JPPIPA 9(10) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Teacher's and Student's Perceptions of Green Chemistry and its Principles in Chemistry Learning in High Schools

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Received: July 21, 2023
Revised: August 3, 2023
Accepted: October 25, 2023
Published: October 31, 2023

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DOI: 10.29303/jppipa.v9i10.4756

Abstract: Green Chemistry (GC) is an issue that is very relevant to chemistry subjects in senior high schools. Chemistry subject is closely related to the environment as one of the pillars of sustainable development. This certainly contributes to the possibility integration of green chemistry principles into chemistry learning. This exploratory research aims to describe the principles of GC that allow it to be integrated into chemistry learning in grades X and XI; describes the high school teacher's and students' perceptions and understanding of GC and its principles in chemistry learning. The subjects in this study were 230 students who were selected purposively from five Senior high schools. Totally 40 chemistry teachers were purposively used as research subjects from a number of high schools throughout South Sulawesi. The instrument used was ten items of teacher's perception questionnaires, while the students' perception questionnaire consisted of twelve items. Guidelines for interviewing teachers and students were used to describe more deeply about their understanding of GC. All instruments have been validated by two experts. The results of the exploration of material elements for phases E and F show that five GC principles can be integrated into learning chemistry. In general, the teacher's perception of GC is good, which assumes that GC is an environmentally friendly concept. Understanding of the five principles of GC for students and teachers is in the moderate and poor categories. This shows the importance of integrating GC principles in the form of positive habits in chemistry learning.

Keywords: Chemistry learning; Green chemistry; Student's perception; Teacher's perception

Introduction

The world's people realize that the Earth's condition is not good, so we must take collective action to save it. In education field, the solution action is implementation of Green Chemistry principles in learning. Education according to Wardencki et al. (2005) has a special role in socializing green chemistry. Green Chemistry is a philosophy or concept that drives the design of products or processes that reduce or eliminate the use and production of hazardous substances (Anastas & Zimmerman, 2018). The principles of green chemistry can be adapted to be applied in human attitudes and actions as an effort to save the environment which is realized through education or green education.

This policy is realized by implementing the Independent Curriculum with recommendations for strengthening student character. The characters in question include concern for the environment to support education for sustainable development (EoSD) (Sánchez et al., 2022). The environment is one of the three pillars of sustainable development which is relevant in the formation of character values in the education system. The environmental pillar relates to two of the 17 goal of SDGs (Government Sierra Leone, 2016).

In implementing the learning process in the classroom, the teacher has accidentally inserted

How to Cite:
Jusniar, J., Syamsidah, & Auliah, A. (2023). Teacher's and Student's Perceptions of Green Chemistry and its Principles in Chemistry Learning in High Schools. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7924–7934. https://doi.org/10.29303/jppipa.v9i10.4756

character values that are oriented toward green chemistry. It's just that teachers sometimes don't realize that what they are doing is part of the principles of green chemistry. This is due to the teacher's lack of understanding of the principles of green chemistry. Green Chemistry is a philosophy or concept that drives the design of products or processes that reduce or eliminate the use and production of hazardous substances (Manahan, 2005). Green Chemistry has 12 principles (Anastas & Warner, 1998) that can be adapted to be applied in human's attitudes and behavior to save the environment. Not all of these principles can be applied in the integration of chemistry learning in high school. Mitarlis et al. (2023) reports that five principles out of 12 can be integrated into basic chemistry courses at College or university. Of course, the same thing can also be integrated into chemistry learning in high school so that education contributes to saving the environment.

Actions to save the environment can be carried out by implementing them in education field at all levels by integrating relevant green chemistry principles in learning. Research on instilling ESD and SDGs values in the curriculum has been carried out by (Zguir et al., 2021); SDGs with an independent curriculum in Indonesia (Purnomo et al., 2023); Studies on the relationship between quality education and ESD and learning with sustainability have also been conducted (Didham & Ofei-Manu, 2020). The relationship between education and learning related to green chemistry principles and SDGs has been carried out by Mitarlis et al. (2023). The results of observations and interviews with several high school teachers in South Sulawesi found that the principles of green chemistry were not well understood. Most of them assume that green chemistry is only related to environmental friendliness, so they don't mention things related to energy efficiency as green chemistry principles. This is what makes this research important to do. Because not much research has been discussed that explores teacher and student perceptions of GC principles in chemistry learning. Research Questions are: What GC principles can be integrated in the E and F phases of chemistry learning? What is the teacher's perception of green chemistry and its principles in Chemistry learning?; How are students' perceptions of green chemistry and its principles in Chemistry learning?

