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Needs Analysis for Infusing Green Chemistry into the Analytical Chemistry Micro-Curriculum to Enhance Enviromental Literacy of Pharmacy Students

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Abstract: *This study aims to analyze the need for developing a micro-curriculum for the Analytical Chemistry course that integrates green chemistry competencies to enhance environmental literacy among pharmacy students. A descriptive approach was employed using survey and Focus Group Discussion (FGD) methods involving 243 students, analytical chemistry lecturers, and the head of the study program. The results indicate that Analytical Chemistry learning remains focused on technical aspects and has not optimally incorporated environmental issues. A total of 65.43% of students considered the material to be not comprehensive, 72.43% reported that environmental impacts were rarely discussed, and 68.72% indicated a lack of emphasis on environmentally friendly chemicals. Students' understanding of green chemistry was also low, with 81.1% reporting limited exposure and 70% lacking understanding of waste prevention. However, 70.8% of students demonstrated high environmental awareness, yet 60.5% of students did not adequately understand analytical chemical waste management principles and 63.0% exhibited behaviors that were not in accordance with proper waste disposal procedures. These findings indicate a discrepancy between the affective aspect (awareness) and the cognitive and psychomotor aspects (knowledge and behavior). The FGD findings revealed that green chemistry competencies have not been explicitly integrated into the curriculum and are not supported by institutional policies. Therefore, the development of a micro-curriculum that systematically integrates green chemistry competencies is necessary to improve students' environmental literacy.*
Keywords: *Analytical Chemistry, Environmental Literacy, Green Chemistry, Needs Analysis*

1. INTRODUCTION

Environmental degradation caused by industrialization, excessive use of chemicals, and unsustainable exploitation of natural resources has become a serious global issue. The impacts include climate change, environmental pollution, and a decline in biodiversity. In this context, chemistry education plays a strategic role in fostering environmental awareness and sustainability-based problem-solving skills. As the central science, chemistry makes significant contributions across various fields, including pharmacy, as well as in the development of more environmentally friendly solutions [1][2]. However, conventional chemistry education still tends to emphasize cognitive aspects and laboratory skills without being balanced by an understanding of environmental impacts, resulting in graduates who have not yet fully developed ecological responsibility[1].

In response to these challenges, the Green Chemistry approach is evolving as a paradigm that emphasizes designing safer and more sustainable chemical products and processes. This concept was first introduced by Anastas and Warner through the twelve principles of Green Chemistry, which include waste prevention, efficiency in the use of raw materials, safer use of solvents, energy efficiency, and the design of

environmentally degradable products[3]. These principles are the foundation for directing chemical practices to be more environmentally responsible from the design stage, not just at the waste treatment stage. Various studies show that the application of Green Chemistry in learning can improve students' understanding of concepts, critical thinking skills, and environmental awareness [1][2][4]. In addition, this approach has also been proven to be able to shape pro-environmental attitudes and behaviors through contextual and problem-based learning [5][6].

Environmental literacy itself is a multidimensional competency that includes knowledge, attitudes, skills, and behaviors related to environmental conservation efforts[7]. In the context of higher education, environmental literacy is an important indicator in assessing the readiness of graduates to face complex global challenges[8]. Students with good environmental literacy are expected to be able to make decisions that consider ecological, social, and economic aspects in a balanced manner[9]. Therefore, the development of green chemistry needs to be systematically integrated into the educational curriculum, including in the field of pharmacy.

In the context of pharmaceutical education, the urgency of applying sustainability principles is becoming increasingly important because pharmaceutical activities contribute to environmental pollution, especially through chemical waste and drug residues. Therefore, pharmacy graduates are required not only to have technical competence, but also adequate environmental literacy. Research shows that environmental literacy plays an important role in shaping students' attitudes and behaviors towards sustainability[10][3]. However, various studies also reveal that sustainability content in the pharmacy curriculum is still limited and has not been systematically implemented in the learning process[11]. The implementation of Green Chemistry in higher education, especially in analytical chemistry courses, is still relatively limited. In fact, this course has a strong relationship with sustainability principles, such as the use of reagents, the efficiency of analysis methods, and chemical waste management. Most of the previous research focused more on the development of learning media, the effectiveness of methods, or curriculum integration in general, and has not touched on curriculum development at the micro level (courses). In addition, the approach used is generally still in the form of curriculum integration broadly, while the competency infusion approach, i.e. the insertion of specific sustainability values and skills into course learning outcomes, is still not widely studied.

