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THE INTEGRATION OF GREEN CHEMISTRY PRINCIPLES IN BASIC CHEMISTRY LEARNING TO SUPPORT ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT GOALS (SDGs) THROUGH EDUCATION

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Abstract

Recently the trend of words in the world is related to sustainable development such as "green" has become a new trend in everyday human life. This study aimed to analyze and map the chemistry learning with green chemistry insight for undergraduate students of chemistry education program as an effort to conserve the environment as one of the Sustainable Development Goals (SDGs). The urgency of this study is to support the achievement of SDGs through education, especially the target number 12, responsible consumption and production and/or number 13, climate action. Data collection was used exploratory method by combining primary and secondary exploratory framework. The primary method was focused on the observation qualitative or quantitative and the secondary on the literature research. Data analysis were used qualitative and quantitative descriptive. It can be concluded that; the efforts to preserve the environment through education can be pursued with green chemistry insight learning. The principles of green chemistry that can be implemented in chemistry learning on suitable material represent in some action such as; waste prevention, use the safe solvent, energy efficiency, and creating safe and secure conditions in learning both in the classroom and laboratory. Chemistry learning have the role to support SDGs through education by using some learning model/methods, such as discussion, concept map, or practical methods as well as Project Based Learning. So, the results of this study can be refer as an alternative learning that have contribution in SDGs achievement through education.

Keywords – SDGs, Green chemistry, Chemistry learning.

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1. Introduction

The current trend of terms that often heard and being studied by experts such as sustainable development, green chemistry, and sustainable chemistry, etc. (Anastas & Zimmerman, 2018; Chanshetti, 2014) *green industry* (Bolivar, 2019; Grillitsch & Hansen, 2019; Edi & Soebandrija, 2011; UNIDO, 2011), *green technology* (Bhowmik & Dahekar, 2014; Guo, Nowakowska-Grunt, Gorbanyov & Egorova, 2020; Iravani, Akbari & Zohoori, 2017; Mueller, 2017; Odigure, 2016; Wira, Shafiei & Abadi, 2017); *green economy*

(Acharya & Sequeira, 2012; Georgeson, Maslin & Poessinouw, 2017; Khoshnava, Rostami, Zin, Štreimikiene, Yousefpour, Strielkowski. et al., 2019) and so on. The word "green" has become a new trend in human daily life today. Every element of society begins to realize that the Earth is not in a good condition, so we must take action to save our Earth together. Regarding sustainable development, (Gupta & Vegelin, 2016) emphasizes three core concepts, namely social, ecological, and political dimensions that can be applied in 17 target goals known as Sustainable Development *Goals* (SDGs). Green Chemistry is a philosophy or concept that encourages the design of a product or process that reduces or eliminates the use and production of hazardous substances (Manahan, 2005; Anastas & Zimmerman, 2018). The principles of green chemistry can be adapted to be applied in human attitudes and actions in an effort to save the environment which can be realized through education or green education. This is in line with the statement that education has a special role in disseminating green chemistry (Wardencki, Curyło & Namieśnik, 2005).

Sustainable Development and Education for Sustainable Development (ESD) also had been studied a lot (Andersson, Jagers, Lindskog & Martinsson, 2013; Colás-Bravo, Magnoler & Conde-Jiménez, 2018; Evans, Stevenson, Lasen, Ferreira & Davis, 2017; Kioupi & Voulvoulis, 2019; Gokool-Ramdoo, 2017; Segara, 2015). To care the environment there was the significance of educating in values related to sustainability and a relevant importance in the education system to provide ESD (Sánchez, González-Gómez & Jeong, 2022).

Sustainability has been important agenda (Guo, Liang, Sun, Chen, Wang, Li et al., 2022) and detailed as Sustainable Development that has targeted as set out in 17 goals (SDGs) which were categorized into three pillars (social, economic, and environmental) (Clune & Zehnder, 2018; Purvis, Mao & Robinson, 2019); environment, health, and economy (Taghvaee, Nodehi, Saber & Mohebi, 2022) or four pillars namely ethical, social, economy, and environment (Mori, 2014; Suhonen & Sutinen, 2014). Some even categorize it into five pillars that are social, economy, environment, politic, and corporate (Greenland, Saleem, Misra & Mason, 2022); meanwhile (Bervar & Bertoncelj, 2016) proposed the five pillars were economic, social, environmental, and cultural. Environmental pillars are observed and involved in all categories. Environmental pillar involves sustainable chemistry or green chemistry.

This paper presents the results of the study on basic chemistry learning with green chemistry oriented to support the SDGs targets, especially in the environmental pillar, based on the three pillars as simplest pillars categories. From the three pillars can be detailed as 17 targets of SDGS and this study focus on the environment aspect such as implicit on targets no 12 or 13 (Government Sierra Leone, 2016). The study has started from the research in the field of chemistry synthesize procedure with the principles of Green Chemistry and implementation of science character values with green chemistry-oriented (Mitarlis, Azizah & Yonata, 2018). The Basic Chemistry course as a branch of science and its practical activities has a very good opportunity to implement environmental education to realize Green Education. Chemistry students have the privileged opportunity to start from the ground up in expressing and developing the field of green chemistry (Hjeresen, Boese & Schutt, 2000).

Actually, in the implementation of the learning process in the classroom or laboratory activity so far the character values have been inserted, especially those with green chemistry oriented which sometimes we do not aware. Green Chemistry is a philosophy or concept that encourages the design of a product or process that reduces or eliminates the use and production of hazardous substances (Manahan, 2005).

> "*Green chemistry is the practice of chemistry in a manner that maximizes its benefits while eliminating or at least greatly reducing its adverse impacts. Green chemistry is the sustainable practice of chemical science and manufacturing within a framework of industrial ecology in a manner that is sustainable, safe, and non-polluting, consuming minimum amounts of energy and material resources while producing virtually no wastes*".

Green chemistry has 12 principles (Anastas & Warner, 1998) that can be adapted to be applied in human attitudes and behaviors to save the environment. The actions to save the environment can be carried out by implementing them in the field of education at all levels.

Higher education as a continuation and culmination point of the educational process informal education also has a responsibility to participate in preserving the beloved earth. This role can be realized through Green Education. The higher education takes a role in preserving our beloved earth with its eco-campus program. Eco-campus as one of institution program has 10 strategic targets, namely: 1) The success of the urban forest and campus greening program; 2) The success of waste management towards zero waste; 3) The success of the water recycle program; 4) The creation of clean air free of pollution; 5) The creation of a smooth, safe, orderly, and comfortable campus transportation system. 6) The realization of efficiency and savings in the use of electrical energy; 7) Improving water quality and water use efficiency; 8) Implementation of the environmental culture education and learning; 9) Eco Campus-oriented research development; and 10) Evaluation and revitalization of the University development master plan (Syaiful, 2015).

This role in item 8 can be carried out through learning, especially in this case the Basic Chemistry Subject which is programmed by first-year students in the Chemistry Department, so that they can provide these insights early. Therefore, it is very necessary to design learning and equipment with Green Chemistry (GC) oriented that can be implemented to realize Green Education, which can support and fulfill one of the strategic targets of Higher Education program such as Eco campus. By achieving one of the eco campus targets, it is hoped that it can contribute to one of the goals of sustainable development (SDGs) through education.

Sustainable development is developed with the principle of "fulfill the needs of the present without compromising meeting the needs of future generations". Sustainable development refers to use the existing resources to accomplish the needs of the present generation by saving for future generations (Abeyrathna, 2021). This principle is further formulated in the achievement target of 17 SDGs. The efforts to achieve the SDGs target have also been carried out, such as by embedding the values of ESD and SDGs in the curriculum (Zguir, Dubis & Koç, 2021). Studies on the relationship between quality education and ESD and learning with sustainability have also been carried out (Didham & Ofei-Manu, 2020). However, the relationship between education and learning related to the principles of green chemistry and SDGs has not been widely discussed. The whole community have the opportunity to play a role in achieving the SDGs targets, including in the education field. On the other hand, the principle of green chemistry known as sustainable chemistry is important to be integrated in learning to provide early insight to students as the next generation. Thus, it is necessary to study the relationship between sustainable development, green chemistry, and its learning, especially in this case chemistry learning as a reference that can be a guide and motivate the real action as the contribution of education in achieving the SDGs.

Based on the background this study aims to: Describe the relationship between education, green chemistry, SDGs and lesson design at chemistry learning and their contribution in conserving the earth to support one of the SDGs achievement targets; Describe the integration of green chemistry principles in learning to support one of the SDGs achievements; Describe a green chemistry-oriented learning model to support one of the SDGs achievements; and Describe the role of green chemistry-oriented in chemistry learning to support the achievement of SDGs.