Green Chemistry Principles as Part of Development Sustainable

Sustainable development is developed with the principle of "meeting the needs of the present without compromising meeting the needs of future generations". Sustainable development refers to the use of existing resources to meet the needs of the present generation by saving for future generations (Zakiyyah et al., 2021). This principle is further formulated in the achievement targets of the 17 global goals of the Sustainaible Development Goals (SDGs) as shown in Figure 1. Efforts to achieve the SDGs targets have also been carried out, including by embedding the values of ESD and SDGs in the curriculum (Zguir et al., 2021). Studies on the relationship between quality education and ESD and learning and sustainability have also been conducted (Didham & Ofei-Manu, 2020). Sustainable Development and Education for Sustainable Development (ESD) have also been extensively studied (Anderson et al., 2017; Colás-Bravo et al., 2018; Evans et al., 2017; Kioupi & Voulvoulis, 2019; Aubrecht et al., 2019; Segara, 2015). To care for the environment there is the importance of educating values related to sustainability and relevant interests in the education system to provide ESD (Sánchez et al., 2022).

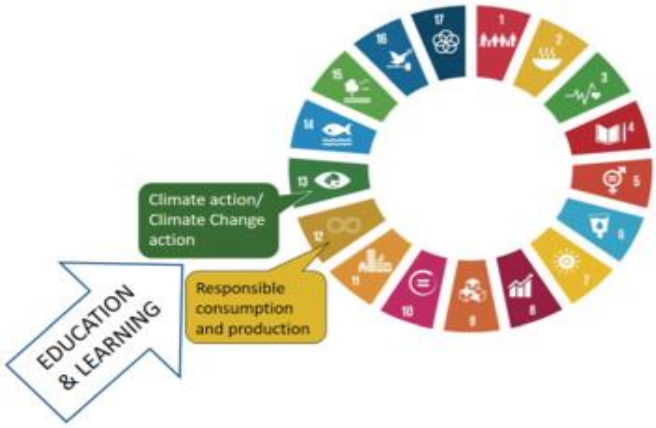

Figure 1. Seventeen Sustainability Development Goals (SDGs)

Sustainability has become an important agenda (Guo et al., 2022) and is detailed as Sustainable Development which has been targeted as set forth in the 17 goals SDGs which are categorized into three pillars namely social, economic, and environmental (Purvis et al., 2019). The environmental pillar involves sustainable chemistry or green chemistry. Education and chemistry learning contribute to the two SDGs pillar goals for environmental aspects (Evans et al., 2017) as shown in Figure 1. The 12th goal related to responsible consumption and production and climate change action is the thirteenth goal. Green chemistry has 12 principles or principles of Green Chemistry that can be adapted to be applied in human attitudes and actions to save the environment. Actions to save the environment can be carried out early on through education to support the achievement of sustainable development targets, one of which is green chemistry. According to Anastas et al. (1998) Green chemistry is a chemical practice in a way that maximizes its benefits while eliminating or at least

reducing its negative effects. Green chemistry is the sustainable practice of chemical science and manufacturing within the framework of industrial ecology in a sustainable, safe and non-polluting manner, consuming a minimum amount of energy and material resources while producing almost no waste.

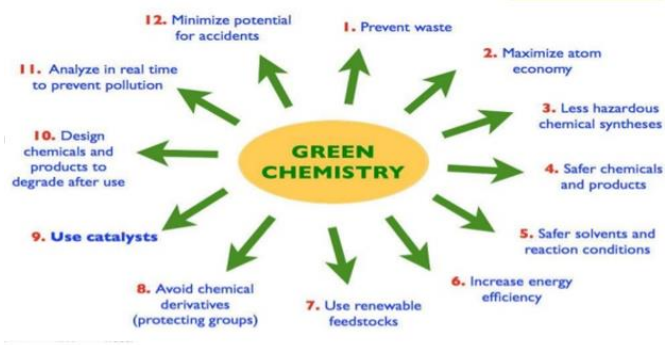

Figure 2. The twelve principles of green chemistry (Anastas & Warner, 1998)

The Twelve Principles of Green Chemistry in simple language are preventing waste, maximizes atomic economy, designs safe chemicals and chemical products, designing less dangerous chemical synthesis, use safe solvents and reaction conditions, improve energy efficiency, using renewable raw materials, avoid chemical derivatives, use catalysts instead of stoichiometric reagents, design chemicals and products that decompose after use, real-time analysis to prevent pollution, and minimizing the potential for accidents (Manahan, 2006; Anastas & Warner, 1998).

