendly and healthy (Inayah, et.al., 2022; Jiang, Li, J. Shah, & You, 2023).

Ethics is concerned with the analysis of normative and evaluative issues, with questions about how one should live and how one should act (Chen, 2014). Ethics education in chemistry with a green chemistry perspective is carried out by teaching and training integrated into courses with the hope that it will become ethical habituation that will build chemistry ethics (Suryani et al., 2019). A congress of several chemists produced the The Global Chemists' Code of Ethics (GCCE) which is an important regulation for chemists around the world, a self-reflection of chemists about what they have and can do for nature as a whole. It is not only the small environment that must be protected, but all the conservation and life processes on earth are affected (Chemical Security Program, 2022). It is also implemented in chemistry education, namely green chemistry. Green chemistry in education also must be accompanied by ethical considerations (Wonorahardjo, et.al, 2021).

Green chemistry in education also aims to achieve sustainability by teaching students how to make chemistry and societal decisions depending on the multidimensional green chemistry and consideration of social factors associated with green chemistry and sustainable development (Wang, 2020; Zuin et al., 2021). The ethical implications of sustainability, which is a continuation of the presence of green chemistry, have an inherent ethical dimension. This dimension is related to the orientation aspect which means giving direction, guiding one's actions, distinguishing between right and wrong, telling how one should act and live (Parodi et al., 2011; Chen, 2014).

Therefore, there is a need for research on the understanding of ethics education through the twelve basic principles of green chemistry which is an important research area in research on the role of green chemistry in building ethics education. This research is a statistical description through several statements based on twelve basic principles related to building ethics education. This is due to the need for related research on the role of green chemistry in building ethics education.

Method

This type of research is descriptive research. Descriptive research is directed to provide symptoms, facts, or events systematically and accurately about the properties of certain populations or areas (Creswell, 2015; Edmonds & Kennedy, 2017). In descriptive research, there is no need to look for or explain relationships and test hypotheses (Aggarwal & Ranganathan, 2019; Bloomfield & Fisher, 2019; Hardani, et.al., 2020). The data collection method of this research is a questionnaire with a likert scale model and literature review. The sample in the study was 30 undergraduate chemistry education students who had received courses on green chemistry.

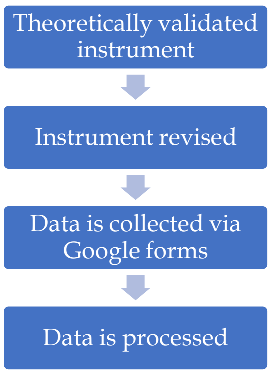

Figure 1. Research Flow

Table 1: Questionnaire Statement Items

Items	Statement
I1	I have learned about the dangers of chemical waste.
I2	I understand the 12 principles of green chemistry.
I3	I can apply the knowledge about green chemistry that I have gained in everyday life.
I4	I understanding the benefits of having green chemistry.
I5	I care about the environment from chemical hazards.
I6	I do not throw plastic waste carelessly because it can harm the environment.
I7	I often throw plastic waste carelessly because I have to.
I8	Products derived from chemicals must be designed to be biodegradable.
I9	I want to know more about the recycling process.
I10	I am willing to use recycled products (eg. recycling paper, glass, and cans).
I11	I have to save water when doing chemistry labs.
I12	I am willing to turn off any lights that I am not using in the chemistry lab.
I13	When working in a chemical laboratory, I am willing to limit the use of air conditioners and fans.
I14	I feel happy when I save energy.
I15	I love educating others about waste, pollution, and environmental problems caused by chemicals.
I16	I am willing to disseminate information about efforts to prevent waste that is harmful to the environment.
I17	I can apply the principles of green chemistry in chemistry learning.
I18	Chemistry learning with an emphasis on caring for the environment is needed from the start.
I19	The development of chemistry must be accompanied by the identification of impacts that will occur as well.
I20	The impact arising from the development of chemistry must pay attention to the principles of green chemistry.