2. Research Method

The method of this research is used exploratory research design, emphasizes on the qualitative data more than quantitative (Creswell, 2012). The qualitative research method based on the text (document) or image analysis, have certain stage data analysis, and various research strategy (Rahmawati, Zulhipri, Hartanto, Falani & Iriyadi, 2022).

2.1. Design of The Research

The research used exploratory (Alamer, 2022) design to obtain the deeper understanding (Gama, Sjödin, Parida, Frishammar & Wincent, 2022) of sustainable development, green chemistry and chemistry learning linkages as well as chemistry lesson design to achieve one or more SDGs. The type of exploratory framework was used combination between primary and secondary type research method.

The main stage of this research there were four stages namely; initial stage by preparing and analyzing document of Basic chemistry subject, main stages or second by mapping and describing, third stage developing learning materials and limited trial, and the final stage is evaluation.

2.2. Data Collecting

In this study, data collecting in exploratory was used at the primary method was focused on the observation qualitative or quantitative method was done at the laboratory or classroom activity in Basic Chemistry lesson. Secondary method focused on the literature research method (Zulkipli & Wills, 2021). The secondary method on exploration was used qualitative procedures had been conducted by analyzing and mapping several documents of Basic Chemistry Course. Besides that, data collection was also supported by questionnaires (Criado & Zarate-Alcarazo, 2022). The research procedure involved the development of learning materials with mostly qualitative data, consisting of a preliminary study (with document analysis and mapping) and test of students understanding about green chemistry and how the implementation the principles in learning or daily life. The research subjects were 31 students 4 male and 27 female majoring in chemistry who are programming Basic Chemistry courses.

The instrument of this study used observation sheets, validation questionnaire sheets, response questionnaires, and test instruments. Research tools and materials consist of practical equipment and materials that are commonly used in practical activities for Basic Chemistry courses. In addition, the research materials were used in the form of Basic Chemistry learning documents consisting of Semester Learning Plans (SLP/RPS), student books, and available practicum instructions, as well as library documents and literature related to green chemistry. Other research tools or instruments used at this stage are research instruments in the form of mapping sheets or study sheets and observation sheets.

The research procedure begins with analyzing the curriculum for Basic Chemistry learning. The analysis is carried out on the measurement of learning outcomes, competencies that must be achieved by students, and learning activities experienced by students. Learning activities are associated with the integration of green chemistry principles based on the results of the related literature review. The data analysis technique was carried out in a qualitative and quantitative descriptive based on the data from the document mapping. Data analysis was initial done by organizing, comparing, and linking (Anderson, Krathwohl & Bloom, 2001) based on the suitability of the data obtained.

3. Results and Discussion

3.1. Mapping of Green Chemistry and Sustainable Development in Chemistry Learning

Green Chemistry, also called sustainable chemistry, is a chemical philosophy that encourages the design of products and processes to reduce or eliminate the use and formation of harmful substances. The chemical environment here covers the natural environment and green chemistry in the natural environment serves to reduce and prevent pollution directly from the source. Green Chemistry is very effective because it applies innovative scientific solutions to the world's environmental situations. Green chemistry has 12 principles or principles *Green Chemistry* (Anastas & Warner, 1998) which can be adapted to be applied in human attitudes and actions to save the environment. Actions to save the environment can be carried out from an early age through education to support the achievement of sustainable development targets.

Twelve Principles of Green Chemistry can be stated in simple phrases as follow:

1. Prevent waste
2. Maximize atomic economy
3. Designing safe chemicals and chemical products
4. Design a less dangerous chemical synthesize

5. Use safe solvents and reaction conditions
6. Improve energy efficiency
7. Using renewable raw materials
8. Avoid chemical derivatives:
9. Using a catalyst instead of a stoichiometric reagent:
10. Design chemicals and products that can decompose after use:
11. Analyze in real-time to prevent pollution:
12. Minimize the potential accidents

(Manahan, 2006; Anastas & Warner, 1998).

From the 12 principles of green chemistry that can be implemented in learning, among others, principle number (1) waste prevention; principle number (6) energy efficiency; and principle number (7) use of renewable raw materials; as well as principle number (12) minimize the potential accidents. Meanwhile, sustainable development has three main pillars, as depicted on Figure 1; namely sustainable development related to economic, socio-political, and environmental aspects (Gupta & Vegelin, 2016; Strange & Bayley, 2011). In this study refer to three pillars of SDGs, although there are some state of the SDGs Pillars such as four or five pillars SDGs (Bervar & Bertoncelj, 2016; Tremblay, Fortier, Boucher, Riffon & Villeneuve 2020; Greendland, et al., 2022).

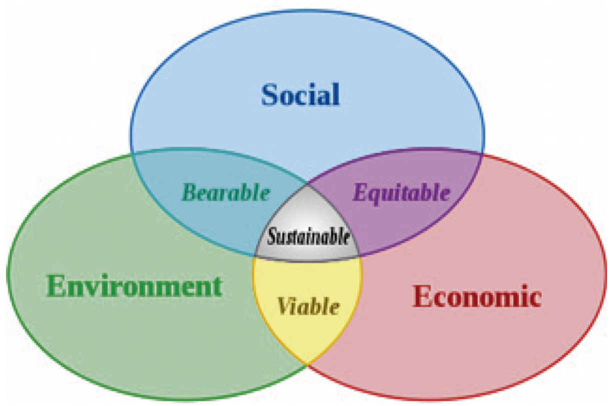


Figure 1. Scheme of sustainable development
(http://www.thwink.org/sustain/glossary/ThreePillars OfSustainability.htm)

Based on its goals, sustainable development has 17 targets (Alisjahbana & Murniningtyas, 2018). One of them is the purpose of item number 12; ensure responsible consumption and production for sustainability and presented in Figure 2. Furthermore, if the several of the certain green chemistry principles (GCP) can be achieve, will give the impact to support the target of SDGs number (13) climate change, such as GCP number (1) waste prevention/reduce. Because it have relationship with the environmental, although environmental chemistry is different from green chemistry (Manahan, 2005).

The pillars of sustainable development and their specific target number (12) responsible consumption and production and target number (13) climate action/climate change action when associated with the principles of green chemistry that can be integrated into learning, especially in this case was Basic Chemistry learning. Learning chemistry in addition to having content or concept aspects that must be studied with classroom learning cannot be separated from experimental activities in the field or in the laboratory which of course require chemical materials. Learning chemistry with a green chemistry oriented by applying principles number 1 (waste prevention), number 5 (used the safe solvent), number 6 (energy efficiency), number 7 (use of renewable feedstock), and number 12 (minimizing the potential for accidents) as presented in Figure 3. It can contribute in achieving the target of sustainable development goals through education.

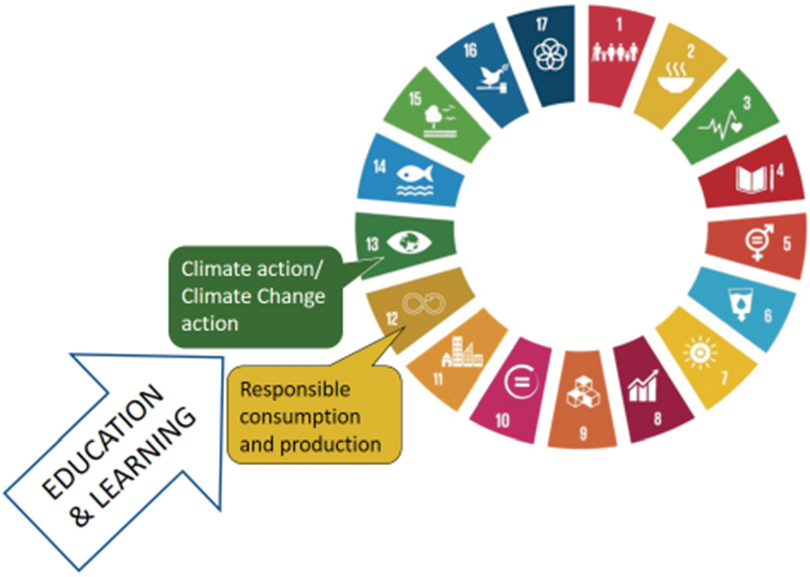


Figure 2. The role of Education in achievement of Seventeen Goals of sustainable development and related target focus (https://public.wmo.int/en/files/sdgs-circlejpg)

Figure 3. Five (yellow mark) of the twelve principles of green chemistry that can be integrated into learning

The five principles of green chemistry that can be integrated into learning in this study especially for the chemistry education program. The choosing based on the appearance of these principles accordance with the learning experience when the students doing practicum especially at the basic chemistry course.

The pattern of linkages between the principles of green chemistry, the pillars, and goals of sustainable development and their integration in chemistry learning is illustrated in Figure 4.

