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Analysis of green chemistry content in form IV and V high school chemistry textbooks in Malaysia

Aura Heidya Septa ✉ [1], **Antuni Wiyarsi** [2]

[1, 2)] Department of Chemistry Education, Universitas Negeri Yogyakarta, Indonesia

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Abstract

Malaysia is one of the countries that has integrated the STEM (Science, Technology, Engineering, and Mathematics) approach in its education curriculum since 2017, to prepare young people with 21st century skills. In the context of chemistry education, Malaysia also applies the concept of Green Chemistry to encourage environmental awareness and improve science literacy through materials relevant to global sustainability issues. This study examines the integration of Green Chemistry principles in Level IV and V high school chemistry textbooks in Malaysia. Utilizing a qualitative descriptive content analysis, the study focuses on six themes: Green Chemistry principles, application fields, presentation stages, presentation levels, locality aspects, and related chemistry concepts. Analysis of the textbooks revealed that seven out of twelve Green Chemistry principles are integrated, with "Preventing Potential Accidents" appearing most frequently (56.52%), followed by "Waste Prevention" (14.50%). The application fields of Green Chemistry predominantly cover health (50.73%) and environmental issues (28.99%). Presentation stages emphasize content deepening (52.17%) and core materials (21.74%), while presentation levels are largely explicit (52.17%), enhancing conceptual clarity. However, locality aspects are underrepresented, with global contexts dominating (92.75%) over local ones (7.25%). The integration of related chemistry concepts includes "Acid and Base" (26.09%) and "Organic Compounds" (18.84%) as the most frequent. Despite the significant integration of Green Chemistry, the study highlights gaps in contextual representation and recommends future research focus on enhancing the relevance of textbook content to local and global environmental issues.

✉ Corresponding Author:
Aura Heidya Septa
auraheidya.2021@student.uny.ac.id

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INTRODUCTION

The importance of 21st century education skills makes Malaysia one of the countries in the world that has implemented the STEM approach in its education curriculum. The implementation of the STEM (Science, Technology, Engineering, and Mathematics) approach plays an important role in advancing the education system on a global scale (Tan, 2018). Previous research by Bryan, Moore, Johnson, and Roehrig (2015) identified that integrated STEM learning involves mastering multidisciplinary knowledge, such as science, chemistry, and mathematics, combined with relevant technological practices. The STEM learning approach is considered capable of encouraging learners as the younger generation to actively use and develop their understanding in solving various problems faced in the real

world context (Aydin et al., 2018; Pratiwi et al., 2019). Malaysia introduced STEM education starting in 2014 and has incorporated STEM concepts into the Secondary School Standard Curriculum since 2017 [MOE, 2016]. Previous research by Edy, et al. (2017), stated that the STEM approach has been introduced from level one to five through Malaysia's national syllabus. To date, various strategies and initiatives focusing on STEM-based education in Malaysia, whether through elective subjects at the secondary school level or specialized subjects at the pre-university level, are expected to increase learners' interest, satisfaction and learning achievement, thereby supporting their career development as young people in STEM fields (Abdullah, et al., 2022). The Malaysian Ministry of Education (MOE) integrates higher order thinking skills (HOTS) into STEM learning. These skills include reflection, value reasoning, innovation, problem solving and decision making with an emphasis on incorporating HOTS into the content of learning topics to make the Malaysian education curriculum more relevant to everyday life (Mohamad Hisyam, et al., 2019).

The initiative to implement the STEM approach in Malaysia is in line with the Malaysian Education Development Plan (PPPM) 2013-2025 which aims to improve the achievement of the Program for International Student Assessment (PISA) results. However, Malaysia's PISA performance has decreased by 6.26% from 431 in 2018 to 404 in 2022 and science literacy results are below the OECD average, with an average score of 415 (OECD, 2023) Assessment of students' science literacy skills is based on scientific competencies which include: Scientific Knowledge, Scientific Process and Scientific Context. The integration of Green Chemistry in science learning has significant relevance, because science literacy does not only focus on mastering science, but also includes social aspects. Green Chemistry content contributes to improving students' environmental literacy, encourages critical thinking, and helps them understand how scientific innovation can be a solution to global and sustainability issues, which is aligned with the competencies measured by PISA. In Malaysia, the concept of Green Chemistry has been incorporated into the Chemistry subject at levels IV and V, equivalent to the Secondary School level in Indonesia.

