Intergrating Green Chemistry Principles in Chemical Reaction Learning Packet for the Grade 10 Learners

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ABSTRACT

This study investigates the integration of Green Chemistry principles into Grade 10 chemistry education through the development of a Green Chemistry Learning Packet (GCLP), aimed at promoting environmental sustainability. The research assessed the impact of the learning packet on students' conceptual understanding, awareness, and attitudes toward Green Chemistry specifically focusing on topic such as *Chemical Reactions*. This topic was identified as the least mastered in the K-12 curriculum. Using a quantitative-descriptive research design, a 50-item Needs Assessment Instrument was developed and validated. The study employed purposive sampling to selected Grade 10 students, and the effectiveness of the learning packet was evaluated through post-assessments, including pilot testing. Findings revealed significant improvements in students' post-test scores and increased awareness and positive attitudes toward Green Chemistry principles. Despite these improvements, a considerable number of students still failed to meet proficiency standards, highlighting the need for continuous support and targeted interventions. This study aligns with the Sustainable Development Goals (SDGs) of quality education, responsible consumption, and climate action, emphasizing the importance of integrating sustainability education into the curriculum. The study concludes that Green Chemistry principles may be formally included in the junior high school science curriculum to foster both academic growth and environmental responsibility.

Keywords: Chemistry Education, Green Chemistry, Environmental Sustainability Learning Packet

INTRODUCTION

The Philippines faces increased vulnerability to climate change due to environmental deterioration and unsustainable development practices within its borders, even though climate change itself is a hazard originating from outside the country (Holden, 2019). A sustainable environment is necessary for good and healthy living; hence, we should take actions that remove threats and foster environmental sustainability. Green chemistry, also known as sustainable chemistry, is a perceptive approach to prevent pollution. It is aimed at preventing pollution rather than managing it after its formation (Awoyode, 2024). Green Chemistry is an academic field that develops safe, environmentally friendly technologies. This supplementary approach to environmental research identifies sources, explains mechanisms, and quantifies issues. For these issues, Green Chemistry develops safe, alternative methods. Teaching chemists to create non-hazardous goods and materials reduces waste, dangers, and costs. Green Chemistry can revitalize classrooms and guide academic research. Its concepts may energize classrooms and improve the planet for responsible citizens (Sajeena, 2021).

This research aligns with Sustainable Development Goal 4 (Quality Education), promoting inclusive, equitable quality education and lifelong learning. It supports Target 4.7 by integrating education for sustainable development (ESD) into the curriculum, equipping learners with the knowledge and skills to engage with environmental sustainability. It also supports Sustainable Development Goal 12 (Responsible Consumption and Production), focusing on waste reduction, minimizing hazardous substances, and promoting renewable resources. These actions align with Target 12.4, environmentally sound management of chemicals) and Target 12.5, reducing waste generation. Additionally, this study contributes to Sustainable Development Goal 13

(Climate Action) by promoting eco-friendly chemical processes that reduce greenhouse gas emissions and support energy efficiency, in line with Target 13.3, which emphasizes education and awareness on climate change mitigation. Finally, this research supports Sustainable Development Goal 17 (Partnerships for the Goals), highlighting the importance of collaboration among educators, policymakers, and industry to integrate Green Chemistry principles into curricula, advancing sustainability through multi-stakeholder partnerships

Objectives

This study aims to assess the conceptual understanding, awareness, and attitudes of Grade 10 learners integrating Green Chemistry Principles in chemistry education in promoting environmental sustainability. Furthermore, it aims to determine the influence of the Learning Packet on Green Chemistry Principles in enhancing learners' conceptual understanding, awareness and attitudes. Specifically, to develop and evaluate a Learning Packet integrating Green Chemistry Principles; determine the Grade 10 learner's level of Conceptual Understanding, Awareness and Attitudes towards Green Chemistry, and assess the teacher's acceptability and usability perception of the Green Chemistry Learning Packet.