Integration of Green Chemistry Principles in Chemistry learning in the Merdeka Curriculum Era

The implementation of the Independent Curriculum in Indonesia, called Merdeka Curriculum provides new nuances and paradigms that provide freedom of thought (Kusumastuti et al., 2021) and encourages students and teachers to be able to change their educational paradigm from traditional to contemporary (Telaumbanua et al., 2022). The Indonesian government carries the idea of "Freedom" as an effort to achieve independence in students to be creative, critical, and collaborative (Yulianto, 2022). In addition, the Merdeka Curriculum is different from the previous curriculum in terms of projects, introducing issues of sustainability, local wisdom, ideology, Indonesian spirit, democracy, technological innovation, and entrepreneurship (Tjaija, 2022). The independent curriculum in its implementation focuses more on basic material, Students' characters and competencies. The independent curriculum upholds the concept of independent learning, namely providing freedom and independence for students and schools so that students can further explore their individual interests and talents to form a Pancasila student profile. The dimension of the Pancasila student profile is strengthening the character of students as a foundation competency that needs to be developed in educational units.

The dimensions of the Pancasila student profile are: faith, piety to God Almighty, and have noble character; independent; global diversity; work together (collaborative); critical reasoning; and creative. Assessment of learning outcomes in this curriculum is focused on two aspects, namely: first; summative assessment in quantitative values form as learning outcomes with Minimum Completeness Criteria. Second, formative assessment is carried out to identify the achievement of learning objectives through process assessment (both skills and students' social attitudes) (Purwananto, 2022). This formative assessment aims to evaluate and reflect on learning activities based on the results of process observations and student self-assessment. Learning outcomes for the high school level is known to have two phases, namely phase E for class X level and phase F for class XI and XII levels.

Based on research by Mitarlis et al. (2023) there are five of 12 principles of green chemistry (GC), that can be implemented in basic chemistry learning, including principle: waste prevention; safer solvent and reaction condition; energy efficiency; use of renewable raw materials; minimizes the potential for accidents. The 12 principles of green chemistry (GC) Of course, this provides an overview of GC principles that can be integrated into chemistry learning in high schools.

Method

Research Design and Procedure

This study uses an exploratory descriptive design that emphasizes qualitative rather than quantitative data (Creswell, 2012). According to Alamer (2022) the exploratory research design is to gain a deeper understanding (Gama et al., 2022) of teacher and student perceptions regarding Green chemistry and its principles in chemistry learning. The exploration carried out was to analyze the perceptions of teachers and students towards GC. Besides that, analyze documents, images or other sources from research (Rahmawati et al., 2022). The exploratory framework used is a combination of primary and secondary research methods.

The main stages of this research are three stages: First stage; document analysis on the principles of green chemistry and the achievements of independent curriculum chemistry learning. Second stage; describes the perceptions of teachers and students towards GC principles that allow them to be integrated into

chemistry learning. The third stage is formulating follow-up.

Research Subject

The research subjects for the perception test were 40 high school chemistry teachers from 8 schools throughout South Sulawesi. Places of teaching have represented 16 people in urban areas and 24 people served in areas outside the city of Makassar. Service tenure varies between 3-25 years. The student subjects were 230 people from 6 high schools in South Sulawesi. Sampling was carried out purposively by both teachers and students (Creswell, 2012). The subjects for in-depth interviews were three Chemistry teachers from SMAN 1 Gowa, SMAN 2 Gowa and SMA Insan Cendekia Sech Yusuf. This data is to reveal more deeply about the teacher's understanding of green chemistry in chemistry learning.

