STUDENTS' COGNITIVE PERFORMANCE USING DESIGN-BASED LEARNING INSTRUCTIONAL MATERIAL IN A GREEN CHEMISTRY ENVIRONMENT

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ABSTRACT

This study investigated the cognitive performance of students in Chemistry using Design-Based Learning in a Green Chemistry Environment Instructional Material (DBL-GCE IM). Specifically, it aimed to determine the level of cognitive performance of students exposed and not exposed to the instructional material and to test whether a significant difference existed between the two groups. A quasi-experimental research design was employed in a public secondary school in Northern Mindanao, Philippines, involving two intact sections selected through total enumeration. One group was exposed to the DBL-GCE IM, and the other group was exposed to non-DBL-GCE IM instruction. Data were gathered using the Regional Unified Quarterly Assessment (RUQA), a standardized test from the Department of Education in Region X, and performance levels were interpreted using the proficiency scale adapted from Department of Education Order No. 8, s. 2015. The data were analyzed using frequency, percentage, mean, and Analysis of Covariance (ANCOVA) at the 0.05 level of significance. Results revealed that both groups had comparable pretest performance; however, after the intervention, the DBL-GCE IM group obtained a higher Mean Percentage Score of 83.00, interpreted as Satisfactory, compared with 69.30 for the non-DBL-GCE IM group, interpreted as Did Not Meet Expectations. ANCOVA further showed a significant difference in posttest cognitive performance between the groups, with a significant group effect, $F = 42.740$, $p < .001$, and a large effect size (partial $\eta^2 = .424$). The findings indicate that DBL-GCE IM effectively enhances students' cognitive performance in Chemistry.

Keywords: *cognitive performance, Chemistry education, design-based learning, green chemistry, instructional material*

INTRODUCTION

Science education is expected to develop learners' capacity to explain phenomena, solve problems, and apply scientific ideas in meaningful contexts. In the Philippine curriculum, this expectation is reflected in the emphasis on learner-centered and inquiry-based instruction, the use of evidence in constructing explanations, and opportunities for collaboration, innovation, and engineering design in science classes (Department of Education [DepEd], 2024). These curricular directions highlight the importance of improving students' cognitive performance in chemistry, a discipline that demands not only factual recall but also conceptual understanding and the application of knowledge to unfamiliar situations.

The urgency of this concern is reinforced by international assessment results. In PISA 2022, students in the Philippines performed below the OECD average in science, and only 23% attained at least Level 2 proficiency, indicating that many learners continue to struggle in explaining familiar scientific phenomena and in identifying whether simple conclusions are supported by data (OECD, 2023). These findings suggest that science instruction must extend beyond routine content transmission toward approaches that more effectively promote understanding, reasoning, and knowledge application. This need is particularly pronounced in chemistry, where many concepts are abstract and difficult to comprehend when instruction relies primarily on passive classroom discussion.

One instructional approach that may address this need is Design-Based Learning (DBL). DBL engages students in solving real-world challenges through design practices, thereby providing a meaningful context for the use and development of science concepts during learning activities. Research in design-based science education has shown that design experiences can support the development of scientific understanding and problem-solving skills, while recent studies in chemistry education indicate that DBL can reveal and strengthen students' conceptual understanding as they explain, justify, and refine their ideas through design talk and drawings (Stammes et al., 2023). These findings suggest that DBL is relevant to the improvement of cognitive performance because it situates learners in active contexts in which conceptual understanding is applied rather than merely memorized.

Another important direction in chemistry education is green chemistry. Green chemistry promotes safer, more environmentally responsible, and resource-efficient practices in chemical teaching and experimentation (Anastas & Eghbali, 2010). A systematic review by Ferk Savec and Mlinarec (2021) showed that green chemistry has been implemented across chemistry fields and educational levels as a means of making experimental work more feasible, meaningful, and sustainable. This is particularly relevant in school settings, where limited laboratory resources and safety concerns often constrain hands-on learning. By emphasizing safer and more accessible materials, green chemistry can provide learning experiences that are both practical and educationally sound, thereby enabling students to engage more meaningfully with chemistry concepts.