METHODOLOGY

Initially, this study employed a quantitative-descriptive research design to assess the level of mastery in selected chemistry topics among Grade 10 students. A researcher-made 50-item Needs Assessment Questionnaire was developed, validated by three experts. A purposive sampling method was implemented in determining the participants to be included in both try-out and implementation procedures. The criteria of the respondents is Grade 10 students currently enrolled in SY 2024-2025. The research instrument consisted of 40-item validated Needs Assessment Questionnaire related to General Chemistry topics and that is aligned with the DepEd Most Essential Learning Competencies (MELCs) in General Chemistry. The data collection procedures involved administering the Needs Assessment Questionnaire and Pilot-Test of the Conceptual Understanding Questionnaire to the participants that fit the inclusion criteria. Descriptive Analysis were used to the learner's performance and responses on the questionnaire for their mastery level.

The participants for this study were selected using a purposive sampling approach, a method that optimizes resources by intentionally selecting individuals who are most aligned with the study's objectives. This approach ensured that the learners had nearly completed the Most Essential Learning Competencies (MELCs) in their Grade 10 chemistry curriculum. During the try-out phase of the Needs Assessment, three classes of Grade 10, participated- summing up to 150 students. Following a thorough evaluation of the test items based on their difficulty and discrimination indices, some items were retained for the final version of the questionnaire. The final version of the Needs Assessment Questionnaire is refined and reduced to 40-items and was then administered into two classes of Grade 10 students, with a total of 100 participants. This approach ensured that the final data collection focused on students who met the necessary academic criteria.

The researcher-designed Needs Assessment Questionnaire consisted of 50 items, all aligned with the DepEd Most Essential Learning Competencies (MELCs) in science. The questionnaire underwent rigorous face and content validation by the experts in both content and methodology. Based on the feedback and suggestions from the experts, a try-out phase was conducted to further evaluate the validity and reliability of the instrument. Following this, an item analysis was performed, calculating the difficulty and discrimination indices of each question. As a result of this analysis, the original 50-item questionnaire was refined and reduced to a 40-item version, which was then prepared for the implementation phase of the study.

To establish the reliability of the test, using purposive sampling method, the original 50-item questionnaire was administered to 150 participants currently enrolled in the 2024-2025 school year at a public school in Iligan City. The calculated Cronbach alpha of 0.73445 indicates that the scale demonstrates an acceptable level of internal consistency and reliability. Additionally, the Difficulty Index was determined to be 0.565, suggesting that the test items are of average difficulty. The Discrimination Index, with a value of 0.317, indicates that the test items have an average ability to differentiate between higher and lower-performing students. These reliability metrics confirm that the test is suitable for measuring the participants' mastery of the assessed chemistry topics.

Table 1: Needs Assessment Instrument Cronbach Alpha, Variance, Difficulty and Discrimination Indices

Cronbach Alpha	Interpretation	Variance	Difficulty Index	Discrimination Index
0.73445	Acceptable	42.5056	0.565	0.317

In adherence to research ethics, a consent and assent form was provided to the participants. Participation in the study was entirely voluntary, ensuring that participants could choose to participate without any coercion. To maintain confidentiality, coding was implemented to protect the identities. The questionnaires collected were carefully reviewed, and the data obtained were tabulated and analyzed using descriptive statistics, including mean scores and percentages. The performance of the learners was then interpreted according to the criteria outlined in Table 1, with the interpretations following the DepEd K to 12 Grading System as specified in DepEd Order No. 8, s. 2015.

Table 2: Interpretation on Learners Performance on Needs Assessment Instrument

Score Range	Descriptors	Range	Interpretation
39-40	Outstanding	100	PASSED
37-38		95	PASSED
35-36	Very Satisfactory	90	PASSED
33-34		85	PASSED
31-32	Satisfactory	80	PASSED
29-30	Fairly Satisfactory	75	PASSED
28 and below	Did Not Meet the Expectations	70 and below	FAILED

Reference: DepEd Order No.8 s. 2015

RESULTS AND DISCUSSION

Mastery Level Per Needs Assessment Instrument

The 10 learner's mastery in chemistry revealed significant challenges in meeting the expected academic standards.