In this context, textbooks become one of the main learning resources that play an important role in supporting the success of learning. Chemistry textbooks based on Green Chemistry can be used to teach scientific literacy to students, especially with a 21st century approach that emphasizes not only content aspects, but also context aspects. Therefore, this study aims to deeply analyze the content of Chemistry textbooks from various aspects, including Green Chemistry principles, application fields, presentation stages, presentation levels, locality aspects, and other related chemistry concepts to evaluate the extent to which Green Chemistry integrated learning has been implemented in the education curriculum in Malaysia.

METHOD

Type and Design of the Research

This qualitative research uses Documentary method with Descriptive Content Analysis design. This research design was used because the data collection focused on analyzing the Green Chemistry content in Malaysian high school chemistry textbooks, which was studied based on six main themes: green chemistry principles, application fields, presentation stages, presentation levels, locality aspects, and other related chemistry concepts integrated with relevant Green Chemistry content and concepts.

Participants and Context of the Research

The data source in this study is chemistry textbooks for level IV and V SMA (Sekolah Menengah Kebangsaan) used in Malaysia. The selection of textbooks analyzed was determined based on purposive sampling technique by taking interview data from several teachers and high school students in Tanjong Malim, Malaysia to strengthen the research data. The criteria for chemistry textbooks analyzed are books recommended by the Malaysian Ministry of Education and consider the curriculum variations used in the book and coding is carried out based on the two types of books obtained. The books analyzed amounted to 2 pieces, namely level IV and V books.

Data Collection Technique and Instrument

The instrument used in the study was a Green Chemistry content coding analysis sheet which was an adaptation of Calik & Wiyarsi's SSI coding analysis sheet (2021). From the adaptation process, the author obtained the codes used to compile the themes of the primary coding sheet, including the themes of green chemistry principles, application fields, presentation stages, presentation levels, locality aspects, and other related chemistry concepts.

Data Analysis

The author analyzed the data into primary codes and checked the codes repeatedly to ensure compatibility. Then created secondary codes for each theme by reviewing the primary codes Interpretively and Inductively. In addition, the author and other authors with similar research checked each other's codes to confirm the compatibility of the secondary codes. Furthermore, after obtaining the results of secondary coding, a Delphi group approach was carried out. This was chosen because the Delphi Group Approach is a data collection technique similar to Focus Group Discussion but in its implementation the experts or raters do not have to meet physically. Then the data from the discussion were tabulated, data analysis was carried out using descriptive statistical procedures. In descriptive statistical procedures the data that has been obtained is summarized and interpreted. The final results of the coding are represented in numerical form according to Cohen's Kappa Coefficient.

FINDINGS AND DISCUSSION

Findings

After re-matching the results of secondary coding with raters, it was found that some Green Chemistry content was added and subtracted. The comparison table of the number of Green Chemistry contents of secondary coding after matching is as follows:

Table 1. Differences in Secondary Coding Results from raters

Books Code	Secondary Coding Results	Differences from raters
IV	34	4
V	35	2
Total	**69**	**6**

Table 2. Kappa Rater Index Recapitulation Findings

Level	Kappa Indeks
IV+V	**0,90%**

Both books show a very good Kappa Index value or included in Almost Perfect because it has a kappa index value> 0.81. The kappa index value on chemistry textbooks is 0.90%. The results of the study were tabulated in the form of data on the percentage value of Green Chemistry content in both textbooks. The content includes the principles of green chemistry, fields of application, stages of presentation, level of presentation, aspects of locality, and other related chemical concepts.

