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Students' Performance and Cognitive Skills in Chemistry Through Case-Based Learning Approach

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ABSTRACT
Objective: This study investigated the effects of a case-based learning (CBL) approach on academic performance and cognitive skills among Grade 9 students. Specifically, it aimed to determine the level of students' academic performance in Chemistry as exposed to CBL and non-CBL; assess students' level of cognitive skills; ascertain significant differences in students' cognitive skills; find out the difference in the student's academic performance and determine the significant difference on students' level of knowledge retention. **Method:** The study employed a quasi-experimental research design using two comparable group classes. A validated teacher-made questionnaire was used to determine students' academic performance. The Gibson Cognitive Skill questionnaire was used to measure cognitive skills. **Results:** It was found that students in both groups had better academic performance in the post-test than in the pre-test. Students exposed to CBL performed better and scored higher than those under non-CBL. Meanwhile, students exposed to CBL had high cognitive skills, while those exposed to non-CBL had moderate cognitive skills. There was a significant difference in students' cognitive skills between CBL and non-CBL groups. Moreover, a significant difference existed in students' academic performance in the post-test and retention test between the two groups. **Novelty:** Recognizing the positive effect of case-based learning on students' performance, science teachers may consider integrating CBL as a practical alternative pedagogical approach to address the problem of lack of retention of science concepts.

INTRODUCTION

Science education aims to help students grasp ideas and improve their capacity to apply them to new situations. Educators must give learners the information and abilities to tackle complicated problems and think critically. However, this aim was impeded due to a lack of understanding and cognitive skills, which have an inevitable role in the student's academic performance. This problem is persistent in the Philippines, the low performance of Filipino students in science is evident in the National Achievement Test (NAT), Trends in International Mathematics and Science Study (TIMSS), and even the recent Programme for International Student Assessment (PISA) results. In PISA 2022, the country obtained an average scientific literacy score of 356 points, significantly lower than the standard score of the Organization of Economic Co-operation and Development (OECD), 485 points (OECD, 2023). The scientific literacy of the Philippines needs to catch up to that of the ASEAN countries that participated. This is quite alarming to note about studies on academic performance. Teaching approaches should be developed and applied to meaningful and retentive learning (Andarino, 2019).

A previous study found that Filipino students have relatively low scores on cognitive skills assessments in chemistry (Hasanah & Shimizu, 2020). According to Shi and Qu (2021), if the overall level of cognitive ability is poor or a specific cognitive capacity is inadequate, part of the information will be lost in processing, lowering the output of practical information and resulting in lower academic performance. Some studies have been conducted on specific aspects of cognitive skills in chemistry, such as problem-solving and critical thinking. A limited study examines the full range of cognitive skills in the chemistry of Filipino students. More research is needed on instructional strategies to enhance cognitive skill development in chemistry.

Case-based learning is a teaching approach that provides an interactive learning environment where students analyze real-life problems related to the subject matter (Yan et al., 2024). This approach allows students to apply theoretical knowledge to real school contexts, reason critically about complex situations, develop self-knowledge, and recognize their assumptions. Moreover, it compares and evaluates their and others' perspectives, which could help hone critical thinking. Moreover, implementing the K to 12 curriculum requires teachers to be more innovative in delivering quality classroom instruction. More importantly, students can enhance their performance in science by developing their cognitive abilities combined with competence, which becomes a hallmark of self-efficacious learners.

This study bridges the research gap by investigating the effects of the case-based learning approach on students' performance and cognitive skills in chemistry. Unlike previous studies that mainly focus on content knowledge, this research comprehensively assesses overall performance, perceived level of cognitive skill, and retention in chemistry during post-pandemic. Specifically, it sought to answer the following questions:

- What is the student's level of academic performance when exposed to case-based learning (CBL) and non-CBL?
- What are students' levels of cognitive skills when exposed to CBL and those in a non-CBL approach?
- Is there a significant difference in students' cognitive skills when exposed to CBL and those in non-CBL?
- Is there a significant difference in students' academic performance when exposed to CBL and those in non-CBL approach?
- Is there a significant difference in students' knowledge retention levels as exposed to CBL and those in a non-CBL approach?