Result and Discussion

Green chemistry has 12 basic principles that can provide positive messages to students about environmental sustainability, so as to increase knowledge and increase awareness to protect the environment and increase student awareness of environmental sustainability and environmental conservation (Nurbaity, 2016). As many as 75% of students in this study with a good enough category have understood the 12 principles of green chemistry. The following is a data presentation regarding the results of student statements after getting green chemistry material as follows:

Table 2: Descriptive Statistics

Items	N	Mean	Std. Dev	TCR (%)
I1	30	3,87	1,252	77
I2	30	3,77	,774	75
I3	30	3,67	,661	73
I4	30	3,93	1,015	79
I5	30	3,97	,964	79
I6	30	3,97	,999	79
I7	30	3,43	1,040	69
I8	30	3,80	,664	76
I9	30	3,87	,900	77
I10	30	4,03	,999	81
I11	30	4,00	1,145	80
I12	30	4,10	1,029	82
I13	30	3,90	,885	79
I14	30	3,77	1,040	75
I15	30	3,87	,973	77
I16	30	3,97	,850	79
I17	30	3,83	,913	77
I18	30	3,87	,973	77
I19	30	3,97	1,066	79
I20	30	3,87	1,074	77
Valid N (listwise)	30			

The sample findings indicate an understanding and positive attitude towards green chemistry principles in the context of ethics education, with the following interpretations:

The sample showed a good understanding of chemical effluent hazards with an average of 3.87 with moderate variation in the understanding of chemical effluent hazards, as seen in the standard deviation of 1.252.

The sample shows a good understanding of the twelve basic principles, with an average of 3.77, and is consistent with the principles of green chemistry, as seen in the standard deviation of 0.774. Although the application of green chemistry must be strengthened with an average of 3.67, as the sample shows a moderate attitude in the sense of moderately applying green knowledge in daily life, which is seen in the standard deviation of 0.661.

The sample showed a high understanding and appreciation in the utilization of green chemistry with an average of 3.93, with moderate variation meaning moderate utilization, as seen in the standard deviation of 1.015.

The majority of the sample shows high concern for the dangers of chemical waste to the environment with an average of 3.97, with moderate variation meaning that they do not dispose of chemical waste carelessly, as seen in the standard deviation of 0.964.

The sample has a high concern for the environmental impact of plastic waste disposal with an average of 3.97, and moderate variation meaning an attitude of not littering, as seen in the standard deviation of 1.040. Although, the sample mean of involuntary littering is lower at 3.43 with moderate variation, as seen in the standard deviation of 1.040.

The sample showed a mean of 3.87 for favorable agreement that chemical products should be designed to be biodegradable, with low variation, as seen in the standard deviation of 0.664.

The sample indicated a mean of 3.87, about wanting to understand more about the recycling process, with moderate variation, as seen in the standard deviation of 0.900. The sample indicated their readiness to use recycled products with a mean of 4.03, with moderate variation, as seen in the standard deviation of 0.999.

In chemistry practicum, the sample with a mean of 4.03, showed readiness in saving water during chemistry practicum, with moderate variation, as seen in the standard deviation of 1.145. Readiness to save energy such as turning off the lights used was high, with a mean of 4.10, with low variation showing the consistency of the sample, shown in the standard deviation of 1.029. Readiness to limit the use of air conditioners and fans during practicum, with a mean of 3.90, with low variation showing the consistency of the sample, shown in the standard deviation of 0.885. The sample felt happy with their energy-saving actions, with a mean of 3.37, and high variation, shown in the standard deviation of 1.040.

In green chemistry socialization efforts, the sample, with a mean of 3.87, showed a passion for educating others about waste, pollution, and environmental problems caused by chemicals, with moderate variation meaning a fairly good passion, as indicated by a standard deviation of 0.973.

The majority of the sample, with a mean of 3.97, was in favor of disseminating information on efforts to prevent waste that is bad for the environment, with low variation meaning high consistency for this effort, indicated by a standard deviation of 0.850.

The sample, with a mean of 3.83, is able to apply the principles of green chemistry in chemistry learning with low variation which means consistency in its application, shown by a standard deviation of 0.913.

The majority of the sample, with a mean of 3.87, had the belief that learning chemistry with an emphasis on caring for the environment needs to start from the beginning, with a moderate variation meaning that it is enough to believe that care must be built from the start, which is shown by a standard deviation of 0.973. Also, the majority of the sample, with a mean of 3.97, agreed with the development of chemistry accompanied by the identification of impacts that will occur, with a high variation meaning a tendency to agree, which is shown by a standard deviation of 1.066. Thus, the sample, with a mean of 3.97, believed that the impact of chemical development must pay attention to the principles of green chemistry, with high variation meaning a tendency to believe, which is shown by a standard deviation of 1.074.