Collectively, the literature suggests that DBL provides the pedagogical structure for active, design-oriented, and conceptually focused learning, while green chemistry offers a safe and sustainable context for the implementation of chemistry activities. Their integration is educationally significant because DBL may foster conceptual understanding through authentic problem-solving, whereas green chemistry may enhance the feasibility of such learning experiences in resource-constrained classrooms. However, despite the promise of both approaches, studies examining their combined use in secondary chemistry instruction remain limited, particularly in localized school contexts. Existing literature has largely discussed DBL in relation to conceptual understanding and green chemistry in relation to sustainable experimental work, yet fewer studies have directly examined how instructional materials integrating both approaches may influence students' cognitive performance in chemistry.

This gap provides the rationale for the present study. Given the continuing need to improve science learning outcomes, the curriculum's emphasis on inquiry and engineering design, and the practical constraints experienced in many chemistry classrooms, the use of Design-Based Learning instructional material in a green chemistry environment is both timely and necessary. Thus, this study examines the cognitive performance of students using Design-Based Learning instructional material in a green chemistry environment. Specifically, it aims to determine the level of cognitive performance of students exposed to the instructional material and those not exposed to it, and to test whether a significant difference exists between the two groups.

Research Questions

The study aimed to investigate the students' cognitive performance in Chemistry using design-based learning in green chemistry environment instructional material (DBL-GCE IM). Specifically, it sought to answer the following research questions:

1. What is the level of students' cognitive performance in chemistry to those exposed and those not exposed to design-based learning instructional material in green chemistry environment?
2. Is there a significant difference on the level of students' cognitive performance to those exposed and those not exposed to design-based learning instructional material in green chemistry environment?

METHODOLOGY

The study was conducted in a public secondary school in Northern Mindanao, Philippines. A quasi-experimental research design was employed, involving an experimental group exposed to the Design-Based Learning in Green Chemistry Environment Instructional Material (DBL-GCE IM) and the non-Design-Based Learning in

Green Chemistry Environment Instructional Material (non-DBL-GCE IM). The participants were selected through the total enumeration of two intact sections. The investigation was limited to determining the effect of the instructional material on students' cognitive performance in Chemistry during the implementation period.

Data were gathered using the Regional Unified Quarterly Assessment (RUQA), a standardized test from the Department of Education in Region X, which was used by the researcher to assess students' cognitive performance. The level of performance was interpreted using the proficiency scale adapted from Department of Education Order No. 8, s. 2015, otherwise known as the Policy Guidelines on Classroom Assessment for the K to 12 Basic Education Program.

Score	**Percentage Score**	**Descriptive Rating**	**Qualitative Interpretation**
46 – 50	90 – 100	Advance	Outstanding (O)
41 – 45	85 – 89	Proficient	Very Satisfactory (VS)
36 – 40	80 – 84	Approaching Proficiency	Satisfactory (S)
30 – 35	75 – 79	Developing	Fairly Satisfactory (FS)
0 – 29	74 and below	Beginning	Did not meet expectations (DNME)

The data gathering procedure involved administering the RUQA to both groups following the implementation of the instructional intervention. Collected data were organized, tabulated, analyzed, and interpreted using appropriate statistical tools. Descriptive statistics such as frequency, percentage, and mean were used to determine the level of students' cognitive performance. To test whether a significant difference existed in cognitive performance between the group exposed to the Design-Based Learning in Green Chemistry Environment Instructional Material (DBL-GCE IM) and the non-Design-Based Learning in Green Chemistry Environment Instructional Material (non-DBL-GCE IM), Analysis of Covariance (ANCOVA) was employed. All statistical analyses were performed at the 0.05 level of significance. The study was limited to the variables included in the investigation and to the assessment of cognitive performance as measured by the standardized instrument used.

RESULTS AND DISCUSSION

Level of Students' Cognitive Performance

Table 1. Students' Cognitive Performance in Chemistry to those exposed DBL-GCE IM and Non-DBL-GCE IM.

Raw Score	**Percent Equivalent**	**DBL-GCE IM**				**Non-DBL-GCE IM**				**QI**
		Pretest		Posttest		Pretest		Posttest		
		N	%	N	%	N	%	N	%	
46-50	90-100	0	0	5	16.7	0	0	0	0	O
41-45	85 – 89	0	0	13	43.3	0	0	5	16.1	VS
36-40	80 – 84	0	0	12	40.0	0	0	6	19.4	S
30-35	75 – 79	0	0	0	0	0	0	19	61.3	FS
0-29	74 and below	30	100	0	0	31	100	1	3.2	DNME
	TOTAL	30	100	30	100	31	100	31	100	
	Mean Score	13.43		41.50		13.45		34.65		
	Overall MPS	**26.86 DNME**		**83.00 S**		**26.90 DNME**		**69.30 DNME**		