More specifically, the linkage is in the formulation of the SDGs target 12 point 12.5, namely: In 2030, substantially reduce waste production through prevention, reduction, recycling, and reuse and target No. 12 point 12.8 stated that in 2030 ensure the community where also have relevant information and awareness towards sustainable development and lifestyle in harmony with nature. (Alisjahbana &

Murniningtyas, 2018). This can be realized through learning such as basic chemistry by applying the principles of green chemistry no. 1 to prevent or reduce waste generation or number 5 use the safe solvent. The other principles that can be integrated into basic chemistry learning are principle no. 6, energy efficiency, and principle No. 12 create safe conditions and prevent accidents. Hopefully the achievement of this target by implementing learning chemistry with green chemistry oriented will give continued impact that contributes to target no. 13 (climate action) point 13.3, improving education, raising awareness of human and institutional capacity in mitigating and adaptation to climate change and reducing impacts and early warning (Alisjahbana & Murniningtyas, 2018). Thus, the integration of green chemistry principles in chemistry learning is expected to provide knowledge for students and link them in contributing to support the achievement of the SDGs. In line to the result of the previous study (Aubrecht, Bourgeois, Brush, Mackellar & Wissinger, 2019) state that by integrating green chemistry in curriculum, students was equipped with the knowledge and ability to apply green chemistry and sustainable principles and the ability to connect with systems thinking will be prepared to contribute to solve sustainability challenges today's.

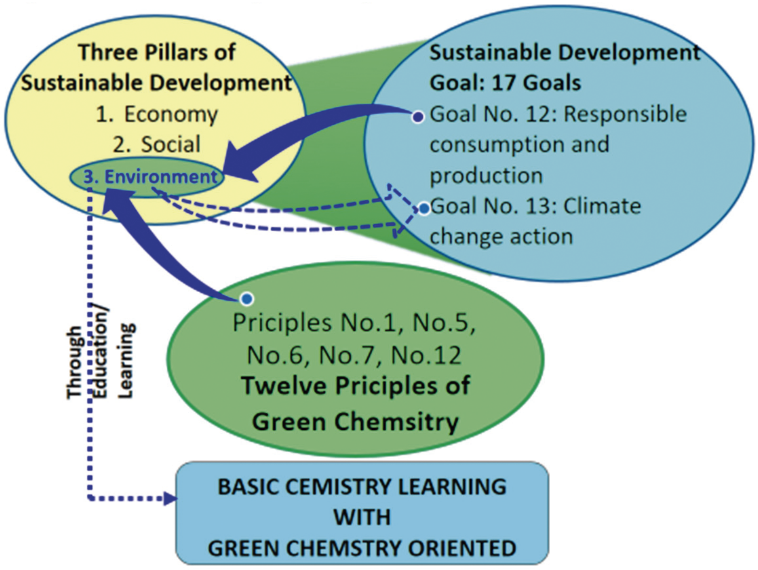


Figure 4. The patterns of linkages between green chemistry and Sustainable Development Goals and their integration in basic chemistry learning

Based on the results of the mapping, there was a linkage between the principles of green chemistry that can be integrated into basic chemistry learning in supporting the achievement of SDGs through education. The integration of the principles of green chemistry begins with the formulation in the lesson plan concerning the formulation of the Semester Learning Plan.

3.2. Semester Lesson Plan (SLP) of Basic Chemistry Course

Analysis was also carried out on the SLP formulated for Basic Chemistry courses. The focus of the SLP analysis was on the components of learning outcomes, indicators, study materials or materials, learning experiences, strategies/models/learning methods used. Based on the Semester Learning Plan, the Basic Chemistry course has the following learning achievement formulations:

1. Utilizing learning resources and ICT to support mastery of concepts and theories of Basic Chemistry.
2. Make decisions about the relationship between basic concepts of chemistry with laboratory activities and the existence of chemistry in everyday life.
3. Know the scientific method, the properties of matter, stoichiometry, atom structure, the periodic system of elements, chemical bonds, energetics, and solutions.

4. Have an honest and responsible attitude in carrying out lectures and practicums.

The learning achievements will be accommodated in the implementation of learning which is also as a reference in the development of basic chemistry learning materials with green chemistry oriented. The descriptions of Basic Chemistry I courses are; Study of basic concepts: Scientific Methods, Properties of Matter, Stoichiometry, Atomic Structure, Periodic System of Elements, Chemical Bonds, Energetics, Solutions, as well as appropriate laboratory activities through discussions, assignments, and practicums. In this case, it is limited to the study of basic concepts: chemistry, the scientific method, properties of matter, which are contained in the Introduction Chapter. The formulation of learning outcomes and descriptions of the Basic Chemistry course is described as competencies that will be mastered by students, namely understanding chemistry as a result of scientific activities studying material with universal properties. In the context of this research, the competencies achieved by students are associated with green chemistry insights. The results of the SLP analysis for Basic Chemistry courses associated with green chemistry insights in the Introduction Chapter are briefly presented in Table 1.

No.	Study material	***Green Chemistry* Principles (GCP)**	Learning Experience	Strategy/Model/ Method of Learning
1	**Introduction:** The stages of the scientific method, Chemistry as a scientific activity, matter and energy, extensive and intensive properties, chemical and physical properties, elements, compounds, and mixtures.	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. Use safe solvents or chemicals, GCP No. 6. Energy Efficiency (Save energy, save chemicals) GCP No. 7. Uses renewable feedstock, and GCP No. 12. Prevent or minimize potential accidents	1. Ask and answer the steps of the scientific method 2. Give examples of extensive and intensive properties, 3. Create concept maps and define chemical and physical properties, elements, compounds, and mixtures 4. Doing practicum with green chemistry oriented in titled mixture separation	1. Discussion Learning Model (Think Pair Share type) 2. Asked and Questions 3. Learning strategies for making concept maps 4. Practicum
2	**Stoichiometry:** Basic Laws of Chemistry, Atoms and Molecules, Mole Concepts, Avogadro's Constant, Compound Formulas, Chemical Reactions and Equalization, Molarity and Equivalents	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. Use safe solvents or chemicals, GCP No. 6. Energy Efficiency (Save energy, save chemicals) GCP No. 7. Uses renewable feedstock, and GCP No. 12. Prevent or minimize potential accidents	1. Practice the problem solving of Basic Chemistry Law. 2. Create a concept map of atoms and molecules, as well as the concept of moles 3. Practice questions on Avogadro's constant and compound formulas, 4. Practice working on chemical reactions and Equivalence, Molarity and Equivalent questions 5. Doing practicum about the law of mass conservation with green chemistry insight	1. Group discussion 2. Assignment 3. Making concept maps 4. Practicum
3	**Solutions:** Electrolyte and non-electrolyte solutions, colligative properties, acid – base, pH of the solution, hydrolysis, common ion, buffer solution, and titration	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. Use safe solvents or chemicals, GCP No. 6. Energy Efficiency (Save energy, save chemicals) GCP No. 7. Uses renewable feedstock, and GCP No. 12. Prevent or minimize potential accidents	1. Summarizing, looking for the main ideas of teaching materials, questions and answers, and practice questions 2. Doing practicum with green chemistry insight on topic: • Electrolyte and non-electrolyte solutions • Acid-base titration • Indicators	1. Cooperative learning model 2. Asked and Questions 3. Practicum

Table 1. Summary of Analysis Result of Basic Chemistry SLP with Green Chemistry Oriented

Based on Table 1, shows the relationship between the study materials for Basic Chemistry courses, the principles of green chemistry, and student learning experiences, as well as the learning model/strategy/method. Overall in this study, during the learning process at basic chemistry course by using cooperative learning model with a question and answer strategy, assignment method and practicum. Thus the appearance of several green chemistry principles was seen during practicum with selected materials such as presented in Table 1. So the appearance was not in all chemistry subject matter and also depends on the model, strategy or learning method used. Study materials of Introduction include studies on chemistry, the stages of the scientific method, chemistry as a scientific activity, matter and energy, extensive and intensive properties, chemical and physical properties, elements, compounds, and mixtures. Student learning experiences during the classroom learning process include; question and answer activities on the steps of the scientific method, provide examples of extensive and intensive properties, create concept maps and define chemical and physical properties, elements, compounds, and mixtures. In addition, it is in the form of learning activities in the laboratory by conducting a mixture separation practicum with green chemistry insights. The next matter about the stoichiometry, which discussing about Basic Chemistry law, atoms and molecules, Mole Concepts, Avogadro's constant, compound formulas, chemical reactions and equalization, molarity and equivalent. Learning experience can be doing by students in this matter such as Practice and discussion about the problem solving of Basic Chemistry law, create a concept map of atoms and molecules, as well as the concept of moles, practice questions on Avogadro's constant and compound formulas, practice working on chemical reactions and Equivalence, Molarity and Equivalent questions and doing practicum about the law of mass conservation with green chemistry insight. Furthermore, an analysis of the learning experience in classroom or in the laboratory is carried out with appear or integration of green chemistry principles and their rationale.