RESEARCH METHOD

Research Design

The study employed a quasi-experimental research design to assess the effect of the case-based learning approach on students' performance and cognitive skills in Chemistry. This type of design includes two sample classes, the experimental and control classes (Isnawan, 2022). The experimental class was taught using the CBL approach, and the control class was exposed to the conventional approach. Furthermore, the two classes were given a pre-test, post-test, and retention test.

Participants and Research Setting

Two intact Grade 9 classes from the Philippine College Foundation, Basic Education Department, were chosen. One section experienced the CBL approach through interactive worksheets filled with case-based problems and a PowerPoint Presentation based on the 7E Lesson Plan. The other section was taught using the traditional lecture method. These participants are enrolled for the academic year 2023-2024.

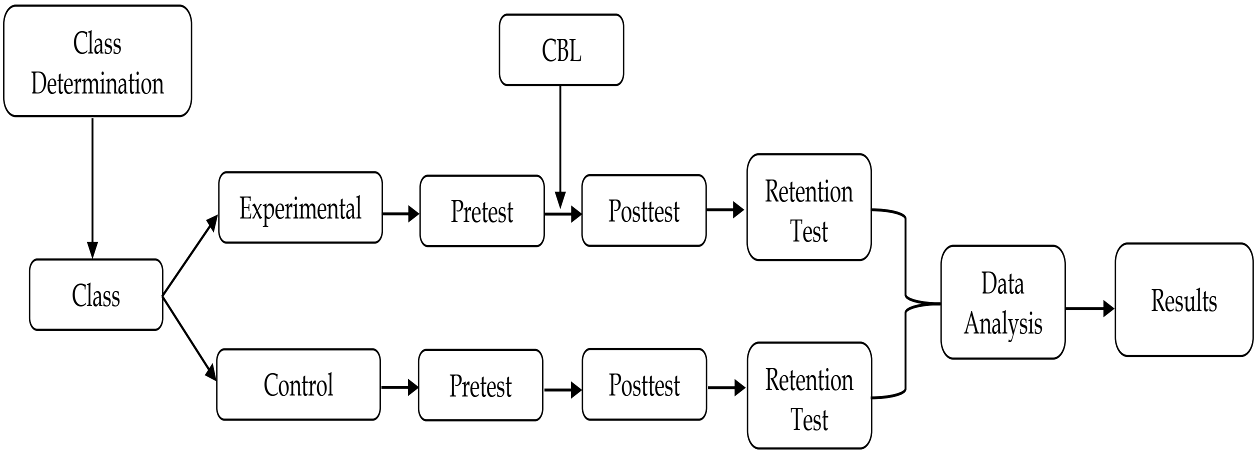

Figure 1. Data gathering procedure.

Research Instrumentation

This study employed a comprehensive assessment process, including academic and non-academic evaluations. The researchers used a fifty (50) item multiple-choice test for academic assessment, validated by a Chemistry experts panel. The researchers conducted a reliability test through a pilot test for Grade 9 classes of Valencia Colleges Incorporated and obtained a Cronbach's alpha of 0.89. To gauge student performance in the case-based learning approach, the researchers used the indicators outlined in DepEd Order No. 8 series of 2015.

Table 1. Student performance indicators.

Percentage Equivalent	Descriptive Rating	Qualitative Description
90 and above	Outstanding	Exceeds the core requirements in terms of knowledge, skills, and understanding. Transfer them automatically and flexibly through authentic tasks.
85-89	Very Satisfactory	Develop the fundamental knowledge, skills, and understanding and transfer them automatically and flexibly through authentic tasks.
80-84	Satisfactory	Develop the fundamental knowledge and, with little guidance from the teacher and/or peer assistance, can transfer this understanding through authentic tasks.
75-79	Fairly Satisfactory	Possess the minimum knowledge, skills, and understanding but needs assistance.
74 Below	Did Not Meet Expectations	Struggles with understanding, prerequisites, and fundamental knowledge and skills have not been developed adequately to aid understanding.

The Gibson Cognitive Skill Test (GCST) was used to measure the level of cognitive skills of the students with a reliability coefficient of 0.87. Fifteen (15) statements determine the students' cognitive skills, including processing speed, working memory, logic and reasoning, long-term memory, and comprehension skills. The five (5) point Likert rating scale was used to analyze the cognitive skills of the Grade 10 students. Table 2 was used for the interpretation of data.

