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ADAPTATION OF BASIC CHEMISTRY LEARNING WITH GREEN CHEMISTRY ORIENTED

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Abstract - The principles of green chemistry can be implemented in chemistry learning. Basic Chemistry learning with Green Chemistry insight can also be adapted to high school chemistry learning. This study aims to describe basic chemistry learning, adaptations of chemistry learning and design of chemistry learning with green chemistry insight at high school based on the results of previous research. The method used in this study was a systematic review, namely a systematic narrative review conducted by mapping or systematic mapping study. Sources of data from electronic documents were traced through Google searching, ERIC document data, and research gates with the keyword's green chemistry and green education. The results show that basic chemistry learning can apply several principles of green chemistry. The principles (preventing/reducing waste, saving energy, and using renewable feedstock) can be implemented in several chemistry topics. The topics cover separating mixtures, chemical reactions, fundamental laws of chemistry, acids and bases, and reaction rates. Also, green chemistry can be adapted to high school chemistry even though it has not been stated in the chemistry curriculum. The design of chemistry learning with green chemistry insight can apply several learning models, such as Problem Based Learning (PBL), Project Based Learning (PjBL), and Inquiry or Contextual Teaching and Learning (CTL).

Keywords: *Green chemistry; Chemistry learning; Learning design*

INTRODUCTION

Environmental issues are still actual until now. Various parties have also tried to preserve the environment through various aspects, including education. Many environmental problems are also studied in environmental science, specifically related to fields of study such as environmental chemistry. The most actual issue currently being studied is related to green chemistry. Green chemistry is different from environmental chemistry but interrelated (Anastas, 1998); (Manahan, 2006: 5-10); Carabineiro, 2021)

Contributions to education can be made to design a learning process that cares about the environment. In chemistry education, applying the Green Chemistry principles in laboratory activities is expected to answer these challenges (Al Idrus, 2020). The American Chemical Society Green Chemistry Institute (ACS GCI) suggests mainstreaming green chemistry into the chemistry education curriculum (Mackellar, 2020).

The role of chemistry and chemistry education is very important in promoting and applying the principles of green chemistry in learning. This becomes important related to the condition of environmental damage that is currently happening. At this time, it shows that chemistry education has not contributed optimally to preserving the environment (Sudarmin, 2013). Thus,

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learning chemistry with a green chemistry perspective to foster an attitude of caring for the environment needs to be instilled from an early age. This effort has a problem green chemistry has not become a norm in the world of education or learning by positioning it as the mission and vision of education or formulated in the curriculum, including chemistry education (Sudarmin, 2013). However, the urgency to preserve and overcome environmental problems by preventing or minimising some problems that can arise is studied in the field of learning by applying the principles of green chemistry both at the college and high school levels.

Many studies on green chemistry at the university level have been carried out (Mitarlis, 2016; Summerton, 2018; Paristowati, 2019; Mirzaei, 2019; Chen, 2020; Al Idrus, 2020; Listyarini, 2020; Carabineiro, 2021) and other researchers. Likewise, at the SMA/MA level (Saptorini, 2014; Rosita, 2014; Afiyanti, 2014; Ahmadi, 2016; Redana, 2017; Risna, 2019; Arif, 2020) and other researchers, even at SMK (Auliah, 2018). Green chemistry-oriented learning is studied not only in science learning but also in the arts (Parrish, 2020). Based on the background described, it is necessary to study the literature on the results of previous research related to green chemistry learning. However, it has not been formulated in the curriculum at the SMA/MA (Senior High School) level. This paper presents the results of review studies related to green chemistry-oriented learning and its adaptation from studies at the university level for basic chemistry courses to learning chemistry at the high school level. By using the literature review method to study green chemistry-oriented learning, hopefully, a map of related research can be developed and followed up.

Based on the background explained above, the problems in this study were 1) How to conduct basic chemistry learning with green chemistry oriented? 2) How to adapt basic chemistry learning with green chemistry oriented to chemistry learning in senior high school?; and 3) How to design chemistry learning with Green Chemistry oriented? To answer these problems, a more in-depth study was conducted by conducting a literature review based on the results of previous studies. Thus, this study aims to describe Basic Chemistry learning with green chemistry orientation, the adaptation of basic chemistry learning with green chemistry to chemistry learning in senior high school and learning chemistry design with green chemistry insight.