These conditions show a significant research gap, namely: (1) there is still a limited needs analysis-based research on the environmental literacy of pharmacy students, (2) the lack of studies at the micro-curriculum level, especially in analytical chemistry courses, and (3) the application of the infusion approach as a curriculum development strategy based on Green Chemistry has not been optimal. In fact, the infusion approach has the advantage of allowing the strengthening of sustainability competencies without having to change the curriculum structure as a whole. Therefore, this research is important to be carried out to analyze the environmental literacy competency needs of pharmacy students and develop Green Chemistry infusion strategie in the analytical micro-chemistry curriculum. The novelty of this research lies in the combination of the needs analysis approach with the curriculum infusion strategy at the course level, which not only makes a theoretical contribution to the development of a sustainability-based curriculum, but also a practical contribution in increasing the relevance of analytical chemistry learning to environmental issues and the demands of the pharmaceutical profession in the future.

2. METHOD

This study uses a descriptive design with *a needs analysis* approach to analyze the needs for the development of an analytical chemistry micro-curriculum that infuses *green chemistry competencies*. Data collection was carried out through survey methods and *Focus Group Discussions* (FGD) to obtain quantitative and qualitative data comprehensively.

In this study, the population is all Pharmacy students at STIKes Widya Dharma Husada Tangerang which totals 617 students. In this study, sample size was carried out using the Slovin technique in [12]. The use of the Slovin formula in the study to obtain a *representative* sample so that the results can be generalized. The Slovin formula for determining a sample is as follows:

$$n = \frac{N}{1 + N\,(0.05)^2}$$
$$= \frac{617}{1 + 617\,(0.0025)}$$
$$= 242.9 \approx 243 \text{ (Tejada et al., 2012)}$$

Description:
n = sample size
N = Total population
E = percentage of sampling error (5%)

Based on the results of the sample determination analysis, the sample that will be used in the needs analysis is 243 students. The samples taken are based on the probability sampling technique, simple random sampling, where the researcher provides the same opportunity for each member of the population to be selected as a sample regardless of the strata in the population. The survey sample (descriptive) is the majority of participants consisting of students of the pharmacy study program who have taken the Analytical Chemistry course at STIKes Widya Dharma Husada Tangerang. The instruments used were in the form of a structured questionnaire to measure environmental literacy, understanding of green chemistry, and students' perception of Analytical Chemistry learning.

The FGD sample consisted of key informants who have a strategic role in the development and implementation of the curriculum, namely three lecturers teaching the Analytical Chemistry course and the Head of the S1 Pharmacy Study Program. The selection of informants is carried out purposively by considering experience, direct involvement in the learning process, and understanding of the applicable curriculum policies. The FGD was carried out in a structured manner with discussion guidelines that included aspects of lecturers' understanding of green chemistry, institutional policies and support, analytical chemistry learning practices, challenges and obstacles to green chemistry infusion, and students' environmental literacy skills. The results of the FGD are expected to be able to provide a comprehensive overview of the actual condition of the curriculum as well as more contextual and applicative development recommendations in supporting the improvement of student environmental literacy.