Table 2. Likert rating scale for cognitive skills.

Scale	Weighted Mean	Descriptive Rating	Qualitative Description
5	4.51-5.00	Strongly Agree	Very High
4	3.51-4.50	Agree	High
3	2.51-3.50	Undecided	Moderate
2	1.51-2.50	Disagree	Low
1	1.00-1.50	Strongly Disagree	Very Low

Implementation of Case-Based Learning Approach

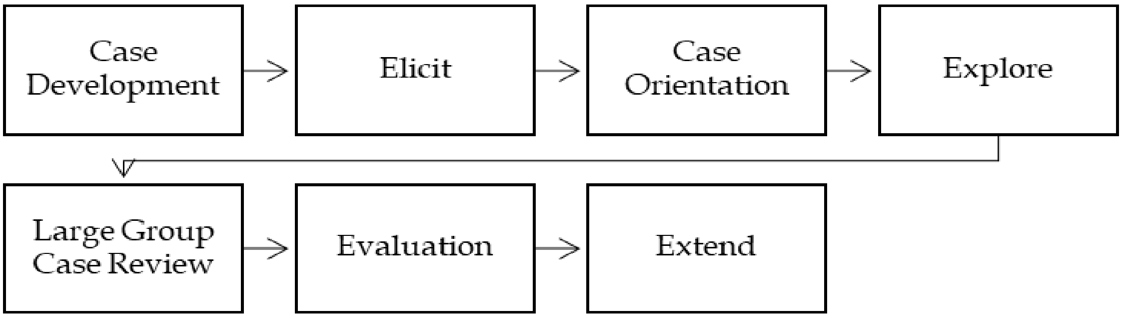

Figure 2. Implementation of case-based learning.

The following phases were employed in implementing a case-based blended learning approach:

Prior to class meetings, cases were developed by the researcher with an expert's guidance. It was outlined from the case development flowchart of Ripert (2021), which starts with defining the learning objectives and selecting the CBL type, which is directed in a small group format. The researcher selected parts of the case, including the setting and characters. It was followed by developing a real-life context and writing learning issues or questions. To elicit students' prior knowledge, they were introduced to the topic by presenting questions about their experiences and a picture activity. It was followed by case orientation; the students were engaged in preparation for the case-based blended learning approach. They were advised to read the case and note essential words or phrases that they think are relevant and potential learning issues.

In the explore phase, the students were grouped into five to seven members for peer instruction. In their small group discussion, their solutions to the case were compiled, and decisions were made to arrive at a correct solution by explaining their answers as needed. During the Large Group Case Review, each group presented their solutions to the class during a face-to-face meeting. The teacher facilitated consensus so the class could access the same unifying answers. For the evaluation, the learners presented their solutions to the case in the class through an extensive case review. They were evaluated as a group based on a rubric. The extended phase sought to deepen students' understanding, and the students were tasked to extend the concepts and skills in new but similar situations in the form of assignments.

For data analysis, descriptive statistics such as weighted mean, standard deviation, and percentages were employed to ascertain the level of student's performance and cognitive skills as exposed to case-based and non-case-based learning. The independent t-test was used to ascertain the significant difference in students' cognitive skills between the CBL and non-CBL groups. Analysis of Covariance (ANCOVA) was used to find a significant difference in student performance and knowledge retention between the CBL and non-CBL groups.

RESULTS AND DISCUSSION

Results

Students' Performance in Chemistry in the Case-Based Learning Environment

Table 3 presents the distribution of students' performance as exposed to case-based learning (CBL) and non-case-based learning (non-CBL) during the pre-test. Data revealed that in the CBL group, only one (3.33%) was very satisfactory, two (6.67%) achieved a satisfactory level, and five (16.67%) attained satisfactory. Moreover, twenty-two (73.33%) got a score below 75, which means they still needed to meet expectations. On the other hand, in the non-CBL group, one (3.13%) achieved satisfactory performance, five (15.63%) obtained satisfactory, and twenty-six (81.25%) did not meet expectations on their pre-test. Furthermore, the overall mean percentage scores of the CBL and the non-CBL groups were 74.50 and 73.71, respectively. Both groups got below 75 scores, meaning they did not meet expectations.