METHOD

The method used in this study is a systematic review. Systematic reviews follow the steps put forward by several experts (Kaufman, 2011; Qazi, 2017). Further steps are taken with a systematic narrative review (Gregory, 2018; Kosztyan, 2021) which can be taken by mapping or systematic mapping study (Wahono, 2015; Mireles 2017; Salam 2017). The procedure taken in this study is depicted in Figure 1.

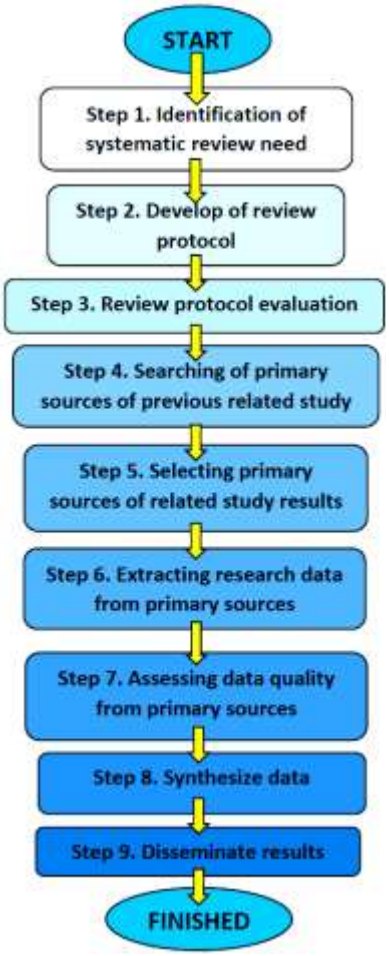

Figure 1 Steps of systematic literature review (Wahono, 2015)

Step 1 was to identify the need for related articles, in this case, the results of previous studies with the keywords green chemistry and green education. Step 2 was the development of a review protocol by determining the source of the search for related articles that are needed. The search was carried out through electronic sources on the current situation and conditions. The review protocol was determined by searching electronic document sources through Google search, Google scholar, ERIC document, and research gate. Step 3 evaluates the review protocol by considering several aspects, such as the publication year and the article's relevance. Stages 4, 5 and so on were carried out according to the steps.

RESULTS AND DISCUSSION

Data of Article systematic review results

Data systematic review results were obtained following the steps specified in the review protocol. The stages of implementing a systematic review are presented in Figure 2.