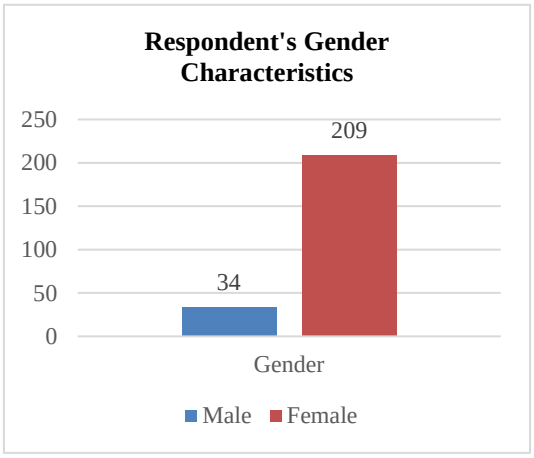
Quantitative data obtained from the results of the questionnaire were analyzed using descriptive statistical techniques in the form of percentage calculation to describe the tendency of students' responses to each indicator measured, namely environmental literacy, understanding of green chemistry, and perception of Analytical Chemistry learning. The data is then categorized into several levels, such as very high, high, medium, and low, to facilitate the interpretation of the results. This analysis aims to identify the actual condition of student competencies and the level of need for the development of green chemistry-based learning. In addition, the percentage results are used as a basis for conducting gap analysis between existing conditions and ideal conditions expected in Analytical Chemistry learning.

The qualitative data obtained from the FGD were analyzed using thematic analysis techniques through several stages, namely data reduction, coding, categorization, and drawing the main theme[13][14]. This process is carried out to identify patterns, issues, and obstacles that arise in the implementation of the curriculum and learning of Analytical Chemistry related to green chemistry infusion. The results of the qualitative analysis are used to deepen and strengthen quantitative findings, so as to obtain a more comprehensive picture of the needs for micro-curriculum development. The integration of quantitative and qualitative analysis results is then used as a basis for formulating recommendations for the development of an infusion of green chemistry analytical chemistry micro-curriculum based on the needs of students and the institutional context.

3. RESULTS AND DISCUSSION

A. Needs Analysis Based on Student Perception (Quantitative Study)

Initial data on Pharmacy students in this study was obtained through a survey given to students. The survey was designed to explore the level of understanding and application of *green chemistry* in the analytical chemistry learning process. In addition, data collection also aims to identify the gap between the expected environmental literacy competencies and the current competency conditions of students, as well as the extent to which green chemistry has been infused in the analytical chemistry micro-curriculum



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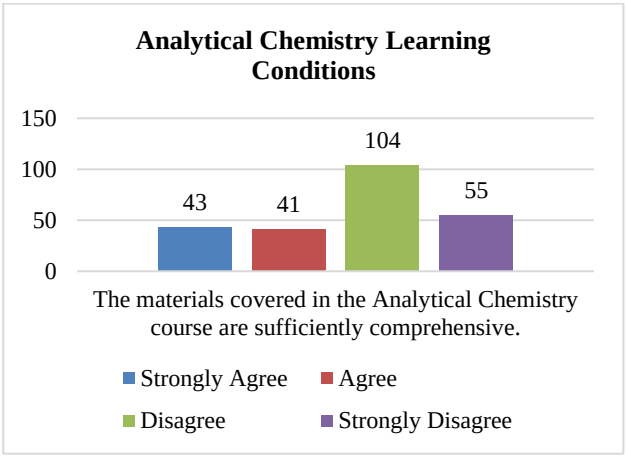

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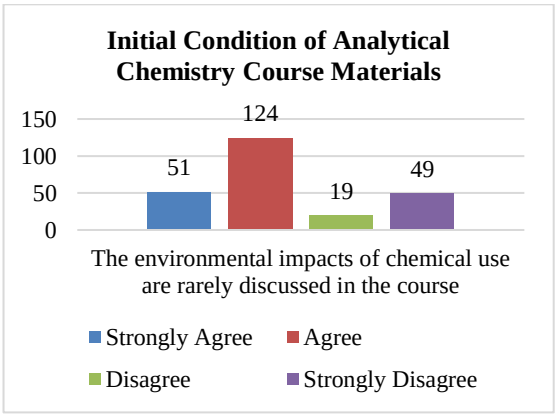
Figure 1. (a) Respondent's Gender Characteristics
(b) The initial condition of the scope of the Analytical Chemistry Learning Material