Research Instruments and Data Collection

The research instrument used observation sheets, interview guides, validation sheets, student response questionnaires, and teacher response questionnaires. The research material used was in the form of Chemistry learning documents (curriculum outcomes; Lesson plan), as well as the source Observation sheets were used for the first stage of data collection using secondary methods, focused on literature review (Zulkipli & Wills, 2021) on the possibility of integrating green chemistry principles in chemistry learning. The secondary method in exploration uses qualitative procedures that have been carried out by analyzing and mapping several documents, for example the Learning Outcomes of the Chemistry Subject for Phases E and F. Green chemistry principles for sustainable development goals (SDGs). The data collection technique for the first stage is by reviewing literature and related secondary sources.

The instrument used in the second stage is a perception questionnaire. The teacher's perception questionnaire consists of 10 items from six aspects, namely: green chemistry in general consists of four items; GC Principles on preventing one item from being wasted; use one item safe solvent; increase the energy efficiency of one item; using one item renewable raw materials; and minimize the potential for two-item accidents. This questionnaire has been validated by two experts from the aspect of language and the suitability of the aspect with the statement. The validity of the two aspects was 92.5 and 91.8 respectively in the very high category. Internal consistency between two experts as raters is 100 percent (Borich, 2003).

The student perception questionnaire consisted of 12 items in six aspects, namely green chemistry in general, three items; the GC principle of three-item waste prevention; GC Principles on preventing one item from being wasted; use one item safe solvent; increase the energy efficiency of two items; using one item renewable raw materials; and minimize the potential for one-item accidents. The five GC principles make it possible to be integrated into learning both through practicum and theory according to the first stage of the study. This questionnaire has been validated by two experts on the suitability of content and language aspects.

Questionnaire data collection techniques for teacher and student perceptions were carried out in two ways, namely direct way by distributing questionnaires and through on-line google forms. Data collection for interviews with several purposive samples for both teachers and students was carried out by direct interviews with interview guide instruments. The aspects that were used as material for interviews in the interview guideline were understanding of sustainable development goals, especially those related to the environment; knowledge of Green chemistry principles, especially principles that can be integrated into learning; green chemistry in general. Interviews were given to obtain more in-depth information (Gama et al., 2022).

Data Analysis

Data analysis was carried out descriptively by looking at the percentage of teacher and student perceptions. For every aspect and principle of green chemistry that allows it to be integrated into learning Chemistry in high school. This description is confirmed by data from interviews with teachers and students. The results of the interview made a written transcript of the interview. Then validation was carried out between the recordings and interviews by the validator.

Result and Discussion

Exploration Results of Chemical Elements of Phase E and F That Can be Integrated with the GC Principle

The results of the exploration of learning outcomes and material elements for Grades X and XI, high schools with the principles of green chemistry can be seen in Tables 1 and 2. The exploration carried out is related to the implementation of the project-based learning model as the recommended learning model in the "Merdeka Curriculum".

Table 1. Analysis of Green Chemistry Principles That Can be Integrated in Phase E (Class X)

Learning Materials	Green Chemistry Principles	Learning Experience	Learning Model/Method
Periodic System of Elements: Atomic theory, Atomic structure, electron configuration, location of elements in the periodic table of periodic elements, Analyzing the properties of chemical elements, Determining chemical formulas, IUPAC	Waste prevention, Safe use of solvents and chemicals, Designing energy efficiency, Using renewable raw materials, and Prevent potential accidents	Make a media model of atomic structure and explain atomic theory. Practice in determining the electron configuration of different elements and determining the location of the element in the periodic table of elements. Doing questions and answers on the topic of the properties of chemical elements. Problem solving exercises on the topic of determining chemical formulas and IUPAC.	Learning Model: Project-based learning Learning Methods: Making projects, Assignments, Group discussions
Stoichiometry: basic laws of chemistry, Lavoisier's law, Proust, Dalton, Gay Lussac, Avogadro, Mole concept, Equation of chemical reactions, Applying the basic laws of chemistry.	Waste prevention, Safe use of solvents and chemicals, Using renewable raw materials, Design energy efficiency, Prevent potential accidents	Problem solving exercises on the topic of basic laws of chemistry. Make a concept map about the concept of moles and determine the number of particles (atoms, molecules or ions) in a substance. Practice solving problems on the topic of chemical equations and determining mole ratios, understanding changes in substances, and predicting reaction results. Conducting practicum based on green chemistry principles on the topic of chemical reactions.	Learning Model: Project based learning Learning Methods: Assignments, Discussion groups, Making concept maps, Practicum