Table 3. Student's performance in the pre-test.

Range	CBL		Non-CBL		Qualitative Interpretation
	N	%	N	%	
90-100	0	0.00	0.00	0.00	Outstanding (O)
85-89	1	3.33	0.00	0.00	Very Satisfactory (VS)
80-84	2	6.67	1	3.13	Satisfactory (S)
75-79	5	16.67	5	15.63	Reasonably Satisfactory (FS)
Below 75	22	73.33	26	81.25	Did Not Meet Expectations (DNME)
Total	30	100	32	100	
Overall	MPS=74.50 (DNME)		MPS=73.71 (DNME)		

*MPS- Mean Percentage Score

Based on the results, both groups achieved an overall mean percentage score that did not meet expectations. Both groups have comparable MPS of 74.50 for CBL and 73.71 for non-CBL groups. This is good baseline data for determining the effectiveness of a particular teaching intervention.

Table 4 shows the distribution of students' performance as exposed to CBL and non-CBL in their post-test. Data reflects a student performance increase based on their mean percentage score. As shown, in the CBL group, nineteen (63.33%) obtained outstanding performance, five (16.67%) were very satisfactory, one (3.33%) got satisfactory performance, and four (13.33%) achieved a reasonably satisfactory performance. It is noteworthy to mention that in the group, no one got a score that did not meet expectations. An increase in post-test scores was also observed among students in the non-CBL group. There were two (6.30%) who achieved outstanding performance, fifteen (46.90%) who were very satisfactory, eleven (34.40%) who obtained satisfactory, and four (12.50%) who got satisfactory. Also, it is noted that no one got a score that did not meet expectations.

Table 4. Student's performance in the post-test.

Range	CBL		Non-CBL		Qualitative Interpretation
	N	%	N	%	
90-100	19	63.33	2	6.30	Outstanding (O)
85-89	5	16.67	15	46.90	Very Satisfactory (VS)
80-84	1	3.33	11	34.40	Satisfactory (S)
75-79	4	13.33	4	12.50	Reasonably Satisfactory (FS)
Below 75	0	0	0	0	Did Not Meet Expectations (DNME)
Total	30	100	32	100	
Overall	MPS=89.57 (VS)		MPS=84.34 (S)		

* MPS-Mean Percentage Score

Based on the findings, students taught using CBL obtained higher mean percentage scores than those exposed to non-case-based learning (non-CBL). As noted, students exposed to CBL achieved an overall mean percentage score of 89.57, which means very satisfactory performance. Students exposed to non-CBL obtained an overall mean percentage score of 84.34, which indicates satisfactory.

Students' Perceived Level of Cognitive Skills

Table 5 presents the cognitive skills of students exposed to CBL and non-CBL. As presented, students exposed to CBL were found to have high cognitive skills in terms of processing speed (4.02), comprehension (3.99), long-term memory (3.87), working memory (3.84), and logic and reasoning (3.81). Overall, students exposed to CBL had a high cognitive skill level (3.91). Meanwhile, students under non-CBL had moderate cognitive skills in terms of processing speed (3.48), comprehension (3.41), long-term memory (3.37), working memory (3.11), and logic and reasoning (3.40). Students exposed to non-CBL had a moderate cognitive skill level (3.35).

Table 5. Students' cognitive skills.

	CBL		Non-CBL	
Indicators	**Mean**	**Qualitative Interpretation**	**Mean**	**Qualitative Interpretation**
Processing Speed	4.02	High Cognitive Skills	3.48	Moderate Cognitive Skills
Comprehension	3.99	High Cognitive Skills	3.41	Moderate Cognitive Skills
Long Term Memory	3.87	High Cognitive Skills	3.37	Moderate Cognitive Skills
Working Memory	3.84	High Cognitive Skills	3.11	Moderate Cognitive Skills
Logic and Reasoning	3.81	High Cognitive Skills	3.40	Moderate Cognitive Skills
Overall Mean	3.91	High Cognitive Skills	3.35	Moderate Cognitive Skills

It can be inferred that students' exposure to a case-based learning approach enhances their cognitive skills. Students under CBL were exposed to tasks that developed their ability to process information from the given case-based problem. Students' working memory could be enhanced as they collaborate with their peers.