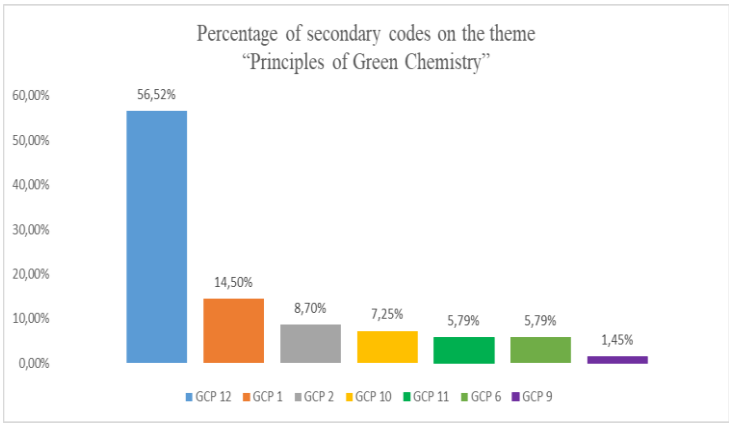

Figure 1. Percentage of Secondary Codes on the Theme "Principles of Green Chemistry"

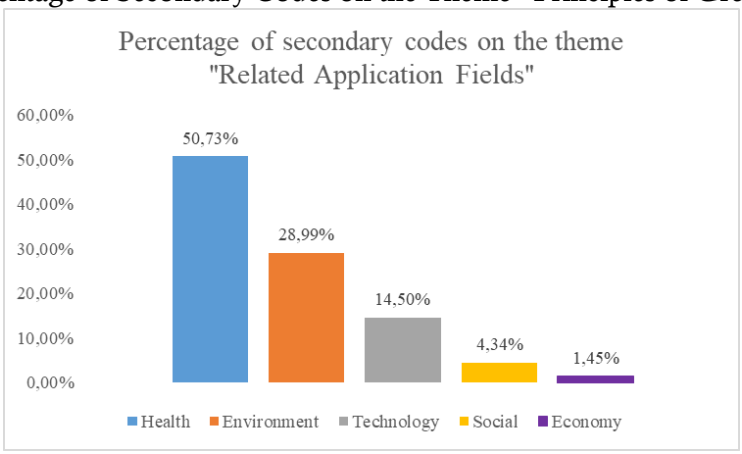

Figure 2. Percentage of Secondary Codes on the Theme "Related Aplication Fields"

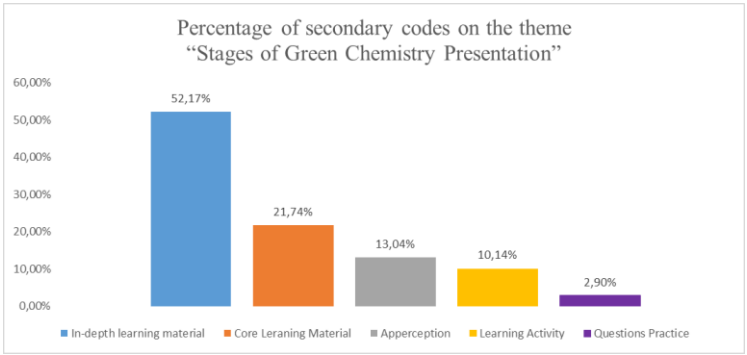

Figure 3. Percentage of Secondary Codes on the Theme"Presentation stage"