The results of the analysis showed that the characteristics of the respondents were dominated by female students by 85.98%, while by men by 14.02%. This composition reflects a general trend in pharmacy study programs that generally have a higher proportion of female students. However, gender differences were not the main focus of the study, but rather as an initial description of respondent characteristics. Based on the results of the survey on the learning conditions of Analytical Chemistry, the majority of students (65.43%) stated that the material provided was not comprehensive. In addition, as many as 54.73% of respondents assessed that learning still focuses on technical and analytical aspects alone without relating to the environmental context. These findings are in line with research that states that chemistry learning in college still tends to be oriented towards mastering technical concepts and skills, with minimal integration of sustainability aspects and real context [2]. This condition shows that there is a gap between the learning that takes place and the demands of developing student environmental literacy.



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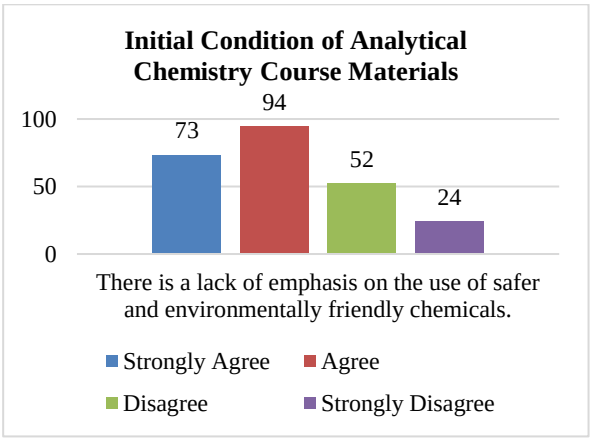

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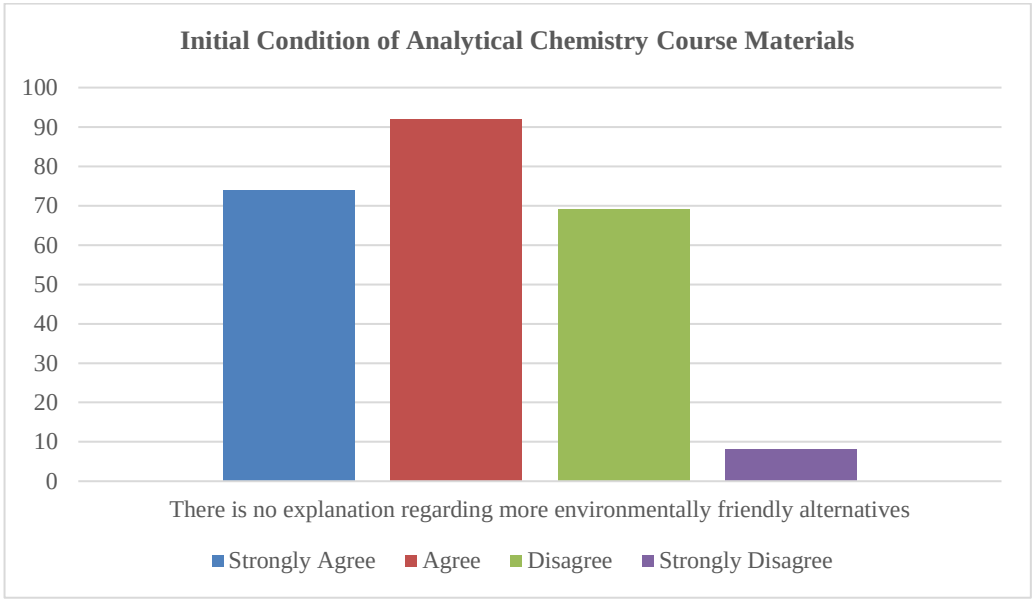