Table 3: Summary of the Mastery Level

Index	Frequency (n)	Percentage	Descriptors	Interpretation
39-40	0	0	Outstanding	PASSED
37-38	0	0		
35-36	2	2%	Very Satisfactory	PASSED
33-34	3	3%		
31-32	9	9%	Satisfactory	PASSED
30	6	6%	Fairly Satisfactory	PASSED
0-29	80	80%	Did Not Meet Expectations	FAILED
TOTAL	**100**	**100%**		
	Mean 23.88	Std. Dev. 6.031	Did Not Meet Expectations	FAILED

Table 3 reveals that most learners performed below the expected standards in the assessment. None of the 100 learners scored *"Outstanding"* (39-40points) or *"Very Satisfactory"* (37-38) ranges. This indicates that no learners reached exceptional or near-exceptional performance. Only 14 learners (14%) scored in the "*Satisfactory*" level (33-36points), with a very small portion achieving scores in the "Fairly Satisfactory" level (30points), totaling at 6%. The most alarming is the large proportion of learners, the 80 participants (80%), scored between 0 and 29. They are categorized as "*Did Not Meet Expectations*". This indicates failure to meet the required standards. The overall mean score of 23.88, along with a standard deviation of 6.03, reflects a generally low level of performance, with substantial variability in learner's results.

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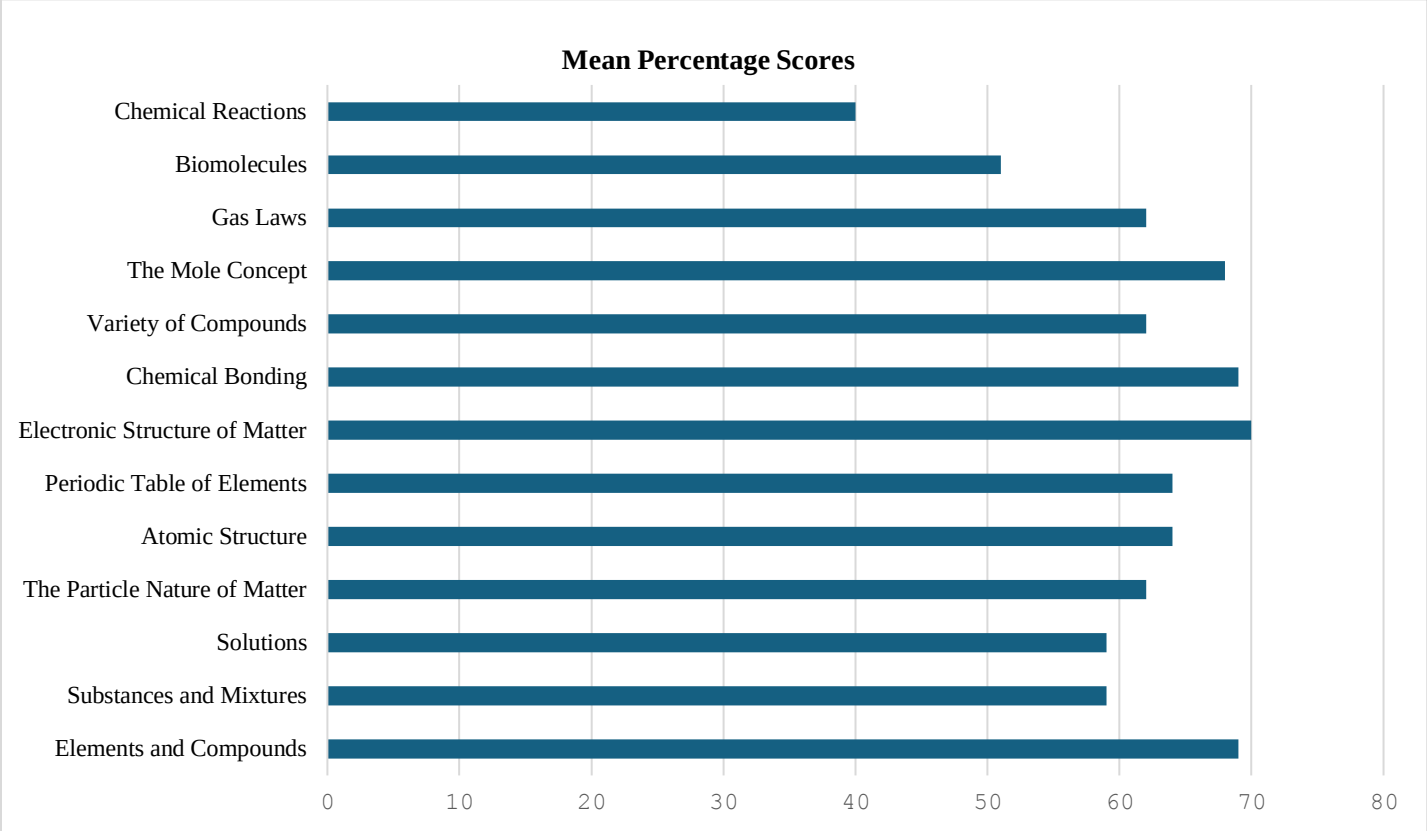