3.3. Analysis of Basic Chemistry Learning Experience with Green Chemistry Oriented

Analysis of basic chemistry learning experiences associated with the green chemistry principles integrated aims to provide rational explanations and determine models/strategies/methods that can be used in learning. Based on the curriculum structure Basic Chemistry courses are given to first semester students. Judging from the students learning experience in lectures, students are still new so they still need to adjust to the atmosphere of the lecture. This is a consideration in choosing a model/strategy/ method of learning. The implementation of Basic Chemistry learning carried out in-classroom for theoretical learning and continued by doing practicum in the laboratory. The analysis was carried out by following the order in which the study material was presented. The results of the learning experience analysis for preliminary study materials can be seen in Table 2.

No.	Learning Experience	Green Chemistry (GC) Principles that can be Integrated	Strategy/Model/ Method of Learning	Rational
1	1. Ask and answer the steps of the scientific method 2. Give examples of extensive and intensive properties, 3. Create concept maps and define chemical and physical properties, elements, compounds, and mixtures 4. Doing practicum of mixture separation with green chemistry insight	Principle No 1. Prevent/reduce the formation of waste Principle No. 6. Save energy, save chemicals when practicum Principle No. 5. Uses safe solvents or chemicals Principle No. 12. Prevent or minimize potential accidents.	1. Discussion Learning Model (Think Pair Share type) 2. Frequently Asked Questions 3. Learning strategies for making concept maps 4. Doing Practicum	• The Think Pair Share (TPS) type of discussion learning model is suitable to be applied in this lesson for new students, discussions are made in pairs. • Learning process was supported by student worksheets with green chemistry insight for preliminary material • The appearance of the GCP No.1 can be integrated in the form of giving examples of the learning atmosphere in the classroom. • Similarly, GCPNo.6 can be related to energy-saving behavior in the classroom.

No.	Learning Experience	Green Chemistry (GC) Principles that can be Integrated	Strategy/Mode 1/ Method of Learning	Rational
2	1. Practice the problem solving of Basic Chemistry Law. 2. Create a concept map of atoms and molecules, as well as the concept of moles 3. Practice questions on Avogadro's constant and compound formulas, 4.. Practice working on chemical reactions and Equivalence, Molarity and Equivalent questions 5. Doing practicum about the law of mass conservation with green chemistry insight	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. Use safe solvents or chemicals, GCP No. 6. Energy Efficiency (Save energy, save chemicals) GCP No. 12. Prevent or minimize potential accidents	1. Group discussion 2. Assignment 3. Making concept maps 4. Practicum	• The group discussion learning model is applied to make students can acquainted with other friends. • This learning is supported by a student worksheet with a green chemistry insight on stoichiometric material in classroom learning. • The GCP No.1 can be appearance in the form of giving examples of the learning atmosphere in the classroom. • Similarly, GCP No.6 can be related to energy-saving behavior in the classroom.
3	1. Summarizing and looking for the main ideas of teaching materials, questions and answers, and practice questions 2. Doing practicum with green chemistry insight on topic: • Electrolyte and non-electrolyte solutions • Acid-base titration • Indicators	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. Use safe solvents or chemicals, GCP No. 6. Energy Efficiency (Save energy, save chemicals) GCP No. 7. Uses renewable feedstock, and GCP No. 12. Prevent or minimize potential accidents	1. Cooperative learning model 2. Asked and Questions 4. Practicum	• Problem based learning model (PBL) is applied to provide a problem solving learning experience. • Learning process is supported by the student worksheet • The practical assignments given are electrolyte and non-electrolyte solutions, natural acid-base indicators and titrations. • Principle of green chemistry No. 1, waste prevention or reduce can be appear by using small scale, so the waste will be produce small too; • Principle No.5, can be done by using saver solvent when preparing natural acid base indicator; • Principle No. 6, can appear if use the small scale it need less energy; and • Principle No. 7, can be done by using natural product (which is the renewable feedstock); as well as • Principle No. 12 can be raised at every practicum activity

Table 2. Data analysis of learning experience in Basic Chemistry Course related to Green Chemistry Principles

Table 2 shows the relationship between the Basic Chemistry learning experience and the principles of green chemistry that can be integrated. Appropriate learning models/strategies/methods have also been identified along with their rationale. These results will underlie the development of learning tools such as Lesson Plan (LP) or Student Worksheet (SW). The appearances of the green chemistry principle as an insight that will be given to students in Basic Chemistry lectures is also identified for both classroom and laboratory learning experiences. Implementation and integration of the principle of green chemistry in learning in the laboratory need to be tested first. This is very important so that the application of the principle of green chemistry can provide benefits according to its objectives, but does not reduce the meaning and essence of the practicum activities carried out. Further analysis and mapping are carried out on the practicum guide documents that support the student learning process following the Basic Chemistry study material. The results of the mapping of representative Basic Chemistry practicum titles with the study materials is presented in Table 3.

No.	Study Material	Green Chemistry (GC) Principles that can be Integrated	Practicum Learning Experience	Practicum
1	**Introduction:** The stages of the scientific method, Chemistry as a scientific activity, matter and energy, extensive and intensive properties, chemical and physical properties, elements, compounds, and mixtures.	Principle No. 1. Prevent/reduce the formation of waste Principle No. 5. Use safe solvents or chemicals Principle No. 6. Save energy, save chemicals when practicum Principle No. 12. Prevent accidents	Doing practicum with green chemistry insight on title a mixture separation topic	1. Elements, compounds, and mixtures (Separation) 2. Separation (solid liquid, evaporation, sublimation) 3. Distillation 4. Physical and chemical changes (demonstration in class)
2	**Stoichiometry:** Basic Laws of Chemistry, Atoms and Molecules, Mole Concepts, Avogadro's Constant, Compound Formulas, Chemical Reactions and Equalization, Molarity and Equivalents	Principle No. 1. Prevent/reduce the formation of waste Principle No. 5. Use safe solvents or chemicals Principle No. 6. Save energy, save chemicals when practicum Principle No. 12. Prevent accidents	Doing practicum the mass conservation law with green chemistry insight	1. Chemical reactions 2. Mass of substances in chemical reaction
3	**Solutions:** Electrolyte and non-electrolyte solutions, colligative properties, acid – base, pH of the solution, hydrolysis, common ion, buffer solution, and titration	Principle No. 1. Prevent/reduce the formation of waste Principle No. 5. Use safe solvents or chemicals Principle No. 6. Save energy, save chemicals when practicum GCP Bo. 7. Used renewable feedstock Principle No. 12. Prevent accidents	Doing practicum of • Electrolyte and non-electrolyte solutions • Acid-base titration • Indicators with green chemistry insight	1. Natural acid base indicator 2. Acid base titration 3. Buffer solution

Table 3. The example of relationship between basic chemistry study materials, and its representative practicum

Table 3 are further analyzed to be able to integrate or implement the principles of green chemistry. Thus the principle of green chemistry can be integrated and does not reduce the purpose and essence of practicum activities, but will provide more meaning with the insight of green chemistry. The analysis was carried out on the possibility of implementing the principles of green chemistry in each selected practicum title.

3.4. Analysis of the Green Chemistry Principles (GCP) and Its Implementation Relationship in Practicum Activities

The results of the analysis of relationship between the meaning of the green chemistry principles and its implementation efforts in practicum activities. The analysis step had been done in the process of developing learning material with green chemistry oriented such as student worksheets. The examples of the analysis result can be seen in Table 4.

No.	Practicum	Green Chemistry Principles (GCP) that can be Integrated	The form of implementation and rationale
1.	TOPIC 1 1. Elements, compounds, and mixtures (Separation) 2. Separation (solid liquid, evaporation, sublimation) 3. Distillation	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. use safe solvents or chemicals GCP No. 6. Energy efficiency (Save energy, save chemicals) GCP No. 12. Prevent accidents	GCP No. 1. Prevent/reduce the formation of waste. This is done by reducing the recipe/dose of the chemicals used. After reacting this material becomes waste. GCP No. 5. By using safe chemicals such as in the sublimation process it is safer to use naphthalene than Iodine. GCP No. 6. By reducing the amount of substance, will be shorten the process duration automatically (can reduce energy if the process requires energy) GCP No. 12. Using safe solvents/chemicals will reduce/prevent accidents
2	TOPIC 2 1. Chemical reaction 2. The law of mass conservation	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 6. Energy efficiency (Save energy, save chemicals) GCP No. 12. Prevent accidents	GCP No. 1. Prevent/reduce the formation of waste. This is done by reducing the recipe/dose of the chemicals used. After reacting this material becomes waste. GCP No. 6. By reducing the amount of substance, will be shorten the process duration automatically (can reduce energy if the process requires energy) GCP No. 12. Using safe solvents/chemicals will reduce/prevent accidents
3	TOPIC 3 1. Natural acid base indicator 2. Acid base titration 3. Buffer solution	GCP No. 1. Prevent or reduce the formation of waste, GCP No. 5. Use safe solvents or chemicals GCP No. 6. Energy efficiency (Save energy, save chemicals) GCP Bo. 7. Used renewable feedstock GCP No. 12. Prevent accidents	GCP No. 1. Prevent/reduce the formation of waste. This is done by reducing the recipe/dose of the chemicals used. After reacting this material becomes waste. GC Principle No.5. By using safer chemicals such as in extraction process of natural ingredients as natural acid base indicator is safer and more economical if it was used water solvent. GCP No. 6. By reducing the amount of substance, will be shorten the process duration automatically (can reduce energy if the process requires energy) GCP No. 7. By using renewable natural materials (such as colored flower extract as an acid base indicator) can support sustainable of learning.