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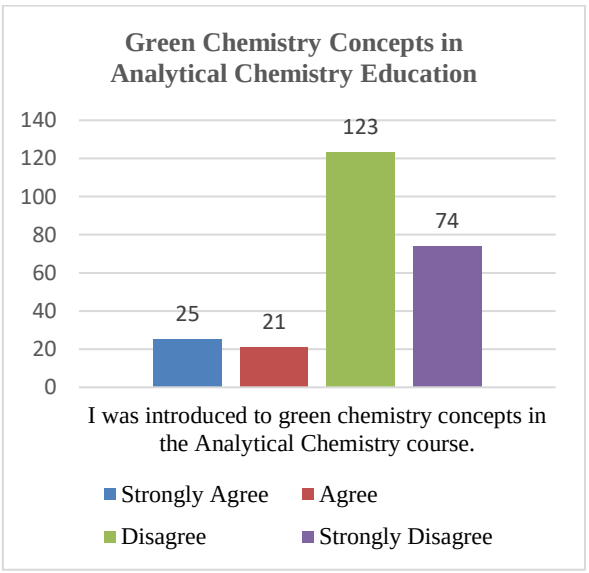
Figure 2. (a). Initial Condition of Analytical Chemistry Material Focus
(b) Environmental impact material in analytical chemistry course
(c) Use of examples of environmentally friendly materials

The results showed that 175 or 72.43% of students stated that the environmental impact of chemical use was rarely discussed in lectures. In addition, as many as 167 or 68.72% of students assessed that the material did not emphasize the use of safer and more environmentally friendly chemicals, and 166 or 68.31% of students stated that there was no explanation of alternative materials that were more environmentally friendly. These findings indicate that *green chemistry* principles, such as safer use of materials and waste prevention, have not been optimally integrated into learning. This is in line with the literature that states that the implementation of *green chemistry* in education is still limited and often not yet an explicit part of the curriculum[3][4][15].



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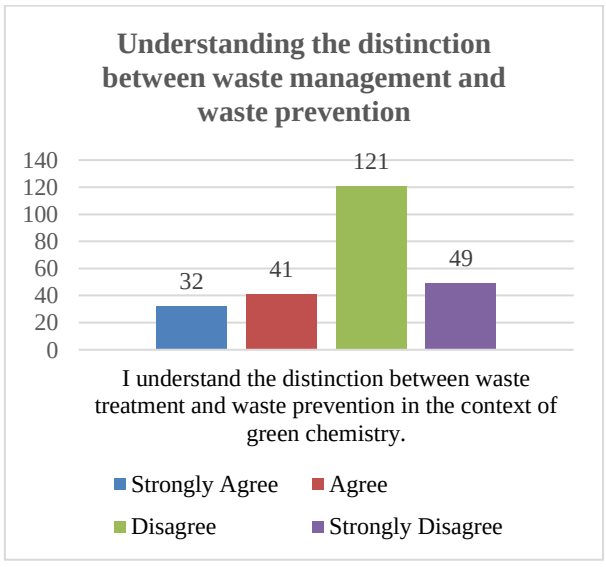

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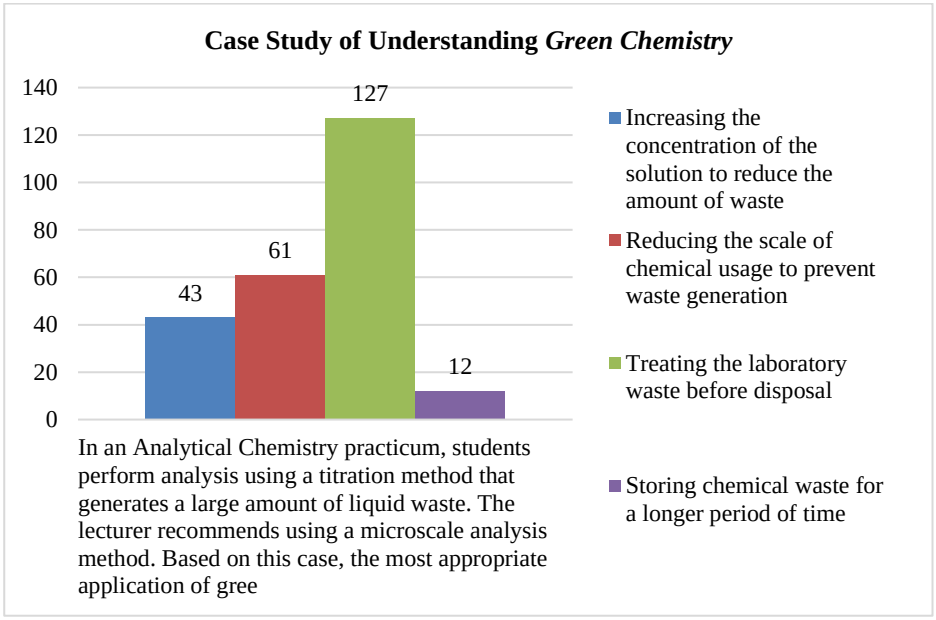