Logic and reasoning were tested when students presented their solutions to the provided problem. Furthermore, the apprehension of the given situational problems enriched students' comprehension. It further reveals that students' highly perceived cognitive skills aligned with their performance.

Comparison of Students' Cognitive Skills as Exposed CBL and Non-CBL

Table 6 illustrates the comparison of students' cognitive skills. Students exposed to CBL obtained a mean score on the following indicators, namely processing speed (4.02), comprehension (3.99), long-term memory (3.87), working memory (3.84), and logic and reasoning (3.81). Students exposed to non-CBL on the following indicators, namely processing speed (3.48), comprehension (3.41), long-term memory (3.37), working memory (3.11), logic and reasoning (3.40). The groups obtained an overall mean of 3.91 (CBL) and 3.35 (n0n-CBL).

Table 6. Comparison of students' cognitive skills.

	CBL		Non-CBL			
INDICATORS	MEAN	SD	MEAN	SD	t-value	p-value
Processing Speed	4.02	.295	3.48	.568	4.723	.000**
Comprehension	3.99	.249	3.41	.603	4.995	.000**
Long Term Memory	3.87	.362	3.37	.689	3.482	.001**
Working Memory	3.84	.463	3.11	.566	5.466	.000**
Logic and Reasoning	3.81	.269	3.40	.525	3.992	.000**
Overall	3.91	.328	3.35	.590	4.531	.000**

*Significant at 0.05 level

The study's results emphasized that students exposed to CBL have higher perceived cognitive skills than those exposed to non-CBL. There is a significant difference in all indicators between CBL and non-CBL groups. It was noted that processing speed got the highest means for both groups, which can be attributed to how students process information as they answer case-based problems in chemistry. High perceived cognitive skills of students in the CBL group can be associated with the interactive nature of the approach. The case-based learning approach necessitates students' ability to apply cognitive skills when confronted with contextualized problems in chemistry. As can be gleaned from the table, comparing students with perceived cognitive skills obtained a t-value of 4.531 with a p-value of 0.000, indicating a significance at 0.05 level. These reject the null hypothesis that no significant difference exists in students' perceived cognitive skills as exposed to case-based and non-case-based learning.

Comparison of Students' Performance as Exposed to CBL and Non-CBL

Table 7 compares students' performance between case-based learning and non-case-based learning groups. It shows that students exposed to CBL acquired a mean percentage score of 89.57 (SD=3.62) and 84.34 (SD=2.79) for non-CBL. Based on the results, students exposed to CBL perform better than those exposed to non-CBL.

Table 7. Comparison of students' performance in the post-test.

Group	N	MPS	SD
Case Based Learning	30	89.57	3.62
Non-case-based Learning	32	84.34	2.79

Group	N	MPS	SD
Total	62	86.96	3.57

As shown in Table 8, the computed F-value between the two groups was 14.150 with a probability (p) value of 0.000, indicating significance at 0.05. Therefore, the null hypothesis is rejected, which states no discernible difference in students' performance when exposed to case-based and non-case-based learning. This implies that students taught using CBL perform better than those exposed to the conventional teaching-learning process.

Table 8. Analysis of Covariance (ANCOVA) of students' posttest.

Source	Sum of Squares	Df	Mean Square	F-value	Sig.
Group	120.570	1	120.570	14.150	0.000**
Pre-test (covariate)	118.346	1	118.346	13.889	0.000**
Error	502.740	59	8.521		
Total	31138.00	62			

*Significant at 0.05 level

Comparison of Students' Retention as Exposed to CBL and Non-CBL

Table 9 illustrates the comparison of students' retention between case-based learning and non-case-based learning. As shown, students in the CBL group obtained a mean percentage score of 89.90 (SD=2.58), and the non-CBL group acquired 84.40 (SD=2.20). Based on the results, students exposed to CBL had higher knowledge retention than those exposed to non-CBL.

Table 9. Comparison of students' retention level between groups.

Group	N	MPS	SD
Case Based Learning	30	89.90	2.58
Non- Case Based Learning	32	84.40	2.20
Total	62	87.37	2.78

As seen in Table 10, the F-value between the two groups was 20.394, with the probability (p) value of 0.000 indicating high significance at 0.05 level. Therefore, the null hypothesis is rejected, which states that no significant difference exists in students' retention exposed to case-based and non-case-based learning approaches. Results reveal that students using the CBL approach can store information in long-term memory and put the knowledge to use in the future.