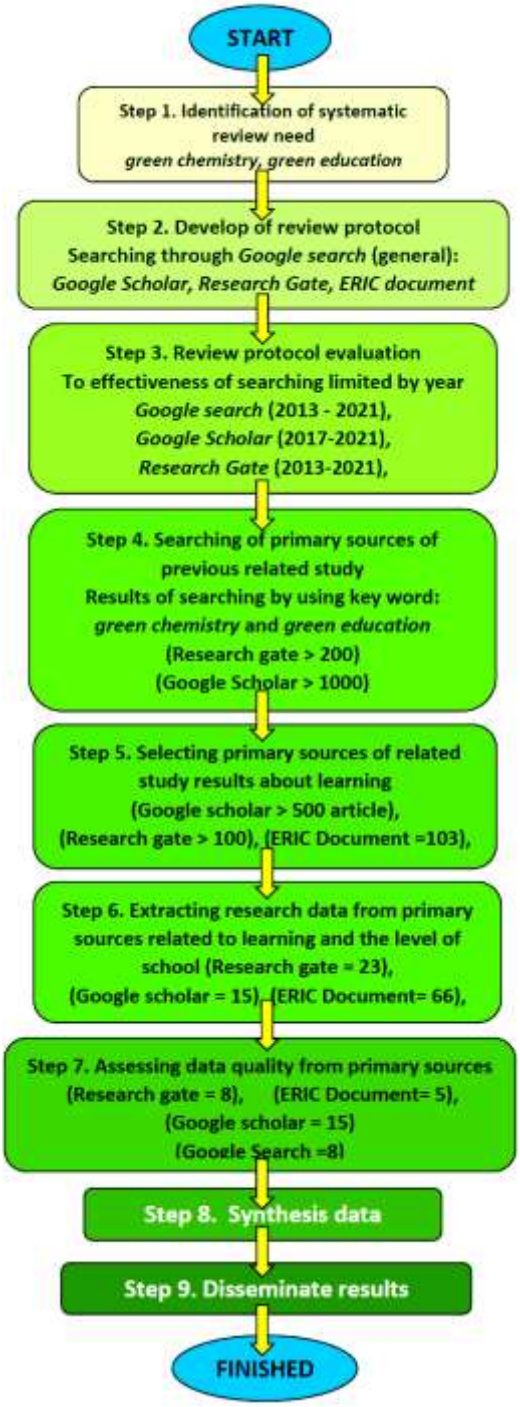

Figure 2 Results of Articles Search According to the Steps of Systematic Review

Figure 2 shows that the results of article searching by using the keywords green chemistry and green education were limited by year. Stage 4 explored the results of related research and the results obtained from each of the searches taken: through Google search, more than 100 articles were found between 2013 and 2021. The search results through the research gate obtained more than 200 articles, from ERIC documents more than 300 articles, and most search results through Google Scholar were more than 1000. Therefore, the next step was taken. So the complete steps and the results as explained in more detail below.

Stage 1 was to identify the need for related articles, in this case, the results of previous research with the keywords green chemistry and green education. Stage 2 is the development of a review protocol by determining the source of searching for related articles that are needed. The review

protocol was determined by searching for electronic document sources through Google search, Google scholar, ERIC document, and research gate. The search was carried out through electronic sources on the current situation and conditions. Phase 3 evaluated the review protocol by considering several aspects, such as the year of publication and the article's relevance.

Stage 5 was selecting articles obtained with the keywords green chemistry and green education. The selection was made by considering the study of articles related to learning. The search result found more than 500 articles related to green chemistry in the fields of chemistry, industry, technology, and the environment. After excluding articles unrelated to learning, it was found that the number of included articles was less but more in line with the purpose of the review.

Stage 6 was carried out again on the included articles. The article extract was based on the level of learning studies in schools, both at the college and secondary school levels. Stage 7 is carried out based on the consideration of the quality of the relationship. This study focuses on the adaptation of green chemistry-oriented chemistry learning. In this case, Basic Chemistry at the university level adapted to SMA/MA chemistry learning materials. The systematic review results at step 5 and so on are shown in Figure 3.

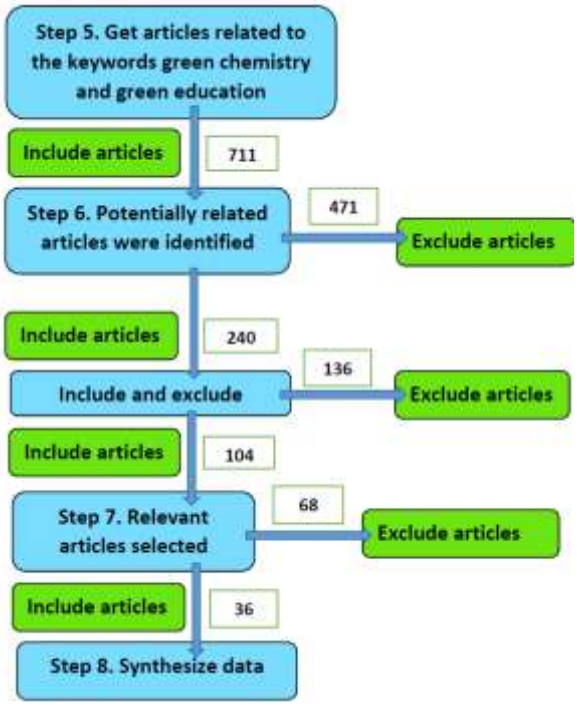

Figure 3. Searching process and the result of related articles selection

The results of searching and selecting related articles to the keywords green chemistry and green education, especially related to the field of learning, obtained 36 articles which were then analysed and synthesised.

Analysis of Learning Curriculum Related to Green Chemistry

Based on the analysis of the Chemistry learning curriculum for SMA/MA (senior high school), materials related to green chemistry have not been included either implicitly or explicitly (Kemendikbud, 2013). Similarly, the 2016 revised chemistry subject syllabus (Kemendikbud, 2016). However, researchers have attempted to study and implement green chemistry principles in chemistry learning with green chemistry oriented.