Table 1 presents the students' cognitive performance when exposed to DBL-GCE IM and those not exposed to Non-DBL-GCE IM. The DBL-GCE IM group showed an overall percentage score of 26.86 in the pre-test and 83.00 in the post-test. For non-DBL-GCE IM group, the overall percentage score is 26.90 in the pre-test and 69.30 in the post-test. As shown in the table, the pretest of both groups demonstrated very low performance 100 % obtained scores within the Did Not Meet Expectations (DNME) level. Their mean scores were also almost identical (13.43 for DBL-GCE IM and 13.45 for Non-DBL-GCE IM), indicating that the two groups were comparable in terms of prior Chemistry knowledge before the intervention.

After the implementation of the instructional materials, there was an improvement in cognitive performance was observed, particularly among students exposed to the DBL-GCE IM. In the posttest, all students in this group achieved at least satisfactory performance, with 16.7% reaching Outstanding, 43.3% Very Satisfactory, and 40.0% Satisfactory levels. Their mean score increased substantially to 41.50, corresponding to an overall Mean Percentage Score (MPS) of 83.00, interpreted as Satisfactory. In contrast, the Non-DBL-GCE IM group demonstrated lower gains. Although some students reached Very Satisfactory (16.1%) and Satisfactory (19.4%) levels, the majority (61.3%) remained at the Fairly Satisfactory level and 3.2% still did not meet expectations. Their mean score rose to only 34.65, with an MPS of 69.30, which remained below mastery. The difference of 6.85 points in mean scores and the shift of the DBL-GCE IM group from DNME to Satisfactory level indicate that the DBL-GCE instructional material was more effective in enhancing students' cognitive performance in Chemistry than the non-design-based material.

The result shows that the DBL-GCE instructional material enhanced cognitive performance by engaging learners in authentic design tasks situated within green chemistry contexts, thereby promoting deeper conceptual understanding and higher-order thinking. Through design thinking processes students were required to apply chemical concepts in practical and meaningful ways and allowed learners to connect abstract ideas to real-world decision-making, making scientific understanding more concrete and relevant. The integration of green chemistry principles encouraged students to evaluate their outputs not only in terms of functionality but also in relation to sustainability, safety, and environmental responsibility which in turn contributed to improved conceptual processing, and cognitive achievement. In contrast, the non- DBL-GCE IM group have relied more on traditional instruction and routine exercises, which tend to develop basic recall rather than conceptual mastery. Without opportunities to design solutions or apply green chemistry principles in authentic contexts, learners may have engaged less in higher-order thinking processes, explaining why many students in the comparison group remained at the fairly satisfactory level.

The result of the study aligns with the findings of Hernandez-de-Menendez et al. (2019) that through design thinking stages students were required to analyze information, apply chemical concepts, and evaluate the effectiveness and environmental safety of their solutions. These processes demand higher-order thinking and repeated application of knowledge, which strengthen conceptual understanding. Moreover, Fan & Yu (2017) shown that design-oriented tasks and prototype development enhance academic performance because learners actively construct and refine solutions rather than passively receive information thus learning environments strengthen cognitive outcomes by requiring learners to integrate knowledge, apply concepts, and evaluate solutions, leading to measurable achievement gains, Similarly, embedding green chemistry and strengthens students' cognitive and academic performance thereby helping learners connect chemical principles with real environmental issues, promoting meaningful understanding and problem-solving ability (Burmeister & Eilks, 2017; Sjostrom et al., 2021).

Analysis of Covariance (ANCOVA) on Students' Cognitive Performance

Table 2. Analysis of Covariance (ANCOVA) for Students' Cognitive Performance when exposed to DBL-GCE IM and Non-DBL-GCE IM

Group	**N**	**Mean**	**Std. Deviation**
DBL-GCE IM	30	41.5000	3.35024
Non- DBL-GCE IM	31	34.6452	4.67296
Total	61	38.0164	5.31818

Source	SS	df	MS	F-value	Sig.	Partial eta squared
Model	724.120[a]	3	362.060	21.585	0.000	0.427
PRETPER	7.733	1	7.733	0.461	0.500	0.008
GROUP	716.893	2	716.893	42.740	0.000	0.424
Error	972.863	58	16.774			
Total	89857.000	61				

Table 2 presents the result of an Analysis of Covariance (ANCOVA) of students' post -test scores for the DBL-GC IM and non-DBL-GCE IM groups. The result shows that the DBL-GCE IM had a mean post-test score of 41.50 (SD=3.35), while the non-DBL-GCE IM group is lower with a mean of 34.65 (SD=4.67). The group factor was statistically significant, with an F-value of 42.740 ($p < 0.001$) and partial eta squared of 0.424, indicating that the intervention had a significant effect.