Table 10. ANCOVA of students' retention.

Source	Sum of Squares	Df	Mean Square	F-value	Sig.
Group	112.424	1	112.424	20.394	0.000**
Pre-test	18.835	1	18.835	3.417	0.070
Error	325.250	59	5.513		
Total	31276.0	62			

*Significant at 0.05 level

Discussion

This study investigated the effects of CBL on students' performance and cognitive skills. Students' performance was assessed before and after the experimental process. The pre-test results revealed that students lacked prior knowledge and skills to perform the expected competency. Notably, both CBL and non-CBL classes exhibited comparable low performance in the pre-test. Students' poor performance in the pre-test calls for targeted interventions to enhance their learning outcomes. The comparable performance of both groups serves as good baseline information for evaluating the effects of CBL. The findings are consistent with previous studies, which revealed that students in both control and experimental groups did not meet expectations in the science pre-test (Liboon & Magday, 2022; Magwilang, 2022). Inadequate prior knowledge is a challenge that impacts students' performance. These gaps could be addressed through practical teaching approaches, such as case-based learning, that fosters the ability to deepen students' understanding.

After the intervention, students taught using CBL obtained higher mean percentage scores than those exposed to the conventional teaching approach (non-CBL). As noted, students exposed to CBL achieved a very satisfactory performance compared to those exposed to non-CBL. This enhanced performance is manifested by active brainstorming and applying critical thinking to solve contextualized problems. According to Dewi and Rahayu (2024), case-based learning is an effective and practical teaching method for Chemistry subjects. This claim was supported by Eissa et al. (2022), who reported an increase in students' performance in biochemistry post-tests after exposure to CBL. Similarly, previous studies have shown that students in the treatment group (CBL) outperformed those in the control group (conventional method). Furthermore, Idika (2021) concluded that the CBL approach facilitates a deeper understanding of Chemistry concepts by promoting the transfer of learning. The effectiveness of CBL is evident in enhancing students' ability to apply their knowledge to real-world problems and enhance their overall academic performance. By Jerome Bruner's theory, discovery learning emphasizes the importance of active exploration, problem-solving, and the construction of knowledge through hands-on experiences. Case-based learning supports this concept by presenting learners with complex, real-world scenarios that require them to apply their mental faculties, including critical thinking, analysis, and inference, to uncover solutions.

A significant difference exists in the perceived level of cognitive skills between students in CBL and non-CBL classes. A high level of perceived cognitive skills, particularly in processing speed, comprehension, long-term memory, working memory, logic, and reasoning, was noted in students in CBL class. Meanwhile, a moderate level was found in students under the conventional approach. Cognitive skills are foundational to the mental processes underpinning knowledge acquisition and learning. These skills refer to solving intellectual task problems (Liu & Fleisher, 2022; Uy et al., 2024). Also, students' core values are positively influenced by cognitive skills. Jean Piaget's theory of cognitive development explains how learners develop cognitively through active exploration and problem-solving. It explains how students progress from concrete operational to formal operational thinking. Case-based learning is anchored to this theory by encouraging learners to utilize their cognitive skills, such as critical thinking, analysis, and problem-solving in real-world situations. Moreover, students who have confidence in their cognitive abilities and exert adequate effort are likelier to perform better (Uy & Azuelo, 2022). This underscores the importance of fostering cognitive development and students' self-efficacy and engagement in academic contexts. The development of cognitive abilities is particularly vital in addressing intellectual challenges.

Information processing was found to be high in students under CBL and moderate level in non-CBL students. Learning student-centered approaches like CBL could enhance students' information processing (Gizaw & Sota, 2023). However, contrasting results were reported on the role of processing speed in academic performance. Processing speed has a substantial role in improving academic performance. On the other hand, Nedungadi and Shenoy (2023) reported that cognitive processing speed does not significantly influence students' performance in organic chemistry. In addition, students' science process skills were moderate despite the different teaching approaches utilized. The previous findings suggest that the impact of processing speed on student performance depends on the complexity of tasks and specific competency standards. Although information processing speed is crucial in some areas, other factors, such as subject-specific strategies and metacognitive skills, could affect students' performance.