While at the university level curriculum, there are several studies on learning related to green chemistry. Green chemistry material can be included as the environmental chemistry study material in Basic Chemistry subjects (Mitarlis, 2016), while Amstrong (2018) develops green chemistry as a concern in the general chemistry practicum curriculum. Green chemistry is also integrated into the general chemistry curriculum to build student mindsets to pay attention to safety in chemical processes (Aubrecht, 2019).

Thus, green chemistry can be implemented in chemistry learning as a basis for consideration in any chemistry study, even though it has not been explicitly stated in the high school curriculum. Meanwhile, most of the college curricula have been formulated explicitly, either as part of other study materials such as in environmental chemistry or stand-alone, even though green chemistry is different from environmental chemistry. Green chemistry is more focused on minimising hazardous materials and maximising energy and chemical efficiency. In contrast, environmental chemistry emphasises environmental phenomena polluted by chemicals (Manahan, 2006).

Basic Chemistry topics at university levels are not much different from the topics in Indonesian secondary schools. Therefore, Basic Chemistry topics with green chemistry orientation can be adapted to the secondary school curriculum. Green chemistry can also be integrated into the Chemistry practicum curriculum (Aubrecht, 2019) or as a separate study material in the semester learning plan (SLP/RPS) of courses (Azizah, 2020).

Design of Green Chemistry-Oriented Learning

The results of the research review related to green chemistry in the study of 36 articles were carried out by identifying the learning designs used by researchers. The results of the identification of learning designs are classified into four dominant strategies/methods/models/approaches studied by researchers, including practicum methods, Problem Based Learning (PBL) models, Project Based Learning (P¡BL) models, or inquiry learning models. The results of the study of green chemistry-oriented learning designs, both at the Higher Education (College) and high school (SMA/MA) levels, are presented in Table 1.

Table 1 Design of Learning with green chemistry oriented by researchers

No.	Author (year)	Learning design and level
1	(Sudarmin, 2013); (Mitarlis, 2017); (Wahyuningsih, 2017); (Paristiowati, 2019); (Al Idrus, 2020); (Listyarini, 2020); (Mirzaei, 2019); (Amstrong, 2019)	Laboratory activity method (College)
	(Hadi, 2019); Listyarini, 2019); (Arif. K., 2020); (Rizkiana, 2020); (Erdawati, 2021); (Ulandari, 2021)	Laboratory activity method (high school)
2	(Rao, 2016); (Chen, 2020)	PBL Model (College)
	(Rosita, 2014); (Fauziah, 2016); (Saptorini, 2017)	PBL Model (high school)
3	(Mitarlis, 2016); (Mitarlis, 2017); (Mitarlis, 2018)	PjBL Model (College)
	Najih, 2019); (Setiyaningsih, 2020)	PjBL Model (high school)
4	(Fardani, 2017); (Summerton, 2018)	Inquiry Learning Model (College)
	Afiyanti, 2014); (Risna, 2019)	Inquiry Learning Model (high school)
5	Active learning (Prescott, 2013); *Student centre learning* with presentation (Manchanayakage, 2013)	Others (College)
	Konstruktivis (Riyanti, 2013); Kontextual Teaching and Learning /CTL (Ahmadi, 2016); Discovery (Redana, 2017);	Others (high school)

Table 1 shows that the green chemistry-oriented learning that researchers have studied uses several learning designs according to the characteristics of the material. In addition to the

dominant learning strategies/methods/models, there are other designs categorised by researchers as constructivist approaches, active learning, contextual, or with the discovery learning model.

CONCLUSION

Based on the results of a systematic review of learning chemistry with a green chemistry perspective, it can be concluded that: Basic Chemistry learning with a green chemistry perspective can apply several green chemistry principles, including preventing waste, saving energy, using renewable chemicals that can be applied to mixture separation learning materials, chemical reactions, basic laws of chemistry, acids and bases, and reaction rates. Chemistry learning with a green chemistry perspective can be adapted to Indonesian secondary school chemistry even though it has not been included in the curriculum. The design of learning chemistry with a green chemistry perspective can use practicum methods, Problem Based Learning (PBL) models, Project Based Learning (PjBL), or Contextual Teaching and Learning (CTL), as well as an inquiry learning model.

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