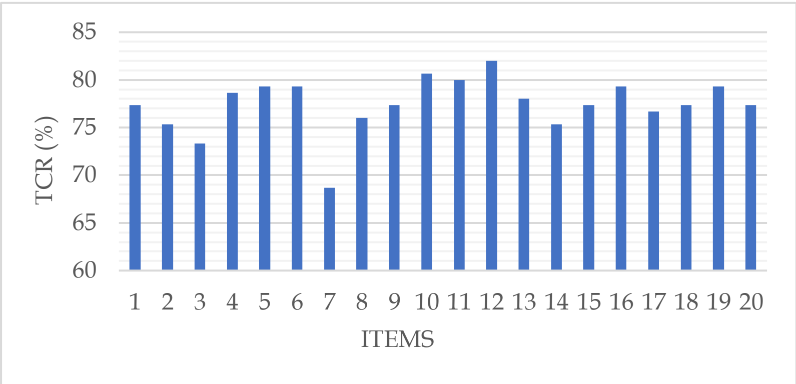

Figure 2. Response Achievement Rate

The integration of green chemistry in learning can enable students to have more connections between the scientific topics they have studied and the problems they face in everyday life. As many as 73% of students in this study with a good enough category have been able to apply the knowledge related to green chemistry that they have acquired in everyday life. The things that have been done after knowing green chemistry, namely being more selective in selecting and sorting out the chemicals used and understanding the nature of the substance, and not overdoing it. If possible, replace it with natural materials that are harmless or environmentally friendly in order to maintain environmental and ecosystem stability.

An important goal in green chemistry education is to learn to participate in societal democratic decision-making processes on issues concerning chemical applications and chemical engineering technologies. It is very important in growing students' environmental awareness through the integration of green chemistry in learning as one of the efforts to protect the environment and reduce environmental pollution (Wang, 2020). As many as 79% of students in this study in the good enough category understood the benefits of green chemistry.

Green chemistry is a strategy to minimize the impact of chemicals on human and environmental risks (Nurbaity, 2016). Green chemistry in the learning process can be implemented as an educational effort on environmental sustainability. Green chemistry education has the ultimate goal of increasing awareness as a chemistry teacher candidate to apply the basic concepts of green chemistry as part of the solution to environmental problems specifically related to chemistry that can have an impact on humans and the environment.

The development of increasingly advanced science and technology in the era of globalization has brought changes and benefits to almost all areas of life. For example, the production of chemicals by industries that are widely used in everyday life, among others H_2SO_4, HCl, $NaOH$, $AlCl_3$, $CuSO_4$, and $Pb(NO_3)_2$. These chemicals are not only used in industry but are also used in education, namely in chemistry labs (Redhana, et.al., 2020). Efficiency in the used of materials is the simplest metric for preventing environmental impacts from harm, so it should be taught before the introduction of energy efficiency metrics. An average of 79% of students in this study with category is good enough thought that they had to apply the principles of energy efficiency when conducting chemistry practicum.

Green chemistry can be applied in laboratories by preventing and minimizing waste and using safer chemicals. As many as 77% of students in this study with a good enough category already know about the dangers of chemical waste. Things that can be done after learning about the dangers of waste and chemicals, namely minimizing the use of chemicals during practicums and treating waste properly before disposal. In addition, grouping waste or waste according to the group; organic, inorganic, and B3 waste.

Hazardous chemicals used in chemistry labs can have negative effects on human health and the environment. Chemistry labs are made safer for humans and more friendly for the environment by applying the principles of green chemistry to chemistry labs. The application of the principles of green chemistry in chemistry practicum can prevent the harm caused to living things and the environment (Redhana, et.al., 2020). Efforts that can be made to make it safer in society, one of which is the effort to use chemicals that are inherently. As many as 79% of students in this study with a good enough category have cared about the environment from chemical hazards.

In addition, responsibility for the waste generated is in the form of recycling, good waste management, and not littering (Wasylka, et.al., 2018). As many as 79% of students in this study with a good enough category have implemented not littering plastic waste because it can harm the environment. Plastic waste that is then subjected to the combustion process will cause chemicals that can have an impact on human health as well. Plastics can degrade through biotic and/or abiotic processes once in the environment.

Chemicals must be designed with environmental aspects in mind, therefore a chemical must be easily degraded and not accumulate in the environment. Such as the synthesis of biodegradable polymers, biodegradable plastics, and other chemicals (Idrus, et.al., 2021). As many as 76% of students in this study in the good enough category agreed that products derived from chemicals must be designed to be biodegradable. Degradable products will help the environment in its decomposition process and reduce pollution of the environment. An environment that is exposed to harmful chemicals can damage healthy ecosystems.