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Figure. 3 (a) The concept *of green chemistry* in analytical chemistry learning
(b) Understanding the difference between waste treatment and waste prevention
(c) Case study of understanding green chemistry

From the aspect of understanding *green chemistry*, the results of the study show that although 84.4% of students stated that they had known green chemistry, most (81.1%) admitted that they did not get the concept in Analytical Chemistry learning. In addition, as many as 70% of students do not understand the difference between waste treatment and waste prevention, which is a basic principle in green chemistry. These findings show that there is a gap between students' general knowledge and deep conceptual understanding. Previous research has also revealed that students often have a limited understanding of the principles of green chemistry and tend to associate it only with waste management, not prevention in the first place[4][16].

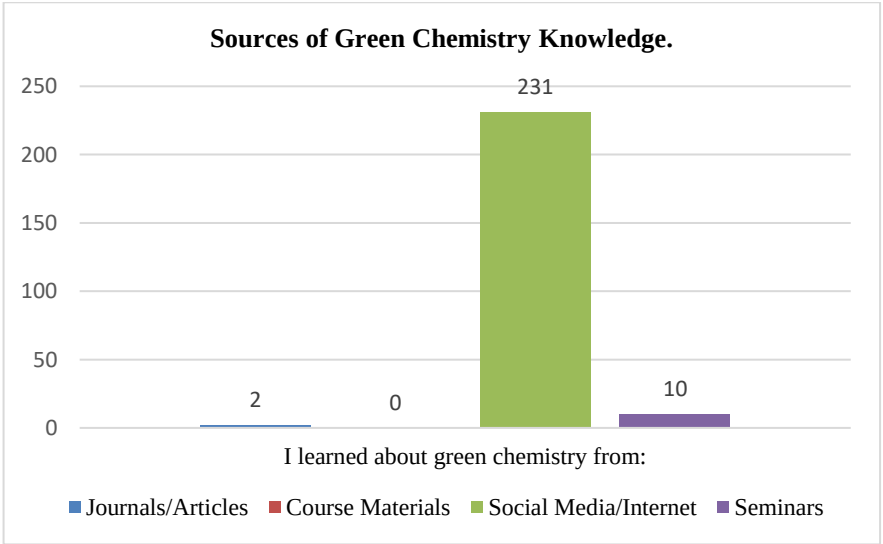

Figure 4. Source of student knowledge about *green chemistry*

Students' sources of knowledge about *green chemistry* are also dominated by social media and the internet (95.1%), while none of the respondents obtained this information from lecture materials. This shows that the role of the formal curriculum in building students' understanding of green chemistry is still very low. In fact, the integration of sustainability concepts in formal learning is essential to ensure a systematic and scientifically based understanding[17][1].