Figure 1. Grade 10 Learners Performance in the Most Essential Learning Competencies

Figure 1 summarized the mastery level in DepEd Most Essential Learning Competencies (MELCs) in Science (Chemistry). This reveals varying levels of mastery of the participants of the Needs Assessment across thirteen (13) chemistry topics. Topics such as Elements and Compounds, The Particle Nature of Matter, Atomic Structure, Periodic Table of Elements, Electronic Structure of Matter, Chemical Bonding, Variety of Compounds, The Mole Concept, and Gas Laws fall under the "*Nearly Mastered*" level, indicating that students performed moderately well, with mean percentages ranging from 60% to 70%. These areas show foundational understanding but still require reinforcement to reach full mastery.

In contrast, topics like Substances and Mixtures, Solutions, Biomolecules, and Chemical Reactions were classified as "*Least Mastered*," with average scores ranging from 40% to 59%. These topics had higher frequencies of errors, suggesting that learners struggled with distinguishing mixtures from pure substances, understanding solution concepts, recognizing biomolecular structures, and analyzing chemical reactions. Notably, Chemical Reactions had the highest average frequency of error (60%), making it the most challenging topic for learners.

Based on the results of the Needs Assessment**, *Chemical Reactions*** emerged as the top - most least mastered topic among Grade 10 students because some teachers are only using video presentations due to lack of equipment in teaching this topic. As a result, it was selected as the focus for the development of a ***Learning Packet*** as an intervention material. This Learning Packet integrates Green Chemistry Principles. This integration aims not only to enhance students' conceptual understanding of chemical reactions but also to promote environmental sustainability. Additionally, the approach seeks to assess and improve learners' awareness and attitudes toward Green Chemistry, fostering a deeper appreciation for eco-friendly practices in scientific learning.

Evaluation of the Green Chemistry Learning Packet (GCLP)

The evaluation of the Green Chemistry Learning Packet was validated by three (3) public school teachers specializing in science. Their expertise ensured that the content aligned with the curriculum and met the instructional standards expected for effective classroom use.

Table 4: Summary of Evaluation for Green Chemistry Learning Packet

	TA	TB	TC	MEAN	INTERPRETATION
A. CONTENT	4	4	4	4	Very Acceptable
B. TECHNICAL QUALITY B1. PRINT	4	4	4	4	Very Acceptable
B2. ILLUSTRATIONS	3	4	4	4	Very Acceptable
B3. DESIGN AND LAYOUTS	4	4	4	4	Very Acceptable
C. PRESENTATION AND ORGANIZATION	4	4	4	4	Very Acceptable
D. ACCURACY AND UP-TO-DATE INFORMATION	4	4	4	4	Very Acceptable
Mean	**4**	**4**	**4**	**4**	**Very Acceptable**
d: 4 = Very Acceptable, 3 = Acceptable, 2 = Partially Acceptable, 1= Not Acceptable; T=Teacher					

The Table 4 evaluation results from three (3) teachers indicate that the Green Chemistry Learning Packet is of high quality, with all categories receiving a mean rating of 4.0, interpreted as Very Acceptable. This reflects a strong material's excellence in content, technical quality, presentation, organization, and accuracy. While all aspects were rated very positively, the illustrations section received one slightly lower score (3) from Teacher A, suggesting a minor area for improvement. Overall, the feedback confirms that the learning material is well-prepared, accurate, and suitable for classroom use, with only slight refinements needed to enhance its visual components.