Knowledge of how to behave towards chemistry, processes, products, and chemicals summarized in the concept of green chemistry is very important for every student to understand. Therefore, it is important to integrate it into the eco-friendly chemistry education curriculum (Eilks dan Rauch, 2012). As many as 77% of students in this study with a good enough category stated that they wanted to know more about the recycling process. In addition, as many as 81% of students in this study in the good category stated that they were willing to use recycled products (for example, recycled paper, glass and cans).

As many as 77% of students in this study with a good enough category stated that they like educating others about waste, pollution, and environmental problems caused by chemicals. Everyone's responsibility to protect the environment. Therefore, the importance of education about waste, pollution, and environmental problems. The existence of education certainly aims to make other people aware of the importance of maintaining environmental balance. If the environment is safe, then we will also feel the impact, and vice versa. As many as 79% of students in this study with a good enough category stated that they were willing to disseminate information about efforts to prevent waste that is harmful to the environment. Disseminating information is the same as educating others, the goal is to maintain environmental stability.

The cornerstone of environmental ethics requires all disciplines to take part in making decisions related to other processes, or to the future. Green chemistry is also one of the major efforts to be discussed in the curriculum to balance the power of chemistry for students and scientists (Wonorahardjo, et.al., 2021). As many as 77% of students in this study in the good enough category thought that learning chemistry with an emphasis on caring for the environment was necessary from the start. We live in the environment, so we must protect and care for the environment. Because education certainly aims to educate students to protect the environment. The existence of an attitude of caring for the environment will certainly keep the environment clean, and safe, and the ecosystem maintained.

All scientific activity will be responsible for the total and all of nature. It is the point of placing ethical relations into consciousness in all scientific activities, including science in cyberspace and databases (Wonorahardjo, et.al., 2021). As many as 79% of students in this study with a good enough category thought that the development of chemistry must be accompanied by the identification of the impacts that will occur as well. Chemistry is not just theory, but also applied in life and will have an impact on the environment. As we know that the existence of an action or treatment will certainly have impact, both positive and negative impacts.

Several congresses of chemists produced the Global Chemist Code of Conduct which is an important regulation for chemists around the world, a kind of self-reflection of chemists about what they have done and can do to nature as a whole. It is not only the small environment that must be protected but all the processes of conservation and life on earth are affected. It is also implemented in chemistry education and green chemistry in industrial activities, always accompanied by chemical ethical considerations (Wonorahardjo, et.al., 2021).

Scientists must be responsible for the environment and nature as a whole, the emphasis on awareness matters to scientists and their ethical attitudes and relationships (Wonorahardjo, et.al., 2021). As many as 77% of students in this study with a good enough category thought that the impact arising from the development of chemistry must pay attention to the principles of green chemistry. With green chemistry, chemists can pay more attention to the environment and participate in protecting the environment. In addition, one way to maintain environmental stability is to apply the principle of green chemistry.

The development of science can cause environmental problems faced in modern society. Science can change the whole of nature from a certain way (how chemistry works) to global environmental problems. The development of science and exploitation of nature causes greater changes in nature and affects the natural balance. It is must be accompanied by ethical considerations at every stage. Ethics is used in general to describe human attitudes towards a problem. This implies that the role of scientists is quite crucial to make changes to nature in the future. Each process requires ethical considerations and the role of chemistry as a basic science followed by increased industrial activity using modern technology (Wonorahardjo, et.al., 2021).

Conclusion

Chemistry learning through green chemistry education has great potential in developing ethics as a method for solving environmental problems. Green chemistry has 12 principles that are expected to address pressing environmental problems. As many as 77% of the average students in this study with a good enough category shows that green chemistry has an important role in building chemistry ethics. Ethics education in chemistry with a green chemistry perspective is carried out by teaching and training integrated into courses with the hope that it will become an ethical habituation that will build chemistry ethics.

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References

Aggarwal, R., & Ranganathan, P. (2019). Study designs: Part 2 - Descriptive studies. Perspectives in Clinical Research, 10(1), 34–36. https://doi.org/10.4103/picr.PICR_154_18

Anastas, P. T. and Warner, J. C. (1998). Green Chemistry: Theory and Practice. New York: Oxford University Press.