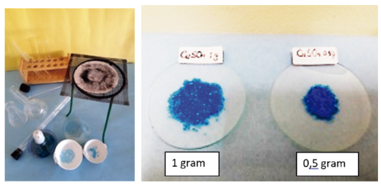
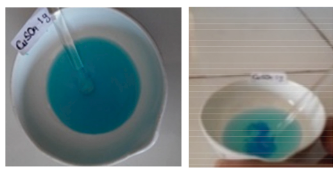
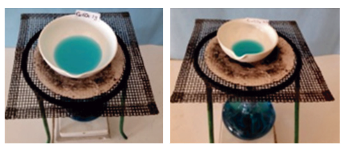
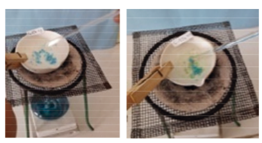
Table 4. The example of Implementation of green chemistry principles in Basic Chemistry Practicum in several Topic

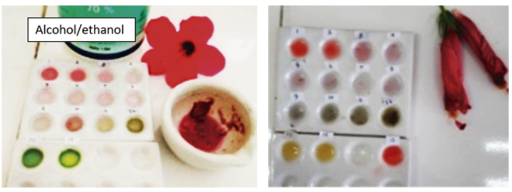
Table 4 shows the results of the analysis and mapping for the study material for the several topic in Basic Chemistry matter or practicum. To facilitate technical work the implementation of basic chemistry practicum divided into several groups topics. One topic can consist of more than one practicum title with different study materials. Grouping in topics based on the complexity or time allocation that was needed to complete practical procedures, so this practicum as an importance learning experience in learning chemistry can be run well. The example of practical materials with titles according to the preliminary study materials were grouped in Topic 1. Topic 1 consists of study materials for elements, compounds, and mixtures. The title of the related practicum is the separation of mixtures (solid-liquid, evaporation, sublimation) and distillation. Topic 2 was involved the practicum of chemicals reaction and mass conservation law. Meanwhile the topic 3 about the natural acid base indicator, acid base titration, and buffer solution. As a supporter of Basic Chemistry lectures with a green chemistry insight, a Student Worksheet (SW) with green chemistry oriented had been developed also. Several principles of green chemistry try to be implemented in the Basic Chemistry practicum. Based on the result of mapping and analysis such as presented in Table 1 to Table 4, there are relationship between education, green chemistry, SDGs and lesson design at chemistry learning and their contribution in conserving the earth to support one of the SDGs achievement. For example study material **Introduction:** The stages of the scientific method, Chemistry as a scientific activity, matter and energy, extensive and intensive properties, chemical and physical properties, elements, compounds, and mixtures **(Table 1)** can be integrated several GCP such as GCP No. 1, Prevent or reduce the formation of waste; GCP No. 5, Use safe solvents or chemicals;

GCP No. 6, Energy Efficiency (Save energy, save chemicals); GCP No. 7, Uses renewable feedstock; and GCP No. 12, Prevent or minimize potential accidents **(Table 2)**. The learning experience by doing practicum with green chemistry insight on title a mixture separation topic such as elements, compounds, and mixtures with the tittle of practicum is separation of mixture (solid liquid, evaporation, sublimation), and distillation **(Table 3).** The rational of integrating of several green chemistry principles in basic chemistry learning is as follows: GCP No. 1, prevent/reduce the formation of waste. This is done by reducing the recipe/dose of the chemicals used. After reacting this material becomes waste, so it can reduce the waste. GCP No.5. By using safe chemicals such as in the sublimation process it is safer to use naphthalene than Iodine. GCP No. 6. By reducing the amount of substance, will be shorten the process duration automatically (can reduce energy if the process requires energy), and GCP No.12. Using safe solvents/chemicals, be careful at work will reduce/prevent accidents **(Table 4).** The other practicum titles such as on the topic of chemical reactions and natural acid-base indicators, also designed based on the results of mapping and analysis that have been presented in Tables 1 to 4, and then tested in the laboratory.

3.5. Limited Trial in the Laboratory

The purpose of the trial is to determine the applicability of green chemistry principles to certain topics without reducing the essence and meaning of the practicum objectives. An example the results of the integration of the green chemistry principles for Topic 1 with the sub-title of the practicum of separating solids and liquids mixture is shown in Table 5.

No.	Procedure	Results	Description
1. TOPIC 1. Separation of Solid and Liquid (Evaporation of $CuSo_4$)			
1	Preparation of Equipment and materials		In the experiment of separating solid and liquid substances, CuSO4.5H2O crystals were used from the initial dose of 1g which was saved to 0.5g. By saving materials can meet the principle of GCP No. 1, 2, and 6.
2	Dissolving process (mixing solid CuSO4 and water as solvent)		By saving materials (solid) will automatically save other materials such as solvents.
			Dissolving process takes less time (less energy) fulfil GCP No. 6. The process of dissolving 1g CuSO4 with 10mL of distilled water takes 2 minutes 10 seconds, while for 0.5g it only takes 1 minute 21 seconds at room temperature with a manual stirrer (spatula).
4	The process of separating mixtures by evaporation		Separation of the mixture by reducing the amount of material also reduces the heating time. Thus the energy required is also less (GCP Principle No. 6)
5	The yield of dry CuSO4 crystal		By applying several of green chemistry principles in this experiment, the results were obtained in the same condition, so that it can achieve the goals of experiment that have been designed.

No.	Procedure	Results	Description
2. TOPIC 2. Chemical reaction			
1	Preparation of tools and materials in experimental for chemical reactions, dehydration of sugar	 The amount of sugar used: Original dose: 1/3 test tube = 5.5g Reduced: 1/6 test tube = 2.7g Reduced again: 1/12 test tube = 1.3g	• In this experiment, the materials needed are sugar and concentrated sulfuric acid. • The amount of sugar used is reduced from the initial dose of 1/3 test tube = 5.5 g; halved (1/6 test tube = 2.5 g); even a quarter of the initial dose (1/12 test tube = 1.3 g) • Concentrated sulfuric acid used is quite dangerous, by reducing the dose will reduce the hazard (GCP No.12). In addition, experiments were also carried out by following laboratory safety procedures
2	Dehydration reaction of sugar		• By reducing the amount of material will also reduce the other reagents used automatically • Reaction products are not used and become practical waste, by reducing the amount of material it also reduces the formation of waste (GCP No.1) • Concentrated H_2SO_4 reagent used is also reduced so as to reduce or prevent accidents (GCP No.12)
3	The result of sugar dehydration reaction		• The reaction results show that reducing the amount of material gives the same results according to the expected practicum objectives. • The result of the dehydration reaction of sugar gives a black color which indicates the presence of the carbon element.
3. TOPIC 3. Acid Base Natural Indicator			
1	Acid base natural indicator of hibiscus flower extract with alcohol solvent	 (A) (Mitarlis, Azizah & Yonata, 2019) (B) The color change of alcohol extract of fresh (A) and wilted (B) hibiscus flower in several pH: pH 0 = red pH 1 = bright red pH 2-4 = bright purple pH 5-8 = dark purple pH 9-10 = light green pH 11-12 = dark green pH 10-12 = brownish green pH 13 = yellowish green pH 14 = dark yelow	• Red hibiscus flower extract showed different color changes at various pH values. Both of alcohol extracts from fresh flowers and wilted flowers showed color changes in several pH values. • Extraction process by using alcohol as a solvent is easier than using water solvent. Because the water solvent produces a very slimy extract, so the extraction process is bit difficult such as at grinding or filtering.

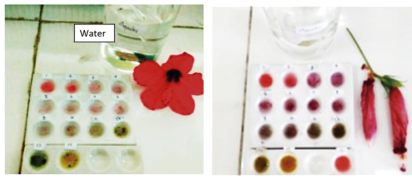
No.	Procedure	Results	Description
2	Acid base natural indicator of hibiscus flower extract with water solvent	 (A) (Mitarlis et al., 2019) (B) The color change of water extract of fresh (A) and wilted (B) hibiscus flower in several pH: pH 0 = red pH 1 = bright red pH 2-4 = bright purple pH 5-8 = dark purple pH 9-10 = light green pH 11-12 = dark green pH 10-12 = brownish green pH 13 = yellowish green pH 14 = dark yelow	• The red hibiscus flower water extract also showed different color changes at various pH values. Both of extracts from fresh flowers and wilted flowers showed very clear color changes in several pH values. • By using water solvent, produce a clearer color change. Water solvent is safer and cheaper than alcohol. • The pH and color trajectories are similar to extracts using alcohol solvents but extracts using water solvent produce a clearer color.