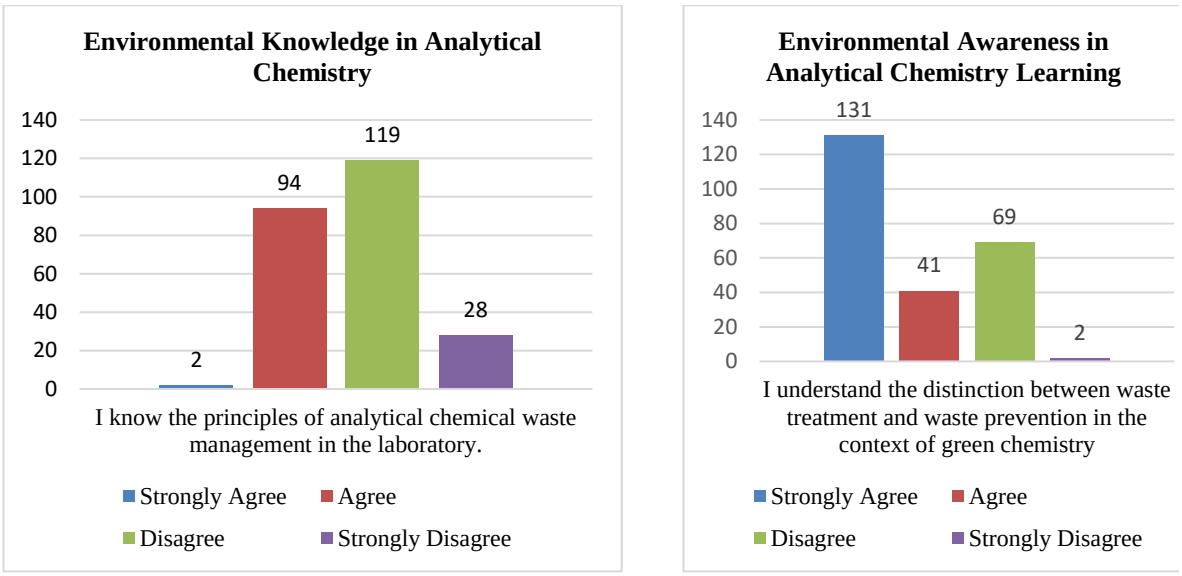

Figure 5. (a) Environmental knowledge in analytical chemistry
(b) Environmental Awareness in Analytical Chemistry Learning
(c)Environmental behavior in analytical chemistry learning

From the aspect of environmental literacy, the results of the study show that although 70.8% of students have a high awareness of the importance of environmentally friendly principles, their knowledge and behavior are still relatively low. As many as 60.5% of students do not understand the principles of analytical chemical waste management well, and 63.0% show behavior that is not in accordance with the correct waste disposal procedures. These findings show a mismatch between the aspect of awareness (affective) and the aspect of

knowledge and behavior (cognitive and psychomotor). This is in line with the concept of environmental literacy which emphasizes that competence includes not only awareness, but also knowledge and real action[7].

B. Needs Analysis Based on the Perspective of Lecturers and Study Program Managers (FGD)

The results of the study show that lecturers' understanding of the concept *of Green Chemistry* in general has been formed, but it is still at the basic conceptual level and has not been comprehensively structured. Based on the results of *the Focus Group Discussion* (FGD), lecturers understand *Green Chemistry* as an approach that emphasizes the use of safer chemicals and waste reduction. This is reflected in the informant's statement that "*Green Chemistry itu pendekatan kimia yang menekankan bagaimana kita menggunakan bahan kimia yang lebih aman dan mengurangi limbah praktikum supaya tidak berdampak ke lingkungan*" (D1), and reinforced by other statements related to the efficiency of chemical use (D2). These findings are in line with *the concept of Green Chemistry* which emphasizes waste prevention and use safer materials as a key principle in modern chemical practices [3]. However, this understanding has not yet developed towards a systematic scientific and pedagogical framework. This shows that lecturers still interpret *Green Chemistry* in the practical aspect, not in the planned curricular integration. According to Anastas and Warner, the implementation of Green Chemistry in education requires an understanding that is not only technical, but also conceptual and systemic in order to be integrated in the learning process effectively [3].