Bloomfield, J., & Fisher, M. J. (2019). Quantitative research design. Journal of the Australasian Rehabilitation Nurses Association, 22(2), 27–30. https://doi.org/10.33235/jarna.22.2.27-30

Burmeister, M., Rauch, F., & Eilks, I. (2012). Education for Sustainable Development (ESD) and chemistry education. Chemistry Education Research and Practice, 13(2), 59–68. https://doi.org/10.1039/c1rp90060a

Chemical Security Program. (2022). Global Chemists' Code of Ethics Introduction-Making Positive Change Happen.

Chen, M., Jeronen, E., & Wang, A. (2020). What lies behind teaching and learning green chemistry to promote sustainability education? A literature review. International Journal of Environmental Research and Public Health, 17(21), 1–24. https://doi.org/10.3390/ijerph17217876

Chen, T. L., Kim, H., Pan, S. Y., Tseng, P. C., Lin, Y. P., & Chiang, P. C. (2020). Implementation of green chemistry principles in circular economy system towards sustainable development goals: Challenges and perspectives. Science of the Total Environment, 716. https://doi.org/10.1016/j.scitotenv.2020.136998

Chen, Y. J. (2014). The ethical dimension of green chemistry and sustainability. Journal of Chemical and Pharmaceutical Research, 6(4), 276-281.

Chowdhury, M. (2016). Emphasizing Morals, Values, Ethics, and Character Education in Science Education and Science Teaching. Malaysian Online Journal of Educational Sciences, 4(2), 1–16.

Clark, J., & Macquarrie, D. (2007). Handbook of Green Chemistry and Technology. In Handbook of Green Chemistry and Technology. Oxford: Blackwell Science Ltd. https://doi.org/10.1002/9780470988305

Creswell, J. W. (2015). Educational Research - Planning, COnducting, And Evaluating Quantitative and Qualitative Research - Fifth Edition. In AORN Journal (Vol. 62).

de Marco, B. A., Rechelo, B. S., Tótoli, E. G., Kogawa, A. C., & Salgado, H. R. N. (2019). Evolution of green chemistry and its multidimensional impacts: A review. Saudi Pharmaceutical Journal, Vol. 27. https://doi.org/10.1016/j.jsps.2018.07.011

Edmonds, A. W., & Kennedy, T. D. (2017). An applied guide to research designs quantitative, qualitative, and mixed methods. London: Sage Publications Ltd.

Eilks, I., and Rauch, F. (2012). Sustainable development and green chemistry in chemistry education. Chemistry Education Research and Practice, 13(2), 57-58.

Harari, Y. N. (2017). Sapiens: A Brief History of Humankind Terj. Yanto Musthofa. Tangerang Selatan: Pustaka Alvabet.

Hardani, et. al. (2020). Metode Penelitian Kualitatif & Kuantitatif. Yogyakarta: Pustaka Ilmu.

Idrus, S. W. A., et. al. (2021). Sosialiasi prinsip green chemistry untuk meningkatkan kesadaran akan bahaya limbah kimia terhadap lingkungan pada mahasiswa Prodi Pendidikan Kimia FKIP UNRAM. Jurnal Pengabdian Masyarakat Sains Indonesia (JPMSI), 3(2), 246-252. https://doi.org/10.29303/jpmsi.v3i2.135

Inayah, S., I Wayan D., & Habiddin. (2022). Implementasi green chemistry dalam pembelajaran kimia: literatur review. Hydrogen: Jurnal Kependidikan Kimia, 10(1), 42-49.

Ivanković, A. (2017). Review of 12 Principles of Green Chemistry in Practice. International Journal of Sustainable and Green Energy, 6(3), 39. https://doi.org/10.11648/j.ijrse.20170603.12

Jiang, A., Li, J., J. Shah, K., & You, Z. (2023). Perspective Chapter: Implementing Green Chemistry Principles for Pollution Control to Achieve Environmental Sustainability – A Review. IntechOpen. https://doi.org/10.5772/intechopen.1003627

Juntunen, M. K., & Aksela, M. K. (2014). Education for sustainable development in chemistry – Challenges, possibilities and pedagogical models in Finland and elsewhere. Chemistry Education Research and Practice, 1–15. https://doi.org/10.1039/x0xx00000x

Lancaster, M. (2002). Green Chemistry: AN Introductory Text. Cambridge: The Royal Society of Chemistry.