Conceptual Understanding of Grade 10 Learners

These participants completed the validated questionnaire before and after the integration of the Green Chemistry Learning Packet. This allows the researcher to assess their prior knowledge and measure improvements in conceptual understanding after the intervention.

TABLE 5: Pre-Test Result of the Learners on Conceptual Understanding Instrument

Scores	**Pre-Test**			
	f	**%**	**Equivalent Percentage of Scores**	**Description**
29-30	0	0	100	Outstanding
27-28	0	0	95	
25-26	0	0	90	Very Satisfactory
23-24	1	3	85	
21-22	1	3	80	Satisfactory
19-20	2	10	75	Fairly Satisfactory
18-below	31	84	70 and below	Did Not Meet the Expectations
Legend: Outstanding = 91-100, Very Satisfactory = 85-90, Satisfactory = 80-84, Fairly Satisfactory = 75-79, Did Not Meet Expectations = Below 75				

Table 5 shows the distribution of Pre-Test Conceptual Understanding Questionnaire scores among Grade 10 learners, categorized into different performance levels based on an established grading scale. Most learners (84%) scored below 75%, falling into the *Did Not Meet Expectations* category, indicating that most were unable to meet the minimum standards set. Only a small portion of the group (6%) scored within the Satisfactory or higher categories, with 3% scoring within the Fairly Satisfactory range (75-79%) and 3% in the Satisfactory range (80-84%). Notably, no learners scored in the Outstanding (91-100%) or Very Satisfactory (85-90%) ranges, suggesting that the pre-test was challenging for the learners, and a significant portion of the group lacked the necessary preparation or knowledge. This distribution highlights the need for further instructional support or intervention to help improve the learners' conceptual understanding and performance in future assessments.

This result is supported by Chemistry playing a vital role in advancing sustainable development through the principles of green chemistry. By incorporating green chemistry into education, sustainable development goals in education can be achieved (Paristiowati et al., 2022).

Table 6: Post-Test Result of the Learners on Conceptual Understanding Instrument

Scores	Post-Test			
	f	%	Equivalent Percentage of Scores	Description
29-30	0	0	100	Outstanding
27-28	1	3	95	
25-26	4	13	90	Very Satisfactory
23-24	5	17	85	
21-22	7	23	80	Satisfactory
19-20	3	9	75	Fairly Satisfactory
18-below	15	35	70 and below	Did Not Meet the Expectations
Legend: Outstanding = 91-100, Very Satisfactory = 85-90, Satisfactory = 80-84, Fairly Satisfactory = 75-79, Did Not Meet Expectations = Below 75				

Table 6 shows the Post-Test Conceptual Understanding Questionnaire after the integration of the Green Chemistry Learning Packet. This shows an overall improvement in learners' performance compared to the Pre-Test Conceptual Understanding. While no learners scored in the *Outstanding* range (29-30points), there was a slight increase in the number of learners scoring in the *Very Satisfactory* category (27-28points), with 3% of learners achieving scores between 95 and 100. In the *Very Satisfactory* range (25-26points), 13% of learners scored between 90 and 94, indicating a notable improvement in the learner's performance. A larger portion of learners (17%) scored within the *Satisfactory* range (23-24points), while 23% of the learners achieved scores between 80 and 84. Additionally, 9% of learners scored in the *Fairly Satisfactory* range (19-20points). Despite the improvement, 35% of learners still scored below 75, falling into the *Did Not Meet Expectations* category, although this is a decrease compared to the 84% in the pre-test.

Overall, the Post-Test results reflect a positive shift in performance, with a greater proportion of the Grade 10 learners moving into higher performance categories, though a significant portion still did not meet expectations. This suggests that while progress has been made, further support and intervention are still necessary to help all participants reach the desired level of proficiency.