Comprehension is a cognitive skill found to be at a high level in students under CBL and at a moderate level in non-CBL students. It is critical in students' ability to acquire and process information. In chemistry, students' excellent comprehension skills are crucial to practical learning. Strong comprehension skills mean excellent academic performance in chemistry (Briones & Janer, 2023). Students with comprehension difficulties may struggle to understand written texts, hindering their learning. This was evident in the study of Handayani et al. (2018), where students' reading comprehension of science and physics texts was lower. These findings support the importance of incorporating training in the reading comprehension strategy of the science text into the curricula. Moreover, there was an evident improvement in comprehension among students associated with the collaborative learning environment. The study's results highlight that CBL fosters a collaborative learning environment where inquiry and knowledge transfer are facilitated. In CBL, students are tasked to encode and integrate new information into their prior knowledge. Meaningful encoding improves students' comprehension and accessibility to information stored in long-term memory.

Long-term memory is among the cognitive skills which play a significant role in students' performance. Current findings revealed a high level of long-term memory as exposed to CBL. Long-term and working memory directly affect a learner's ability to follow instructions and stay on task (Forsberg et al., 2021). Students' foundational concepts gained in previous grade levels serve as a basis for understanding more complex topics at higher levels, like organic chemistry. Students' retention and retrieval of knowledge over time would not be feasible without a high level of long-term memory (Shi & Qu, 2022). Integrating new and existing knowledge enables students to strengthen their foundational knowledge, facilitating better application in advanced subjects. Opposite to the CBL approach, rote memorization is ineffective unless students possess the requisite knowledge and can apply it effectively (Salame et al., 2024). With this dilemma, there is a need to employ teaching methods like CBL that actively equip students with the skills and cognitive resources needed to navigate the complexities of chemistry.

The current findings revealed that CBL positively influences cognitive skills, as manifested by students' high working memory levels. Chemistry performance requires the pivotal role of working memory in developing cognitive capacity. It supports the retention, retrieval, and application of information essential for solving complex chemical problems. The difficulty of learning chemistry is related to the subject and how it is taught at school. Teachers must teach within the working memory capacity of learners. Upahi and Ramnarain (2020) concluded that open-ended, problem-based learning of chemical concepts helps students develop the knowledge required to tackle real-life applications. CBL aligns well with this approach as it utilizes situational problems relating to students' daily encounters. Constructing less complex learning tasks helps students with low working memory to perform at a comparable level to peers with high working memory. Applying CBL as an instructional approach requires the presentation of information in a manageable and engaging manner. This way, students from diverse backgrounds could learn through an interactive learning environment. CBL facilitates the betterment of working memory and critical skills for mastering chemistry.

Logical reasoning is crucial in solving problems with organic chemistry. Amsad et al. (2022) demonstrated a significant correlation between students' logical reasoning abilities and their ability to solve fundamental Organic Chemistry problems. Hasanah and Shimizu (2020) conclude that the crucial skills in science education are primarily located in the domain of reasoning skills. This indicates that logical reasoning acts as a bridge between conceptual understanding and practical application in Chemistry. Various factors, including prior knowledge, performance abilities, mindset, age, gender, intelligence, culture, and social status, influence these reasoning skills. Amir et al. (2022) emphasized the importance of fostering an engaging classroom environment in scientific laboratories or theoretical Chemistry lessons to enhance students' logical reasoning abilities. Interactive and inquiry-based learning experiences, such as those provided by CBL, are convenient in cultivating these skills. CBL engaged students in contextualized scenarios, promoting collaboration and enhancing reasoning (Amelia et al., 2024). It develops logical reasoning and enhances their ability to have practical applications of theoretical knowledge (Azrimaidaliza et al., 2022). Integrating case-based learning into Chemistry class provides a practical framework for addressing the challenges posed by working memory limitations and supporting the development of logical reasoning skills.

Students' exposure to a case-based learning approach enhances their cognitive skills. Students under CBL were exposed to tasks that developed their ability to process information from the given case-based problem. Students' working memory could be enhanced by collaborating with their peers (Firdaus et al., 2019). Logic and reasoning were tested when students presented their solutions to the provided problem—furthermore, apprehension of the given situational problems enriched students' comprehension. Their performance in the retention test showed long-term memory. It further reveals that students' highly perceived cognitive skills aligned with their performance (Turk et al., 2019).