Table 2. Analysis of Green Chemistry Principles That Can be Integrated in Phase F (Class XI)

Learning Materials	Green Chemistry Principles	Learning Experience	Learning Model/Method
Chemical Bonds: ionic bonds, covalent bonds, metallic bonds, hydrogen bonds, van der walls forces, London forces, and molecular shapes.	Waste prevention, Safe use of solvents and chemicals, Design energy efficiency, Using renewable raw materials, and Prevent potential accidents	Ask questions related to chemical bonding material such as the formation of ionic bonds, covalent bonds, and metallic bonds. Make a model of the shape of the molecule using materials that exist in the surrounding environment. Discuss the shapes of molecules that will be made using the valence electron pair theory. Presenting the results of projects carried out related to chemical bonding material.	Learning Model: Project Based Learning Learning Methods: Frequently Asked Questions, Create a project, Group discussion
Thermochemistry: types of chemical reactions, the concept of energy in chemical reactions, enthalpy changes, effects of temperature and concentration, enthalpy formation, thermochemical applications	Waste prevention, Safe use of solvents and chemicals, Design energy efficiency, Using renewable raw materials, and Prevent potential accidents	Asking questions related to thermochemical materials. Designing a project to calculate the enthalpy change of combustion of alcohol. Practice questions related to enthalpy changes based on data on enthalpy of formation and binding	Learning Model: Project Based Learning Learning Methods: Frequently Asked Questions, Create a project, Assignment, Group discussion

Learning Materials	Green Chemistry Principles	Learning Experience	Learning Model/Method
		energy based on Hess's law. Discuss the types of reaction enthalpies. Present the results of the project carried out by the project to calculate the enthalpy change of combustion of alcohol.	
Chemical kinetics: reaction rates, reaction rate equations, collision theory, effect of temperature, concentration and contact area on reaction rates, catalysts	Waste prevention, Safe use of solvents and chemicals, Design energy efficiency, and Prevent potential accidents	Ask questions related to chemical kinetics material. Designing the manufacture of projects related to the factors that affect the rate of reaction. Practice questions related to reaction orders and reaction rate constants. Presenting the results of the project carried out regarding the factors that affect the rate of reaction.	Learning Model: Project Based Learning Learning Methods: Frequently Asked Questions, Create a project, Assignments
Chemical Equilibrium: equilibrium constants (concentration and partial pressure), factors affecting the direction of chemical equilibrium (pressure, temperature, concentration, catalyst), solubility and solubility product.	Waste prevention, Safe use of solvents and chemicals, Design energy efficiency, and Prevent potential accidents	Ask questions related to chemical equilibrium material. Designing the manufacture of projects related to factors that influence the direction of chemical equilibrium. Practice questions related to chemical equilibrium constants. Present the results of the projects carried out regarding the factors that influence the direction of chemical equilibrium.	Learning Model: Project Based Learning Learning Methods: Frequently Asked Questions, Create a project, Assignments, Group discussion

Results of teacher's and students' perceptions

The teacher's perception of green chemistry and the distribution of perception items on the six aspects of green chemistry can be seen in Tables 3 and 4 respectively. Students' perceptions of green chemistry and the distribution of the twelve perception items on the six aspects of green chemistry can be seen in Tables 5 and 6 respectively.

Table 3. Teachers' Perceptions of Green Chemistry

GC Principle	Positive Perception	Negative Perception	% Positive Perception
The teacher's understanding of Green Chemistry (GC) as an environmentally friendly concept	39	1	97.5
The importance of integrating GC in chemistry learning	30	10	75.0
Green chemistry (GC) is something new	29	11	72.5
The use of safe chemicals in practicum is a GC principle	29	11	72.5
Energy efficiency in chemistry lab is included in the GC principle	22	18	55.0
Reducing the portion of the use of chemicals in practice	17	23	42.5
Minimizing the potential for accidents in chemical labs with safety equipment is the GC principle.	23	17	57.5
Promote the use of renewable raw materials	21	19	52.5
The use of safety tools when practicum is important.	20	20	50.0

GC Principle	Positive Perception	Negative Perception	% Positive Perception
Setting up a practicum waste container in the laboratory is included in the GC principle	32	8	80.0