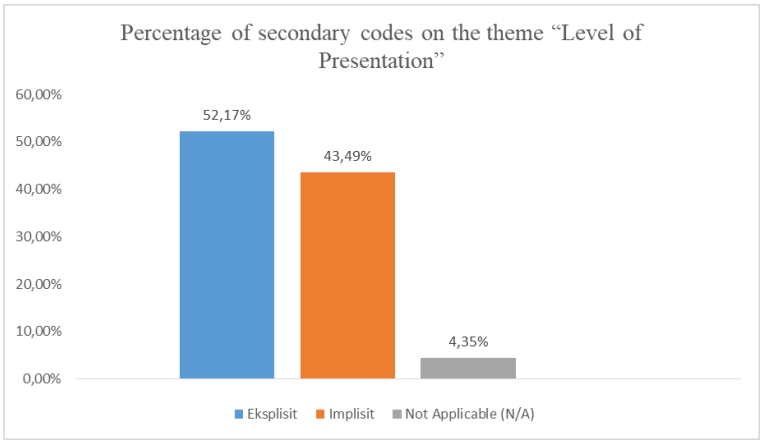

Figure 4. Percentage of Secondary Codes on the Theme "Level of Presentation"

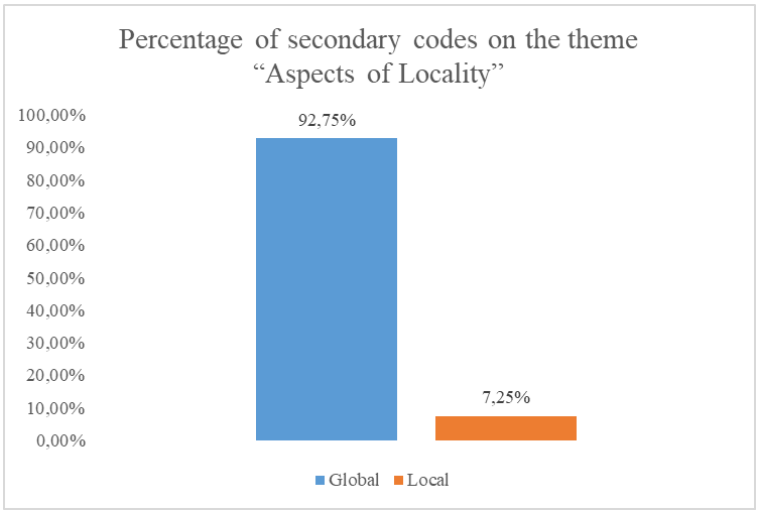

Figure 5. Percentage of Secondary Codes on the Theme "Locality aspect"

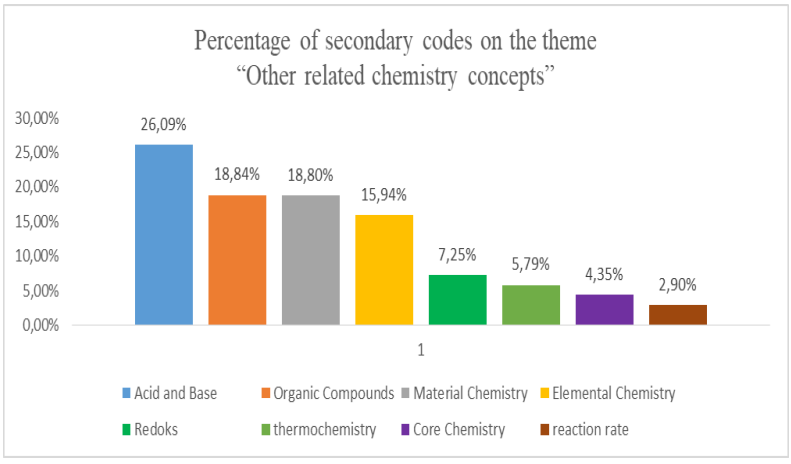

Figure 6. Percentage of Secondary Codes on the Theme "Other Related Chemical Concepts"

Discussion

Theme 'Principles of Green Chemistry'. As seen in figure 1, the theme coding is divided into 7 different codes from a total of 12 green chemistry principles (GCP) by Anastas & Warner (1996). The highest frequency is shown by GCP code 12 "Preventing potential accidents" which is presented in both

chemistry textbooks at 56.52%. In both textbooks analyzed, this principle is mostly found in the context of laboratory activities (first aid), MSDS, use and control of chemicals, information about chemical symbols, work steps, preventive steps, and other similar information needed to minimize the emergence of potential hazards (Nadillah, et al., 2022). Furthermore, there is 14.50% of data included in GCP 1 "Preventing waste" which is presented in the context of handling the use of chemicals, waste pollution in the surrounding environment, and laboratory activities. The integration of Green chemistry code GCP 1 occupies the second position frequency because this code can be used as an approach to students in efforts to prevent chemical pollution that occurs in the environment (Rahmawati & Khamidinal, 2019).