The current findings divulged the effectiveness of CBL in enhancing students' performance, as shown by how their post-test scores increased. Students exposed to the CBL approach had better performance when compared to those exposed to conventional teaching (Liboon & Magday, 2022; Magwilang, 2022; Maia et al., 2023). In addition, Ma et al. (2019) also pointed out that CBL's interactive and student-centered nature contributes to deeper learning and better retention of concepts. CBL positively affected the student's learning experience, concept understanding, and deep understanding of the course (Alani & Grewal, 2024). Using contextualized scenarios and inquiry-based activities may enable students to build critical cognitive and practical skills, thus rendering Chemistry learning more relevant to everyday contexts. Case-based learning promotes learners to be more adept in solving problems using their cognition and critical thinking. This process is rooted in Bruner's discovery learning theory, which posits that students learn effectively when actively involved in the inquiry and discovery process. However, it is important to note that CBL's effectiveness is not always guaranteed. Contrasting results have been reported concerning the effectiveness of CBL. For instance, Kaur et al. (2020) observed no significant differences in students' performance when taught via CBL and traditional teaching methods. Concurrently, Rhodes et al. (2020) found that CBL fosters engagement and critical thinking. However, it does not necessarily result in improved performance. Such contrary results indicate that the effect of CBL would depend on factors such as cases' complexity, prior knowledge among students, specific learning preferences of learners, and general implementation of the method. Although the approach of CBL has excellent potential to improve the performance of students studying chemistry, success could differ depending on the learners' settings and features.

Knowledge retention was significantly high for students taught via a CBL approach. Notably, students performed better on retention tests one month after their post-test, underscoring the long-term advantage of CBL. Students who undertook CBL had significantly superior retention scores using a deep learning strategy. Case-based learning is also highly linked with problem-based learning since both approaches focus on resolving real-life problems to improve understanding and utilization. Research has indicated that students using basic science curriculum principles in problem-solving instructional approaches performed better than those taught using conventional lecture styles in retention tests (Arab & Saeedi, 2024). This would imply that interactive, student-driven pedagogies like CBL enhance knowledge retention through more intimate interactions with the content.

Students taught in a cooperative learning environment performed well and retained knowledge (Simesso et al., 2024). The collaborative nature of CBL also increases its effectiveness on learning outcomes. There was a significant difference in mean retention scores between students taught chemistry through a collaborative concept mapping approach and those taught through a discussion approach. In addition, CBL's focus on contextualized and meaningful problems strengthens students' knowledge retention. CBL makes students more likely to memorize and recall information by situating learning in real-life and meaningful contexts. The findings highlight the effectiveness of the case-based learning approach in enhancing long-term retention of knowledge.

In general, the CBL approach significantly contributes to the development of cognitive skills and encourages an enhanced understanding of the nature of science beyond conventional concepts. With case analysis and problem-solving, students develop essential skills such as research, analysis, interpretation, and creative thinking. These skills are the center of science inquiry and equip learners to engage with challenging, real-world problems. Aside from developing skills, CBL encourages students to deliberately reflect on their learning experience, further strengthening their scientific practice knowledge. By reflecting on their learning, the students can internalize the content, methodologies, and reasoning used in scientific inquiry. By going through cases, students realize science is an evolving process, not a collection of static information, instilling a whole view of discipline.

CONCLUSION

Fundamental Finding: Students exposed to CBL exhibited very satisfactory performance in Chemistry. Meanwhile, satisfactory performance was obtained by students exposed to non-case-based learning. The students exposed to case-based learning had high cognitive skills in contrast to the moderate cognitive skills of students exposed to non-CBL. Results revealed significant differences in students' academic performance, cognitive skills, and knowledge retention. Thus, the null hypothesis was rejected. **Implication:** Recognizing the positive effect of case-based learning on students' performance, cognitive skills, and knowledge retention, science educators may consider integrating it as a practical alternative to traditional teaching methods. **Limitation:** The approach is time-consuming, limiting the number of topics covered within the curriculum. **Future Research:** Further studies could also investigate how digital tools and simulations can enhance CBL's effectiveness, making it more engaging and accessible.

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