Information; N = 40 chemistry teachers

Table 4. Differentiated Teachers' Perception Items on GC Aspects

GC Aspect	GC Principle
Green Chemistry in general	Teacher's understanding of Green Chemistry (GC) as an environmentally friendly concept (item 1).
	The importance of integrating GC in chemistry learning (item 2).
	Green chemistry (GC) is something new (item 3).
Preventing Waste Generation	Preparing practicum waste containers in the laboratory is included in the GC principle (item 10).
	Reducing the share of chemical use in practice (item 6).
Using safe solvents or chemicals	Using safe chemicals in practice is a GC principle (item 4).
Energy efficiency	Energy efficiency in chemistry lab including GC principles (item 5).
Using renewable raw materials	Promote the use of renewable raw materials (item 8).
Prevent or minimize potential accidents	Minimizing the potential for accidents in chemical labs with safety equipment is the GC principle. Promote the use of renewable raw materials (item 7).
	The use of masks, protective goggles, and gloves when practicum is important (item 9).

Table 5. Students' Perceptions of Green Chemistry

GC Principle	Positive Perception	Negative Perception	Positive Percentage	Negative Percentage
Understanding of green chemistry (GC) as an environmentally friendly concept	215	15	93.48	6.52
GC information obtained in chemistry learning	42	188	19.28	81.74
An appeal to turn off lights or tools that are not in use is a GC principle	77	153	33.47	66.53
Green chemistry (GC) is something new	129	101	56.09	43.9
The recommendation to use environmentally friendly materials for practice is a GC principle	102	128	44.35	55.7
Using safe chemicals in practice is one of the principles of GC	163	67	70.87	29.1
Energy efficiency in chemistry lab is a GC principle	86	144	37.39	62.6
Reducing the portion of the use of chemical substances in practice includes the GC principle because it reduces pollution	123	107	53.48	46.5
Minimizing the potential for accidents in chemical labs with safety equipment is one of the principles of GC	88	142	38.26	61.7
Advocating the use of renewable raw materials is a GC principle	131	99	56.96	43
Bring your own drinking bottles so you don't create a lot of waste, including the GC principle of reducing waste formation.	167	63	72.61	27.4
GC information obtained from social media	153	77	66.52	33.5

Table 6. Differentiated Student Perception Items on the GC Aspect

GC Aspect	GC Principle
Green Chemistry in general	Teacher's understanding of Green Chemistry as an environmentally friendly concept (item 1)
	The importance of integrating GC in chemistry learning (item 2)
	Green chemistry (GC) is something new (item 4)
	GC information obtained from social media (item 12)
Preventing Waste Generation (GC 1)	Advice to use environmentally friendly materials for practice is a GC principle (Item 5)
	Reducing the portion of the use of chemical substances in practice including the GC principle because it reduces pollution (8)
	Bring your own drinking bottles so you don't create a lot of waste, including the GC principle of reducing waste formation (11).
Using safe solvents or chemicals (GC 5)	Using safe chemicals in practice is a GC principle (item 6)
Energy efficiency (GC 6)	The appeal to turn off lights or tools that are not in use is the GC principle (item 3)
	Energy efficiency in chemistry lab is a GC principle (item 7)
Using renewable raw materials (GC 7)	Promote the use of renewable raw materials (item 10)

Prevent or minimize potential accidents Minimizing the potential for accidents in chemical labs with safety equipment (item 9) (GC 12)

Discussion

Exploration of the Integration of GC Principles in Class X and XI Chemical Elements

Table 1 shows the relationship between the achievements of the Chemistry phase E subject, green chemistry principles, and student learning experiences, as well as learning models. Overall the learning experience is not only related to theory but also needs practical support. Doing practicum related to material on the periodic system of elements, in this practicum can involve selecting environmentally friendly reagents in chemical reactions involving elements in the periodic system. Green Chemistry Principle No. 1. Prevent or reduce the formation of waste. This can be done by reducing the prescription/dose of chemicals used. In the context of the periodic system of elements, this can be achieved by optimizing synthesis or purification methods to reduce the amount of waste generated. Green Chemistry Principle No. 5. This principle focuses on reducing waste and hazardous emissions during chemical processes. In the context of the periodic system of elements, this can be achieved by optimizing synthesis or purification methods to reduce the amount of waste generated. In addition, considering the use of environmentally friendly chemicals and the use of technology that can reduce greenhouse gas emissions or other pollutants. Green Chemistry Principle No.7. In the context of the periodic system of elements, this principle focuses on the use of raw materials that do not damage the environment and considers the material's life cycle. For example, in the synthesis of chemical compounds, prioritizing the use of renewable raw materials and reducing the use of hazardous or non-renewable raw materials. No. 12. This principle involves measures to enhance safety in the use, storage and transportation of chemicals. In the case of periodic systems of elements, consider the use of methods or technologies that minimize the risk of accidents or leaks that can harm humans and the environment.