GCP code 2 "Atomic economy" presented as much as 8.70% comes from the context related to nanotechnology to maximize the use of starting materials or reagents to produce the final product. In GCP code 10 "designing products for degradation", GCP 11 "direct analysis for pollution prevention", and GCP 6 "designing for energy efficiency", the integration of green chemistry content is mostly presented in the context of using products in everyday life such as fermented drinks, plastic bags, used tires, and chemical pollution.GCP 9 code "catalysis" with the lowest frequency presented at 1, 45% in the context of using catalytic converters in modern cars.Understanding the concept of Green Chemistry integrated in these two chemistry textbooks can encourage and direct students to have a positive perception of environmental care behavior (Chaihanchanchai, 2022).

Theme 'Green Chemistry Application Fields'. As can be seen from figure 2, five codes appear for this theme. Most of the two chemistry textbooks cover the application of green chemistry in health (50.73%), environment (28.99%), technology (14.50%), social (4.34%), and economy (1.45%). These five dominant codes can be generated from several contexts of discussion in the textbook, such as activities in the laboratory related to first aid, the use of chemical products, the decomposition of chemicals into the environment affected by settlements, and technological developments. Furthermore, the integration of green chemistry content in the theme "field of application" emphasizes real cases and the relevance of this concept in everyday life, so that students can better understand the importance of the role of green chemistry in supporting sustainable development.

Theme 'Stages of Presentation'. As can be seen from figure 3, more than half of the presentation of green chemistry material focuses on the material deepening code (52.17%). This means that both textbooks significantly provide explanations regarding the principles, applications, and relevance of green chemistry. This is important to give students a fundamental and thorough understanding, especially on concepts such as the 12 principles of green chemistry, environmentally friendly synthesis, and chemical waste management. Furthermore, the core material code gets the second significant portion (21.74%), which shows the presentation of green chemistry concepts in a more condensed and direct format. The apperception code with a percentage of (13.04) is presented mostly in the context of the discussion of the bulletin section which refers to the initial stage of learning to connect new knowledge with the experience or understanding that students have previously had. Although the percentage is small, this presentation stage is important in attracting students' attention and building a connection between the material and everyday life (Abdul Rahman, et al., 2020). The learning activity code plays a small role in the presentation stage of green chemistry (10.14%). Most of these codes are presented in learning activities such as experiments and project assignments. Finally, the question exercise code becomes a less significant part in the presentation stage of green chemistry material, which only amounts to (2.90%). This code is presented in the textbook as a case study-based written sentence, such as analyzing the environmental impact of a chemical reaction, or asking students to design a chemical process that is more environmentally friendly. This helps students develop critical thinking skills.

Theme 'Level of Presentation'. As can be seen from figure 4, the largest proportion (52.17%) indicates that green chemistry concepts tend to be presented explicitly. This means that the textbook directly explains the concepts, principles, or applications of green chemistry, such as the principle of minimizing waste or the use of renewable raw materials. Explicit presentation is very important to

improve students' understanding because it makes it easier for them to recognize the direct relationship between chemical theory and environmentally friendly practices. Most (43.49%) of the analyzed data fall into the implicit category. This suggests that the integration of green chemistry concepts is often implicit in the context of other topics, such as chemical reactions or chemical production. Although this approach can stimulate students' critical thinking to connect chemistry concepts with environmental issues, there is a risk that students may not fully realize the importance of applying green chemistry principles without additional emphasis from the teacher. Only a small proportion (4.35%) of materials are irrelevant or do not include green chemistry content. This reflects that systematically almost all chemistry content in both chemistry textbooks has the potential to promote the integration of comprehensive green chemistry content.