The results indicate that both the DBL-GCE IM and the Non-DBL-GCE IM groups showed significant improvement from pretest to posttest. The ANCOVA further revealed that the effect of group was statistically significant, indicating that the type of instructional material used had a significant influence on students' cognitive performance. In contrast, pretest performance did not significantly affect posttest scores, with an F value of 0.461 and $p = .500$, suggesting that the differences in cognitive performance were not due to initial ability differences between the groups. This indicates that the DBL-GCE IM was more effective than the Non-DBL-GCE IM in improving students' cognitive performance. Hence, the null hypothesis stating that there is no significant difference in the cognitive performance of students exposed to the DBL-GCE IM and those exposed to the Non-DBL-GCE IM is rejected.

This result aligned with the findings of (Zuin et al., 2021) that the integration of design-based learning and green chemistry principles engage students in authentic problem solving, iterative design, and the practical application of chemistry concepts thus improves students conceptual understanding, systems thinking, and meaningful knowledge construction Similarly, instruction that requires learners to design environmentally responsible products or processes can deepen the connection between chemical concepts and practical application, thereby supporting stronger academic performance (Linkwitz & Eilks, 2022).

Conclusions

The results revealed that students exposed to the DBL-GCE instructional material demonstrated higher cognitive performance than those in the non-DBL-GCE group. Although both groups had comparable pretest results, the DBL-GCE group achieved a higher Mean Percentage Score (MPS) of 83.00, interpreted as Satisfactory, whereas the non-DBL-GCE group obtained a lower MPS of 69.30, interpreted as Did Not Meet Expectations. These findings suggest that the integration of Design-Based Learning and Green Chemistry contexts contributes to more effective learning outcomes.

The Design-Based Learning in a Green Chemistry Environment instructional material (DBL-GCE IM) produced a statistically significant effect on students' cognitive performance relative to non-DBL-GCE instruction. ANCOVA findings indicated that the DBL-GCE IM group obtained a significantly higher posttest cognitive score, with a mean of 41.50, than the non-DBL-GCE IM group, which obtained a mean of 34.65. A significant group effect was observed, $F = 42.740$, $p < .001$, with a large effect size (partial $\eta^2 = .424$). In addition, pretest performance was not a significant covariate, confirming the comparability of the two groups before the intervention. Integrating design-based learning and green chemistry contexts into Chemistry instruction can significantly enhance students' cognitive performance by promoting deeper understanding and more meaningful application of concepts.

Recommendations

Based on the study's findings, the following recommendations are proposed for educators, policymakers, educational institutions, and future researchers.

It is recommended that educators and instructional leaders more widely integrate design-based, inquiry-driven, and sustainability-oriented learning activities into Chemistry instruction to improve students' cognitive performance. Moreover, school administrators and policymakers may support the wider implementation, monitoring, and possible scaling of the DBL-GCE instructional material in secondary Chemistry classes to enhance students' performance. Future researchers may likewise conduct similar studies using larger samples, longer intervention periods, other Chemistry topics, and additional variables such as critical thinking, environmental awareness, problem-solving skills, and long-term retention to further validate and extend the effectiveness of the DBL-GCE instructional material.

Compliance with Ethical Standards

The authors of this study affirm that ethical standards were fully observed throughout the research process. Informed consent was secured from all participants after they were adequately informed about the purpose of the study, the procedures involved, and any possible risks. They were also made aware that participation was voluntary and that they could withdraw from the study at any point without penalty.

The anonymity of the participants was protected throughout the conduct of the research, and no identifying information was disclosed. The researchers likewise ensured that the well-being of the respondents was protected and that appropriate precautions were taken to prevent any form of harm. In addition, the authors declare that no conflict of interest influenced the conduct of the study. Ethical research practices were upheld by properly acknowledging all sources and strictly avoiding plagiarism. Moreover, the findings were interpreted objectively and without bias, and the results were utilized solely for academic and research purposes.

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