Practical experience support, namely doing practical work related to stoichiometry material. Students can study and test reaction methods that use less energy or operating conditions that are more efficient. Green Chemistry Principle No. 1. This principle involves the reduction of waste generated during chemical reactions. In stoichiometry, we can optimize reaction planning and use of reagents to reduce waste generation. This can be done by calculating the correct stoichiometric ratio, using efficient reagents, and choosing a reaction method that produces minimal by-products. Green Chemistry Principle No. 5. This principle emphasizes the use of environmentally friendly reagents in chemical reactions. In stoichiometry, this can mean considering the use of less hazardous or toxic reagents, or looking for more environmentally friendly alternatives to achieve the same result.

Green Chemistry Principle No. 7. This principle emphasizes the use of environmentally friendly reagents in chemical reactions. Use renewable reagents or replace hazardous reagents with safer ones. Green Chemistry Principle No. 12. This principle involves the safe handling of chemicals used in stoichiometric reactions. This includes selecting the appropriate chemical for the intended use, proper storage to avoid unwanted reactions, and safe transportation. A good understanding of the properties and characteristics of chemicals and knowledge of the risks associated with them is important for reducing the risk of accidents.

Based on Table 2, the results of the exploration of literature and secondary sources show that there are five GC principles that can be integrated into Phase F chemistry learning for the upper middle school grade XI level. Besides explaining theoretical learning experiences in class, students can do practical work related to chemical bonding material, namely experiments on determining covalent bonds and ionic bonds; conducting thermochemical practicum, namely studying heat changes through simple experiments; Chemical kinetics practicum, namely experiments to determine reaction orders and reaction rate constants; Practicum for determining chemical equilibrium constants with green chemistry principles. Green Chemistry Principle No. 1. Prevent or reduce the formation of waste. This can be done by reducing the prescription/dose of chemicals used.

Green Chemistry Principle No. 5. Using safe chemicals and solvents. Green Chemistry Principle No. 6. Reducing the amount of substance will shorten the duration of the process automatically or can reduce the energy if the process requires energy. Green Chemistry Principle No. 7. Using renewable raw materials is preferred. Green Chemistry Principle No. 12. Using safe chemicals and solvents will reduce the potential for accidents.

The exploration results of two grade levels (X and XI) in phases E and F show that there are five principles of green chemistry that can be integrated into chemistry learning. The same findings have also been reported by (Mitarlis et al., 2018) in Basic Chemistry learning.

Teacher's Perception of Green Chemistry

In general, teachers understand that green chemistry is an environmentally friendly concept. Of the three perception items about the concept of green

chemistry, generally positive perceptions were greater than 75 percent. If compared to the percentage of perceptions greater than 75 percent, it is included as having a good category of understanding. Based on Figure 3. Shows that there are two GC principles (GC 1 and 5) the percentage is between 60-74 including the category of moderate understanding; and three GC principles (GC 6, 7, and 12) the percentage is 45-59 in the less category.

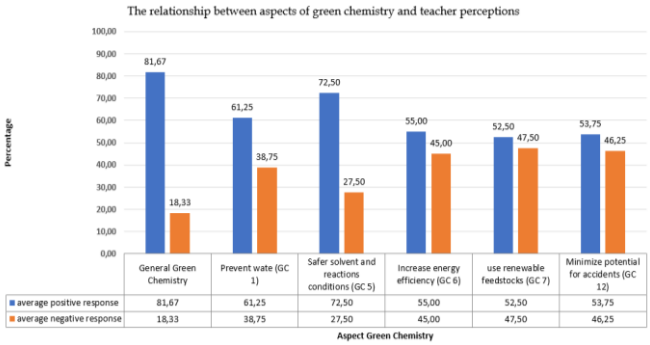

Figure 3. Teachers' perceptions of green chemistry aspects

It's just that interview support from one of the teachers as a respondent shows that in general the teacher's understanding of green chemistry is more about the meaning of environmentally friendly. Likewise, the meaning of his understanding of the relationship between GC and sustainable development; like the following quote:

I : Have you ever heard of the term green chemistry (GC)?
R : Ever.
I : Where did you get the GC information?
R : Heard from the forum; and social media.
I : Do you think GC is the same as environmental chemistry?
R : Seems similar; because GC is an environmentally friendly concept.
I : Have you ever heard of the term sustainable development goals (SDGs)?
R : Yes, I know a little.
I : In your opinion, what aspects are included in the SDGs?
R : I don't really understand that, but I think all aspects including education.

Aspects related to the GC principles of the five principles; the fifth and first principle, namely using safe solvents and preventing wastage and pollution, is moderately understood by chemistry teachers. The three GC principles (GC 6, 7, and 12) show that the teacher's understanding is still lacking. This is also supported by interview excerpts with one of the respondents as follows:

I : Do you know what are the principles of GC?
R : I don't know the details, but everything related to pollution reduction and environmental pollution.
I : How do you respond to students who like to consume bottled water or other plastic packaged drinks?
R : Not good in terms of waste production; but maybe the kids now like to be practical.
I : Why?
R : Plastic waste is difficult to decompose.

The results of the interviews show that the respondents did not understand the principles of GC. His understanding is limited to GC which is the concept of reducing pollution and being environmentally friendly. This shows that it is indeed very important to provide a massive understanding of GC. GC has been explicitly integrated into the independent curriculum in the first material of phase E. According to Braun et al. (2006) integrating GC in the curriculum does not have to include material replacing regular material, but social attitudes that can stimulate positive habits to implement GC principles that need to be done.

Students' Perception of Green Chemistry

Based on Figure 4, it can be seen that only one aspect (GC 5; safer solvent and reaction condition) with the perception of understanding is in the moderate category. The four principles of GC and GC aspects in general are still lacking, namely: waste prevention; energy efficiency principles of GC 6; use of renewable raw materials GC 7 principles, minimizes the potential for accidents, and GC aspects in general. This illustrates that it is very urgent to integrate GC principles in chemistry learning.

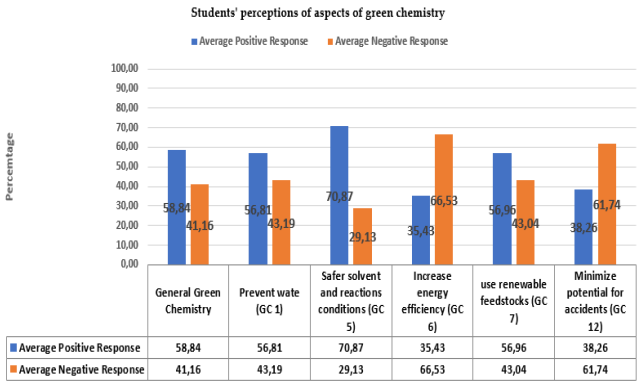

Figure 4. Students' perceptions of aspects of green chemistry

Conclusion

There are five GC Principles that can be integrated in chemistry learning to support education for sustainable development. This is important to do to save the earth whose condition is not good. Massive efforts for both teachers and students need to be made to

promote a better understanding of GC principles. It can be seen from the lack of understanding of teachers and students about GC principles.

Acknowledgments
We would like to thank the Directorate of Research, Technology and Society, Directorate General of Higher Education, Research and Technology for funding research grants under the regular Fundamental Research scheme of 2023. We also thank the Chancellor and Chair of the Makassar State University LP2M for providing the opportunity and facilities in this study.

Author Contributions
Jusniar conceptualized the research idea, designed of methodology, management and coordination responsibility; Syamsidah analyzed data, conducted a research and investigation process; Army Auliah conducted literature review and provided critical feedback on the manuscript.

Funding
This research received funding from the Directorate of Research, Technology and Society, Directorate General of Higher Education, Research and Technology under the regular Fundamental Research scheme of 2023.

Conflicts of Interest
The authors declare no conflict of interest.

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