The result showed an increase in the number of learners who passed the post-test. This result was supported by DeJong & Talanquer (2015) indicates that integrating Green Chemistry contents fosters personal growth by highlighting the socially mediated context of sustainability. Additionally, Teaching green chemistry in schools not only provides a contemporary perspective on traditional chemistry but also ensures safer experiments and fosters critical thinking. It combines science with sustainability, offering students valuable hands-on experiences in science fairs and projects. Given these benefits, teaching green chemistry in high schools is essential (Sajeena, 2021).

Table 7: Internal Reliability of the Conceptual Understanding Instrument (CUI)

	Mean	SD	Cronbach's
Conceptual Understanding Questionnaire	14.171	4.860	0.7409

Table 7 illustrates the reliability coefficient of the Conceptual Understanding Instrument (CUI). The questionnaire compromises of thirty (30) items. Cronbach's alpha value of 0.7409 indicates that the questionnaire is 74.9% reliable. This signifies an extraordinary internal consistency among the items, suggesting that a strong it for study.

Table 8: Paired Sample T-Test of Pre-Test and Post-Test

Group	Mean	MD	SD	t-value	p-value
Pre-Test	14.17		4.86		
Post-Test	18.43	-4.26	5.69	0.001	<0.05

Table 8 stated that the pre-test and post-test scores reveal a significant improvement in learners' performance after the intervention using the Green Chemistry Learning Packet. The pre-test had a mean score of 14.17, while the post-test showed an increased mean of 18.43, indicating a positive effect on learners' conceptual understanding. The mean difference (MD) of -4.26 reflects the change in scores from pre-test to post-test, with the negative sign indicating that the post-test mean is higher than the pre-test mean. The standard deviation (SD) of 4.86 for the pre-test and 5.69 for the post-test suggests that the spread of scores was relatively consistent in both tests. The t-value of 0.001 and the p-value of <0.05 indicate that the difference between the pre-test and post-test scores is statistically significant, meaning that the observed improvement in scores is unlikely to have occurred by chance. This supports the conclusion that the Green Chemistry Learning Packet is effective on enhancing the learners' learning outcomes.

This is supported by the study of Wang et al. (2020) stated that teaching green chemistry in the classroom helps learners understand the connections between people and the natural world, as well as the intangible links between nature and human well-being. It can inspire students to explore green chemistry and various aspects of sustainable development while encouraging them to consider how these issues impact multiple fields simultaneously.

CONCLUSION

The Needs Assessment revealed that most learners struggled to meet the expected academic standards, with Chemical Reactions emerging as the least mastered topic. This prompted the development of a Green Chemistry Learning Packet focused on this topic. Pilot testing with thirty-five (35) Grade 10 students showed a notable improvement in post-test scores compared to pre-test results, indicating the effectiveness of the Green Chemistry Learning Packet. Despite the progress, a substantial number of learners still failed to meet proficiency standards, underscoring the need for continued support and targeted interventions. The study affirms the importance of incorporating sustainability-focused education to foster both academic improvement and environmental responsibility, aligning with global goals such as SDG 4 (Quality Education), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

The findings of this study conclude that integrating Green Chemistry principles into chemistry education significantly enhances Grade 10 learners' conceptual understanding, awareness, and attitudes toward environmental sustainability

Based on these findings, it is recommended that Green Chemistry principles be formally integrated into the junior high school science curriculum to strengthen conceptual understanding and promote environmental consciousness. Teachers should consider utilizing the developed learning packet, especially when teaching complex topics like Chemical Reactions, and apply interactive and contextualized teaching strategies to address varied learning needs. Schools are encouraged to implement sustained remediation programs targeting least mastered competencies through hands-on and real-world applications. Future researchers should expand the scope of the study to include more diverse populations, conduct longitudinal tracking of student progress, and explore alternative assessment methods such as performance tasks and portfolios. Additionally, training programs for teachers on Green Chemistry pedagogy should be provided to enhance classroom implementation. The development of digital and interactive support materials is also suggested to increase student engagement. Through these efforts, educators can advance both scientific literacy and environmental stewardship among learners.

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