Listyarini, R. V., Pamenang, F. D. N., Harta, J., Wijayanti, L. W., Asy'ari, M., & Lee, W. (2019). The integration of green chemistry principles into small scale chemistry practicum for senior high school students. Jurnal Pendidikan IPA Indonesia, 8(3), 371–378. https://doi.org/10.15294/jpii.v8i3.19250

Mandler, D., Mamlok-Naaman, R., Blonder, R., Yayon, M., & Hofstein, A. (2012). High-school chemistry teaching through environmentally oriented curricula. Chemistry Education Research and Practice, 13(2), 80–92. https://doi.org/10.1039/c1rp90071d

Mitarlis, Azizah, U., & Yonata, B. (2023). The Integration of Green Chemistry Principles in Basic Chemistry Learning to Support Achievement of Sustainable Development Goals (SDGs) Through Education. Journal of Technology and Science Education, 13(1), 233–254. https://doi.org/10.3926/jotse.1892

Mitarlis, Ibnu, S., Rahayu, S., & Sutrisno. (2017). Environmental literacy with green chemistry oriented in 21st century learning. AIP Conference Proceedings, 1911. https://doi.org/10.1063/1.5016013

Murphy, M. A. (2020). Early Industrial Roots of Green Chemistry - II. International "Pollution Prevention"

Efforts During the 1970's and 1980's. Subtantia: An International Journal of the History of Chemistry, 4(2), 15–57. https://doi.org/10.13128/Substantia-894

Nurbaity, Y. R. and Ridwan, A. (2016). Integration green chemistry approach in teacher education program for developing awareness of environmental sustainability. Conference of the ASEAN Comparative Education Research Network Conference, Universiti Kebangsaan Malaysia, 2148-2156.

Parodi, O., Ayestaran, I., & Banse, G. (2011). Repositorium für die Medienwissenschaft Sustainable development. Relationships to culture, knowledge and ethics.

Patil, H. I., Singh, M. C., Gaikwad, P., Lade, K. S., Gadhave, N. A., & Sawant, S. D. (2011). Green Chemistry: Why and How — For Sustainable Chemical Industry and Environmentally Commendable Civilization. ChemInform, 4(12), 4798–4804. https://doi.org/10.1002/chin.201325238

Płotka-Wasylka, J., Kurowska-Susdorf, A., Sajid, M., de la Guardia, M., Namieśnik, J., & Tobiszewski, M. (2018). Green Chemistry in Higher Education: State of the Art, Challenges, and Future Trends. ChemSusChem, 11(17), 2845–2858. https://doi.org/10.1002/cssc.201801109

Redhana, I W., et. al. (2020). Pengaruh praktikum kimia hijau pada sikap siswa terhadap kimia. Edusains, 12(2), 154-165.

Sheldon, R. A. (2018). Metrics of Green Chemistry and Sustainability: Past, Present, and Future. ACS Sustainable Chemistry and Engineering, 6(1), 32–48. https://doi.org/10.1021/acssuschemeng.7b03505

Suciati. (2018). Integrasi nilai-nilai etika dalam pembelajaran sains untuk membangun karakter generasi era digital abad 21. Prosiding Seminar Nasional Pendidikan Fisika FITK UNSIQ, Wonosobo, 1(1), 11-19.

Suryani, A., Saifulloh, M., Muhibbin, Z., Hanoraga, T., Nurif, M., Trisyanti, U., Rahmawati, D. (2019). Education for Environmental Sustainability: A Green School Development. IPTEK Journal of Proceedings Series, 6(6), 65–72. Retrieved from http://unesco.unesco.org/images/0010/001056/105607e.p

Wang, et. al. (2020). Green chemistry education.

Wasylka, et. al., (2018). Green chemistry in higher education. CHEMSUSCHEM, 11(17), 2845-2858. https://doi.org/10.1002/cssc.201801109

Wonorahardjo, S., Suharti S., & I Wayan D. (2021). From chemistry back to nature, an ethical perception of chemists. Proceedings of the AIP, 2330(020049). https://doi.org/10.1063/5.0043206

Zimmerman, J. B., Anastas, P. T., Erythropel, H. C., & Leitner, W. (2020). Designing for a green chemistry future. Science, 367(6476), 397–400. https://doi.org/10.1126/science.aay3060

Zuin, V. G., Eilks, I., Elschami, M., & Kümmerer, K. (2021). Education in green chemistry and in sustainable chemistry: perspectives towards sustainability. Green Chemistry, 23(4), 1594–1608. https://doi.org/10.1039/d0gc03313h