Table 5. Example of Trial results of the Students Worksheet on Several Practicum

Limited tests in laboratory for separating mixtures (liquids from solids) with evaporation process by integrating some of the green chemistry principles through material savings, will automatically save the energy needed in the process as shown in Table 5 Topic 1, but the results are the same, to achieve the goals that have been set. The implication of this effort to save materials can also automatically reduce the waste of practicum activities carried out. The application of several principles of green chemistry such as in the experiment of separating solid and liquid substances using $CuSO_4.5H_2O$ crystals from the initial dose of 1g was saved to 0.5g; can meet the principle of GC No. 1, 5, 6, and 12. The process of dissolving 1g $CuSO_4$ with 10mL distilled water takes 2 minutes 10 seconds, while for 0.5g it only takes 1 minute 21 seconds at room temperature with a manual stirrer (spatula). This dissolution process requires a shorter time so that it is more energy efficient (GCP No. 6). Separation of the mixture by reducing the amount of material (Small scale) also reduces the heating time. Thus the energy required is also less (GCP No. 6). By saving the reaction products which are usually immediately disposed of, there is also less. Thus, it can prevent or minimize the formation of waste from practical activities.

The second Topic on Table 5 the dehydration reaction of sugar in variation dose start from standard dose to small dose indicate were shown the similar results. Dehydration reaction of sugar by using small scale is implement the green chemistry principle No.1, because by using small scale materials can also reduce the waste of practicum activities automatically. Concentrated sulfuric acid as reagent used is also reduced so as to reduce or prevent accidents (GCP No.12). The reaction results show that reducing the amount of material became small scale gives the same results according to the expected practicum objectives. In line the statement that by using smaller scale and safer apparatus, is expected to reduce less waste (Listyarini, Pamenang, Harta, Wijayanti, Asy'ari & Lee, 2019). The result of the dehydration reaction of sugar gives a black color which indicates the presence of the carbon element. The reaction results show that reducing the amount of material gives the same results according to the expected practicum objectives.

The Topic three on Table 5 about the acid base natural indicator is show the application of green chemistry principles are GCP No. 7, use the renewable feedstock by using renewable plant such as hibiscus flower. The extraction process was used water solvent as the safer solvent, it mean can apply GCP No. 5. In this practicum had been done by small scale of course to reduce or prevent the waste formation (GCP No. 1). The use of wilted hibiscus flowers can be an alternative and has the advantage that to use it as a natural acid-base indicator does not have to reduce the other benefits of the flowers used, for example, it can still be enjoyed for its beauty when the flower crown is blooming and fresh. Thus, supporting for the SDGs can still be achieved, especially related to environmental conservation, although it is still in small scope.

Based on the description and discussion, it can be understood that by preventing or reducing the formation of waste, saving materials, saving energy as an effort to help preserve the environment through learning. Reducing the amount of material needed will also extend the availability of materials so that the sustainability of practicum activities will increase and be more guaranteed to be carried out and reduce the formation of waste. This result was supported by the statement that learning green chemistry and its practices are required to continue building a sustainable environment (Günter, Akkuzu & Alpat, 2017). This learning experience in the form of practical activities with green chemistry insight is important to be given to students as a provision to be able to participate and contribute in supporting the achievement of SDGs through education both as students and as professionals in the future. When students become a part of professional life, Green, as well as sustainability, are crucial opportunities. Going Green in higher education helps enhancing public image, retaining the highly committed employees, students who value sustainability in life (Abeyrathna, 2021). There were many study in adoption green and sustainable chemistry approach (Derbenev, Dowden, Twycross & Hirst, 2022). The study already discuss about green chemistry perspective not only as a single discipline or a traditional chemistry but also need multiple interdisciplinary as a challenge (Constable, 2021).

Based on the results of stages in this study, from the curriculum analyzing, mapping and limited trial in laboratory it was found the linkage between chemistry learning, green chemistry and sustainable chemistry to support SDGs through education. This is also state by (Aubrecht et al., 2019) that, students was equipped with the knowledge and ability to apply green chemistry and sustainable principles and the ability to connect with systems thinking will be prepared to contribute to solve sustainability challenges today's by integrating green chemistry in curriculum. In this study supported by data from the implementation of the integrating green chemistry principles on basic chemistry learning.

3.5. Integrating Green Chemistry Principles on Basic Chemistry Learning

Implementation of integrating of GCP in Basic Chemistry learning to support SDGs through education used learning tools of basic chemistry with green chemistry insight that have been developed. The learning materials developed have been validated by experts and declared valid. The learning process was observed and tested students understanding and given a student response questionnaire to basic chemistry learning with green chemistry insight to support the achievement of the SDGs.

Based on the observation results implementation of integrating GCP on Basic Chemistry learning to support SDGs through education can be run well. The student responses from questionnaires about the learning materials such as Basic Chemistry student worksheet with Green Chemistry Insight (SWGCI) and implementation of GCP in Basic Chemistry learning as presented on Table 6.

Based on Table 6, most of the student responses showed a positive response in both of category good and very good or agree and strongly agree total above 80%. Thus, it can be concluded that in general students gave a positive response to the tools of Basic Chemistry learning with green chemistry insight and its implementation.

The test instrument was used to determine students' understanding of green chemistry. The test instrument concerns aspects of knowledge about green chemistry, implementation in learning especially basic chemistry, and implementation of the meaning that contained in green chemistry concept in everyday life. The first question as a simple diagnostic about students understanding to green chemistry. The results of the test shown in Table 7.

Table 7 show the results of the pretest and posttest that carried out before and after learning. Referring to the objectives of this study which have been formulated at the beginning, including describing the role of green chemistry-oriented in chemistry learning to support the achievement of SDGs through education. Thus, in this study the test results presented on quantitative descriptive in percentage of correct answer as achievement of classical learning outcomes.

No.	Question/Statement	Students Response (%)				
		1	2	3	4	5
1.	What do you think about the Basic Chemistry SWGCI used in the classroom?	VP	NG	QG	B	SB
		-	-	17.2	62.1	20.7
2.	What do you think about the Basic Chemistry SWGCI used in the laboratory?	VP	NG	QG	G	VG
		-	-	3.4	86.2	10.4
3.	What do you think about the implementation of Basic Chemistry SWGCI used in the classroom?	VP	NG	QG	G	VG
		-	-	20.7	58.6	20.7
4.	What do you think about the implementation of Basic Chemistry SWGCI used in the laboratory?	VP	NG	QG	G	VG
		-	-	13.8	86.2	-
5.	Is learning with the SWGCI useful for you?	NB	LB	QB	B	VB
		-	-	10.4	51.7	37.9
6.	How important do you think the learning with green chemistry is?	VU	NI	QI	I	VI
		-	-	20.6	44.8	34.5
7.	Learning with green chemistry insight can be implemented in other lessons besides basic chemistry	SDA	DA	QA	A	SA
		-	6.9	31.1	51.7	10.3
8.	Learning with green chemistry insight can be easily understood	SDA	DA	QA	A	SA
		-	6.9	41.4	48.3	3.4
9.	Learning with green chemistry insights can be implemented in the classroom, in the laboratory, or even in daily life.	SDA	DA	QA	A	SS
		-	-	13.8	62.1	24.1
10.	Do you agree if the meaning contained in the principle of green chemistry is applied in everyday life?	SDA	DA	QA	A	SA
		-	-	-	77.3	22.7

Note: VP= very poor, NG = not good, QG = quite good, G= good, VG = very good
NB= not benefit, LB = less benefit, QB= quite benefit, B = benefit, VB = very benefit,
VU = very unimportant, NI= not important, QI = quite important, I= important, VI = very important
SDA = strongly disagree, DA = disagree, QA = quite agree, A = agree, SA= strongly agree