Theme 'Aspects of Locality'. As can be seen from figure 5, most of the green chemistry content in the textbooks relates to the global context (92.75%), while the local context only accounts for (7.25%). The dominating global aspect indicates that the textbook prioritizes sustainability issues that are universal, such as waste management and the use of renewable technologies. This is appropriate to prepare students for global challenges (Robert & Hotmaulina, 2023). Local context was only presented as much as (7.25%), indicating the need for increased integration of environmental issues relevant to Malaysia, such as the pollution of the Klang River, the use of palm oil as biofuel, or the degradation of tropical rainforests. Integrating local context can make learning more meaningful and build students' awareness of environmental issues around them.

Theme 'Other Related Chemistry Concepts'. As can be seen from figure 6 that "Acids and Bases" code has the highest percentage (26.09%) in integrating green chemistry content, followed by "Organic Compounds" (18.84%), "Materials Chemistry" (18.80%), and "Elemental Chemistry" (15.94%). Other concepts, such as "Redox" (7.25%), "Thermochemistry" (5.79%), "Core Chemistry" (4.35%), and "Reaction Rate" (2.90%), have smaller contributions. In both textbooks, the acid-base concept is often used to discuss acid or base waste reduction in the chemical industry. Likewise, "Organic Compounds" and "Materials Chemistry" are relevant to discuss the use of renewable raw materials and the development of environmentally friendly materials, such as biodegradable polymers. Although the "Reaction Rates" code has a small percentage. However, this concept has the potential to link green chemistry, such as in optimizing reactions to minimize wasted energy or chemicals, for example in the context of discussing the use of multistage modifiers in modern trains and fermented beverages.

CONCLUSION AND IMPLICATION

The analysis oflevel IV and level V high school chemistry textbooks in Malaysia was carried out based on six focuses, including the theme of green chemistry princi-ples, application fields, presentation stages, presentation levels, locality aspects, and other related chemistry con-cepts. The results of the analysis of 69 data on green chemistry content showed that both textbooks integrated green chemistry content. The number of occurrences of Green Chemistry in terms of the theme of green chemistry principles in high school chemistry textbooks level IV and level V contains 7 of the 12 principles of green chemistry. The frequency of principles that have the highest value is GCP 12 with a percentage of 56.52% followed by GCP 1 (14.50%), GCP 2 (8.70%), GCP 10 (7.25%), GCP 11 (5.79%), GCP 6 ((5.79%), and GCP 9 (1.45%). The number of occurrences of green chemistry in terms of the theme of the field of application includes green chemistry. Applications in the health field (50.73%), environmental field (28.99%), technology field (14.50%), and social field (4.34%), and economic field (1.45%). Based on the theme of the presentation stage, the appearance of code deepen-ing material as much as (52.17%), core material (21.74%), apperception (13.04), learning activities (10.14%) and practice questions (2.90%). The number of occurrences of green chemistry in terms of presentation level theme, high frequency in explicit presentation code (52.17%), foL-lowed by implicit code (43.49%), and not applicable (4.35%). The number of occurrences of green chemistry in terms of presentation level themes, the occurrence of global codes dominates by (92.75%) and local codes (7.25%). The number of occurrences of green chemistry in terms of the theme of other related chemical concepts includes the code "Acid and Base" has the highest per-centage (26.09%) followed by "Organic Compounds" (18.84%), "Material Chemistry" (18.80%), and

"Ele-mental Chemistry" (15.94%). Other concepts, such as "Redox" (7.25%), "Thermochemistry" (5.79%), "Core Chemistry" (4.35%), and "Reaction Rate" (2.90%). Although it can be concluded that both books analyzed cover and integrate green chemistry content, this study still has some shortcomings in reflecting and supporting all relevant components. Therefore, future research should put more emphasis on the interpretation and relevance of each component analyzed properly.

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