Based on the results of the FGD regarding the curriculum aspect, it is shown that *Green Chemistry* has a strong relevance to the Analytical Micro Chemistry course, but it has not been explicitly accommodated in the curriculum document. The informant's statement that "*Green Chemistry belum menjadi bagian yang dirumuskan dalam indikator atau materi kurikulum*" (D1) and "*integrasinya masih implisit dalam RPS*" (D2) menunjukkan adanya kesenjangan antara praktik dan perencanaan kurikulum. Hal ini sejalan dengan previous research findings that the infusion of *Green Chemistry* in the curriculum is often still implicit and not systematically structured [16]. In fact, explicit infusion in learning outcomes is very important to ensure the achievement of student competencies[15]. The absence of formal infusion is also related to the absence of institutional policies that explicitly encourage the implementation of *Green Chemistry*. The Head of Study Program stated that there is no formal policy governing the implementation of *Green Chemistry*, so practice in the field depends on the individual initiative of the lecturer (D3). This is consistent with research showing that institutional policy support is a key factor in the successful integration of continuing education in chemistry curricula[19].

The infusion *of Green Chemistry* in learning practice is still limited, especially in theoretical learning. The lecturer admitted that "*Green Chemistry sebenarnya relevan dengan materi teori, tetapi belum terintegrasi secara eksplisit*" (D1), while the learning method is still dominated by lectures (D2). As a result, students tend to understand Analytical Chemistry procedurally without associating it with environmental aspects (D3). These findings are in line with studies that state that traditional learning approaches are less effective in developing students' contextual understanding and environmental awareness [20]. Therefore, a more contextual and problem-based approach to learning is needed to effectively infuse the concept of *Green Chemistry*[21][19].

The results of the study show that *Green Chemistry* competencies have not been explicitly formulated in the learning outcomes of the course. This makes its implementation partial and difficult to evaluate, as it is revealed that "*Green Chemistry belum dirumuskan sebagai kompetensi pembelajaran*" (D1). This condition is in line with research that emphasizes the importance of formulating clear competencies in sustainability-based curricula to support measurable learning evaluations [23]. In terms of constraints, the results of the FGD show that the main obstacles include policy, pedagogical, and facility aspects. Lecturers have difficulties in translating the concept *of Green Chemistry* into learning materials and assessments (D2), as well as the lack of an integrated learning guide (D3). In addition, the limitation of facilities and the density of materials are also obstacles (Head of Study Program). These findings are in line with studies that state that limited resources and lack of lecturer training are the main challenges in the implementation of *Green Chemistry* in higher education[24][25].

Nevertheless, students show a readiness for a positive attitude towards *Green Chemistry*, even though their understanding is still limited (D1, D2). Student environmental literacy is also still at the basic level, as it was revealed that students are not used to assessing the environmental impact of analytical activities (D1). This is in line with research that shows that environmental literacy of chemistry students tends to be low if not supported by systematic curriculum infusion [3][26]. The results of this study confirm that the infusion of Green Chemistry in Analytical Chemistry learning requires a comprehensive approach, including the formulation of competencies, strengthening curriculum policies, and the development of contextual learning strategies.

Systematic integration is expected to improve students' environmental literacy and support continuous chemistry learning.

4. CONCLUSION

Based on the results of the research, it can be concluded that Analytical Chemistry learning in the Pharmacy study program still focuses on technical aspects and has not optimally integrated environmental issues and *Green Chemistry* competencies. Most students consider that the learning material is not comprehensive, rarely relates environmental impacts, and does not emphasize the use of environmentally friendly chemicals. In addition, the level of students' understanding of the concept of Green Chemistry is still relatively low, although they show a relatively high level of environmental awareness, but their knowledge and behavior are still relatively low.

The results of *the Focus Group Discussion* (FGD) reinforce these findings, where Green Chemistry competencies have not been explicitly formulated in the curriculum, have not been integrated in learning outcomes, and have not been supported by institutional policies. This condition causes the implementation of Green Chemistry in learning to be partial and unsystematic. Therefore, it is necessary to develop an Analytical Chemistry micro-curriculum that systematically infuses Green Chemistry competencies into curriculum components, including learning outcomes, materials, learning strategies, and assessments. This development is expected to increase students' environmental literacy and produce pharmacy graduates who are not only academically competent, but also have awareness and responsibility for environmental sustainability.

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