Table 6. Student responses to basic chemistry SWGCI and its implementation

No.	Question	Answer key	Correct Answer (%)	
			Pre	Post
1.	Based on your knowledge as a chemistry student, is green chemistry the same as environmental chemistry?	Not same, even though there is a strong relationship.	12.90	77.42
2.	If you have ever heard of green chemistry, how many green chemistry principles were formulated by Paul Anastas?	There are 12 principles of green chemistry	0	100
3.	When you work in a laboratory using as few chemicals as possible (little dose) which GCP do you apply?	GCP No. 1, Prevent or reduce the formation of waste	19.35	83.87
4	You are prefer use water solvents over alcohol solvents during the natural indicator extraction practicum, which GCP do you apply?	GCP No. 5, Use safe solvents or chemicals	58.06	93.55
5	You are prefer to walk when you leave the campus or to a place that is not too far away, so saving fuel, which GCP do you apply?	GCP No. 6, Energy Efficiency	16.13	96.77
6.	You are prefer to bring your own drinking bottle so it doesn't cause producing a lot of waste, which GCP do you apply?	GCP No. 1, Prevent or reduce the formation of waste	51.61	93.55
7.	You always turn off the electric current source on equipment/lamps that are no longer used, which GCP do you apply?	GCP No. 6, Energy Efficiency	58.06	93.55
8.	Utilizing natural resources that can be used for chemistry learning in experiments activity, which GCP do you apply?	GCP No. 7, Uses renewable feedstock	38.71	96.77
9	Always put back the packaging cover/bottle cap when finished using substances while working in the laboratory or in daily life, so that keep save conditions, which GCP do you apply?	GCP No. 12. Prevent or minimize potential accidents	51.61	96.77
10	Work carefully in the use of materials in the laboratory, so that it is safe and secure at work, which GCP do you apply?	GCP No. 12. Prevent or minimize potential accidents	38.71	93.55

Table 7. The results of test of students' understanding of Green Chemistry (GC) insight

The results of the pretest showed that the percentage of correct answers was less than 60% for all items, while the results of the post test showed that the achievement of correct answers was above 80% for almost all items. One question item only has the number of correct answers less than 80% namely 77.42% related to understanding of green chemistry, some students (22.58%) understand that green chemistry is the same as environmental chemistry. Whereas green chemistry is different from environmental chemistry, although both of them are often interrelated. Green chemistry also called sustainable chemistry (Manahan, 2005).

The important finding from this study is to support for sustainable development goals can be done in various ways. One of them is through education. Education can be used as a means to train behavior, especially those with green chemistry insight. An effort to preserve the environment through green chemistry-oriented learning can be pursued by carrying out green chemistry-oriented learning activities. The principles of green chemistry can be implemented in chemistry learning with the action of saving materials, energy efficiency, and creating safe conditions in learning both in the classroom and the laboratory; Learning models that can be used to integrate the principles of green chemistry in chemistry learning in classroom such as mixture separation materials by using think pair share type discussion model, stoichiometry by using concept map or mind map strategies, question and answer methods or practical methods. In addition the learning model in acid base indicator can use Project Based Learning.

4. Conclusion

Based on the data analysis of this study by mapping the curriculum for basic chemistry courses, learning outcomes, and learning experiences with integrate the principles of green chemistry, it can be concluded that; The integration of green chemistry principles in insightful chemistry learning to support the achievement of the SDGs can be carried out properly., Several principles of green chemistry can be implemented in chemistry learning with material-saving behavior which will automatically reduce the formation of waste (GCP No. 1), use safer solvent (GCP No. 5), *energy efficiency* (GCP No. 6), use the renewable feedstock (GCP No. 7), *and creating safe and secure conditions (*GCP No. 12), *in learning both at the classroom and laboratory; Chemistry learning has a role to support SDGs through education especially for environment pillar on target No. 12, responsible consumption and production.* Learning chemistry with a green chemistry oriented can play a role in supporting the SDGs, especially in the environmental pillar goal number 12; responsible consumption and production. Learning models that can be used to integrate the principles of green chemistry in chemistry learning in classroom such as mixture separation materials by using think pair share type discussion model, stoichiometry by using concept map or mind map strategies, question and answer methods or practical methods. In addition the learning model in acid base indicator can use Project Based Learning. So, the results of this study can be refer as an alternative learning that have contribution in SDGs achievement through education.

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References

Abeyrathna, A.W.G.N.M. (2021). Green Education in a University Classroom: Benefits and Challenges. *SSRN Electronic Journal*, March. https://doi.org/10.2139/ssrn.3809215

Acharya, S., & Sequeira, A.H. (2012). A Model of Green Economy for Developing Countries. *SSRN Electronic Journal*, *December*. https://doi.org/10.2139/ssrn.2192369

Alamer, A. (2022). Exploratory structural equation modeling (ESEM) and bifactor ESEM for construct validation purposes: Guidelines and applied example. *Research Methods in Applied Linguistics*, 1(1), 100005. https://doi.org/10.1016/j.rmal.2022.100005

Alisjahbana, A.S., & Murniningtyas, E. (2018). *Tujuan Pembangunan Berkelanjutan di Indonesia*. Unpad Press.

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

Anastas, P.T., & Zimmerman, J.B. (2018). The United Nations sustainability goals: How can sustainable chemistry contribute? *Current Opinion in Green and Sustainable Chemistry*, 13, 150-153. https://doi.org/10.1016/j.cogsc.2018.04.017

Anderson, L.W., Krathwohl, D.R., & Bloom, B.S. (2001). *A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives*. Longman. Available at: http://books.google.com/books?id=JPkXAQAAMAAJ&pgis=1

Andersson, K., Jagers, S.C., Lindskog, A., & Martinsson, J. (2013). Learning for the future: Effects of education for sustainable development (ESD) on teacher education students. *Sustainability (Switzerland)*, 5(12), 5135-5152. https://doi.org/10.3390/su5125135

Aubrecht, K.B., Bourgeois, M., Brush, E.J., Mackellar, J., & Wissinger, J.E. (2019). Integrating Green Chemistry in the Curriculum: Building Student Skills in Systems Thinking, Safety, and Sustainability. *Journal of Chemical Education*, 96(12), 2872-2880. https://doi.org/10.1021/acs.jchemed.9b00354

Bervar, M., & Bertoncelj, A. (2016). The Five Pillars of Sustainability : Economic, Social, Environmental, Cultural and Security Aspects. *Management International Conference* (243-244). Available at: http://www.hippocampus.si/ISBN/978-961-6984-26-3/151.pdf

Bhowmik, A., & Dahekar, R.M. (2014). Green technology for sustainable urban life. *Recent Research in Science and Technology*, 6(1), 4-8. http://recentscience.com/%5Cnhttp://scienceflora.org/journals/index.php/rrst/article/viewFile/1151/1136

Bolivar, V. (2019). *The role of Green Industry in the context of the Green Economy / Green Growth strategy of Peru. Policies, initiatives, obstacles and required policies*. February.

Chanshetti, U. (2014). Green Chemistry : Challenges and Opportunities Review Article Green Chemistry : Challenges and Opportunities in Sustainable Development. *International Journal of Current Research*, November.

Clune, W.H., & Zehnder, A.J.B. (2018). The Three Pillars of Sustainability Framework: Approaches for Laws and Governance. *Journal of Environmental Protection*, 09(03), 211-240. https://doi.org/10.4236/jep.2018.93015

Colás-Bravo, P., Magnoler, P., & Conde-Jiménez, J. (2018). Identification of levels of sustainable consciousness of teachers in training through an e-portfolio. *Sustainability (Switzerland)*, 10(10), 1-18. https://doi.org/10.3390/su10103700

Constable, D.J.C. (2021). Green and Sustainable Chemistry – The Case for a Systems-based, Interdisciplinary Approach. *iScience*, 24(12), 1-9. https://doi.org/10.1016/j.isci.2021.103489

Creswell, J.W. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Boston: Pearson Education, Inc.

Criado, J.I., & Zarate-Alcarazo, L.O. (2022). Technological frames, CIOs, and Artificial Intelligence in public administration: A socio-cognitive exploratory study in Spanish local governments. *Government Information Quarterly*, 39(3), 101688. https://doi.org/10.1016/j.giq.2022.101688

Derbenev, I.N., Dowden, J., Twycross, J., & Hirst, J.D. (2022). Software tools for green and sustainable chemistry. *Current Opinion in Green and Sustainable Chemistry*, 35, 100623. https://doi.org/10.1016/j.cogsc.2022.100623

Didham, R.J., & Ofei-Manu, P. (2020). Adaptive capacity as an educational goal to advance policy for integrating DRR into quality education for sustainable development. *International Journal of Disaster Risk Reduction*, 47(May 2019), 101631. https://doi.org/10.1016/j.ijdrr.2020.101631

Edi, K., & Soebandrija, N. (2011). Persepsi Green Industry Di Indonesia: Kondisi Sekarang, Tantangan Dan Pola Pikir Barupersepsi Green Industry Di Indonesia: Kondisi Sekarang, Tantangan Dan Pola Pikir Baru. *Industrial and Systems Engineering Assessment Journal (INASEA)*, 12(1), 55-67.

Evans, N.S., Stevenson, R.B., Lasen, M., Ferreira, J.A., & Davis, J. (2017). Approaches to embedding sustainability in teacher education: A synthesis of the literature. *Teaching and Teacher Education*, 63, 405-417. https://doi.org/10.1016/j.tate.2017.01.013

Gama, F., Sjödin, D., Parida, V., Frishammar, J., & Wincent, J. (2022). Exploratory and exploitative capability paths for innovation: A contingency framework for harnessing fuzziness in the front end. *Technovation*, 113(November 2021). https://doi.org/10.1016/j.technovation.2021.102416

Georgeson, L., Maslin, M., & Poessinouw, M. (2017). The global green economy: a review of concepts, definitions, measurement methodologies and their interactions. *Geo: Geography and Environment*, 4(1). https://doi.org/10.1002/geo2.36

Gokool-Ramdoo, S.A.B. (2017). Education for Sustainable Development: Connecting the Dots for Sustainability. *Journal of Learning for Development*, 4(1), 72-89. https://doi.org/10.56059/jl4d.v4i1.170

Government Sierra Leone (2016). *United Nations Sustainable Development Goals. The 2030 Agenda for Sustainable Development.* Advanced Draft Report on Adaptation of the Goals in Sierra Leone. Government of Sierra Leone Ministry of Finance and Economic Development. Available at: https://sustainabledevelopment.un.org/content/documents/10720sierraleone.pdf (Accessed: April 2017).

Greenland, S., Saleem, M., Misra, R., & Mason, J. (2022). Sustainable management education and an empirical five-pillar model of sustainability. *International Journal of Management Education*, 20(3), 100658. https://doi.org/10.1016/j.ijme.2022.100658

Grillitsch, M., & Hansen, T. (2019). Green industry development in different types of regions. *European Planning Studies*, 27(11), 2163-2183. https://doi.org/10.1080/09654313.2019.1648385

Günter, T., Akkuzu, N., & Alpat, Ş. (2017). Understanding 'green chemistry' and 'sustainability': an example of problem-based learning (PBL)*. *Research in Science and Technological Education*, 35(4), 500-520. https://doi.org/10.1080/02635143.2017.1353964

Guo, H., Liang, D., Sun, Z., Chen, F., Wang, X., Li, J. et al. (2022). Measuring and evaluating SDG indicators with Big Earth Data. *Science Bulletin*. https://doi.org/10.1016/j.scib.2022.07.015

Guo, M., Nowakowska-Grunt, J., Gorbanyov, V., & Egorova, M. (2020). Green technology and sustainable development: Assessment and green growth frameworks. *Sustainability (Switzerland)*, 12(16). https://doi.org/10.3390/su12166571

Gupta, J., & Vegelin, C. (2016). Sustainable development goals and inclusive development. *International Environmental Agreements: Politics, Law and Economics*, 16(3), 433-448. https://doi.org/10.1007/s10784-016-9323-z

Hjeresen, D.L., Boese, J.M., & Schutt, D.L. (2000). Green Chemistry and Education. *Journal of Chemical Education*, 77(12), 1543. https://doi.org/10.1021/ed077p1543

Iravani, A., Akbari, M.H., & Zohoori, M. (2017). Advantages and Disadvantages of Green Technology; Goals, Challenges and Strengths. *International Journal of Science and Engineering Applications*, 6(9), 272-284. https://doi.org/10.7753/ijsea0609.1005

Khoshnava, S.M., Rostami, R., Zin, R.M., Štreimikiene, D., Yousefpour, A., Strielkowski, W. et al. (2019). Aligning the criteria of green economy (GE) and sustainable development goals (SDGs) to implement sustainable development. *Sustainability (Switzerland)*, 11(17). https://doi.org/10.3390/su11174615

Kioupi, V., & Voulvoulis, N. (2019). Education for sustainable development: A systemic framework for connecting the SDGs to educational outcomes. *Sustainability (Switzerland)*, 11(21). https://doi.org/10.3390/su11216104

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

Manahan, S.E. (2005). Green Chemistry and the Ten Commandments of Sustainability. In *ChemChar Research, Inc.*

Manahan, S.E. (2006). *Green Chemistry and the Ten Commandments of Sustainability*. ChemChar Research, Inc. https://www.asdlib.org/onlineArticles/ecourseware/Manahan/GreenChem-2.pdf

Mitarlis, M., Azizah, U., & Yonata, B. (2018). Learning Design to Integrate Scientific Character Values with Green Chemistry Insight in Basic Chemistry Course. *Proceedings of the 1st International Conference on Education Innovation (ICEI 2017)* (222-225). https://doi.org/10.2991/icei-17.2018.58

Mitarlis, M., Azizah, U., & Yonata, B. (2019). Utilization of Colored Flowers as An Alternative Learning Media of Acid Base Indicator On Basic Chemistry Course With Green Chemistry Insight. *Proceedings of the National Seminar on Chemistry 2019 (SNK-19).* https://www.atlantis-press.com/proceedings/snk-19/125929229 https://doi.org/10.2991/snk-19.2019.36

Mori, K. (2014). Global Justice in the Anthropocene: The Fourth Pillar Debate in Sustainable. *Development. The Journal of Social Science*, 77, 101-122. https://core.ac.uk/download/234716943.pdf

Mueller, S. (2017). Green technology and its effect on the modern world. *Oulu University of Applied Sciences "Business Information Technology"*, 54. https://core.ac.uk/download/pdf/84793641.pdf

Odigure, J.O. (2016). Green Technology : A Veritable Tool for Achieving Technological Transformation and Diversification of the Nation's Economy. *7th Biennial National Engineering Conference*, *September* (1-16).

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*, 14(3), 681-695. https://doi.org/10.1007/s11625-018-0627-5

Rahmawati, Y., Zulhipri, Hartanto, O. Falani, I., & Iriyadi, D. (2022). Students' conceptual understanding in chemistry learning using PhET interactive simulations. *Journal of Technology and Science Education*, 12(2), 303-326. https://doi.org/10.3926/jotse.1597

Sánchez, M.A., González-Gómez, D., & Jeong, J.S. (2022). Service Learning as an Education for Sustainable Development (ESD) Teaching Strategy: Design, Implementation, and Evaluation in a STEM University Course. *Sustainability*, 14(12), 6965. https://doi.org/10.3390/su14126965

Syaiful (2015). *Dapat Skor 100, Unesa Sabet Juara 1 Eco Campus*. Availabel at: https://www.unesa.ac.id/dapat-skor-100-unesa-sabet-juara-1-eco-campus (Accesed: October 2015)

Segera, N.B. (2015). Education For Sustainable Development (ESD) Sebuah Upaya Mewujudkan Kelestarian Lingkungan. *Sosio Didaktika: Social Science Education Journal*, 2(1), 22-30. https://doi.org/10.15408/sd.v2i1.1349

Strange, T., & Bayley, A. (2011). Sustainable Development - Linking economy, society, environment. *Energy Policy*, 39(10-2), 6082-6099. https://doi.org/10.1016/j.enpol.2011.07.009

Suhonen, J., & Sutinen, E. (2014). The Four Pillar Model -Analysing The Sustainability Of Online Doctoral Programmes. *Techtrends Tech Trends*, 58, 81-88. https://doi.org/10.1007/s11528-014-0772-3

Taghvaee, V.M., Nodehi, M., Saber, R.M., & Mohebi, M. (2022). Sustainable development goals and transportation modes: analyzing sustainability pillars of environment, health, and economy. *World Development Sustainability*, 1(June), 100018. https://doi.org/10.1016/j.wds.2022.100018

Tremblay, D., Fortier, F., Boucher, J.F., Riffon, O., & Villeneuve, C. (2020). Sustainable development goal interactions: An analysis based on the five pillars of the 2030 agenda. *Sustainable Development*, 28(6), 1584-1596. https://doi.org/10.1002/sd.2107

UNIDO (2011). *Unido Green Industry Initiative for Sustainable Industrial Development*. Vienna: United Nations Industrial Development Organization. Available at: https://www.unido.org/sites/default/files/2011-05/web_policies_green_industry_0.pdf (Accessed: November 2020).

Wardencki, W., Curyło, J., & Namieśnik, J. (2005). Green chemistry - Current and future issues. *Polish Journal of Environmental Studies*, 14(4), 389-395.

Wira, M., Shafiei, M., & Abadi, H. (2017). The Importance of Green Technologies and Energy Efficiency for Environmental Protection. *International Journal of Applied Environmental Sciences*, 12(5), 937-951.

Zguir, M.F., Dubis, S., & Koç, M. (2021). Embedding Education for Sustainable Development (ESD) and SDGs values in curriculum: A comparative review on Qatar, Singapore and New Zealand. *Journal of Cleaner Production*, 319(August), 128534. https://doi.org/10.1016/j.jclepro.2021.128534

Zulkipli, N.H.N., & Wills, G.B. (2021). An Exploratory Study on Readiness Framework in IoT Forensics. *Procedia Computer Science*, 179, 966-973. https://doi.org/10.1016/j.procs.2021.01.086

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