Effect of contextual and manipulative learning approaches on performance in chemistry of grade 12 STEM students

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ABSTRACT

This quasi-experimental study was conducted to investigate the effectiveness of Contextual and Manipulative Learning Approaches on Performance in Chemistry of Grade 12 STEM students of Filamer Christian University for the school year 2024-2025. The participants were seventy-two (72) Grade 12 Science, technology, Engineering, and Mathematics (STEM) students. The independent variables were Contextual and Manipulative Learning Approaches while the dependent variable was Performance in Chemistry of Grade 12 STEM students. The research instrument used to measure the performance in chemistry of the students was the researcher-made Performance in Chemistry Multiple Choice Test. It was a 60-item multiple choice test. The descriptive statistical tools used were mean and standard deviation, while the inferential test used for data analysis was the t-test with a level of significance at 0.05 alpha level. Major findings revealed that the Performance in Chemistry of Grade 12 STEM students during the pre-test of the contextual and manipulative learning approaches was found to be “good” but after the interventions, the post-test results of the two group of students revealed that both approaches had an “outstanding” performance in chemistry. There was no significant difference in the performance in chemistry of Grade 12 STEM students in the pre-test of contextual and manipulative approaches. However, there was a significant difference in the performance in chemistry of Grade 12 STEM students in the pre-test and post-test of both groups under Contextual and Manipulative Learning Approaches. There was no significant difference in the post-test of the Contextual and Manipulative approaches.

Keywords: effectiveness of contextual and manipulative learning approaches, performance in chemistry, grade 12 stem students

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INTRODUCTION

Education in the Philippines has continuously evolved to address the challenges of meeting global standards and enhancing student learning outcomes. In line with these goals, the country adopted the K–12 Basic Education Curriculum, which includes the Science, Technology,

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Engineering, and Mathematics (STEM) strand aimed at preparing students for careers in science and technology. However, STEM education in the country continues to face challenges, such as low student engagement, limited teaching resources, and a lack of instructional materials, which contribute to poor science performance. As part of ongoing reforms, teachers seek innovative strategies to make learning more meaningful and effective, especially in complex subjects such as chemistry. Two promising approaches in this regard are contextual learning and manipulative learning, both of which aim to improve comprehension, engagement, and academic performance by bridging the gap between abstract concepts and real-life applications.

Contextual learning connects theoretical concepts with students' everyday experiences, making lessons more relevant, practical, and engaging. By linking school-based learning to real-life situations, this approach has been shown to enhance motivation, reduce anxiety in challenging subjects, and promote critical thinking. Research has demonstrated that students exposed to contextualized materials often outperform their peers who are taught using traditional methods, as they are able to better understand and retain complex concepts. This method encourages learners to see the significance of their studies in the broader context of daily life, thereby fostering a positive attitude toward learning science.

Similarly, the manipulative learning approach emphasizes hands-on experiences, allowing students to explore abstract concepts through tangible materials such as models, simulations, and physical objects. This method promotes active engagement, problem-solving, and critical thinking while improving retention and understanding of scientific principles. Studies have shown that the use of manipulatives in chemistry, such as molecular models and interactive simulations, helps learners visualize and comprehend otherwise abstract ideas. By enabling students to directly interact with the concepts they are learning, manipulatives not only enhance comprehension but also stimulate curiosity and sustained interest in the subject.

Despite the potential benefits of these strategies, international assessments such as PISA and TIMSS reveal that Filipino students continue to perform below global standards in science and mathematics. While contextual and manipulative approaches have been identified as effective in improving problem-solving skills and scientific literacy, their success can vary depending on factors such as teacher preparedness, resource availability, and time constraints. This indicates a need for further research to explore their effectiveness in specific contexts, such as Philippine senior high school STEM classrooms.

Chemistry, as an applied science subject within the STEM strand, presents particular difficulties due to its highly abstract nature. Traditional lecture-based instruction often fails to engage students or demonstrate the subject's relevance to real-world situations, leading to low interest and poor performance. The present study emerged from the researcher's observations that many students struggle with complex abstractions and respond better when lessons are grounded in concrete applications and experiences. By investigating the effects of contextual and manipulative learning on students' performance in chemistry, this study aims to provide insights into how these strategies can be optimally applied to improve learning outcomes.

The study is anchored on the Constructivist Theory of Learning, as advanced by Jean Piaget and Lev Vygotsky, which emphasizes that knowledge is actively constructed by learners through meaningful engagement with their environment. Piaget highlights the role of real-world problem-solving in fostering deep understanding, while Vygotsky's Zone of Proximal Development underscores the importance of tasks that are challenging yet achievable with appropriate support. Additionally, Gardner's theory of multiple intelligences supports the provision of varied learning experiences to cater to diverse learning styles, suggesting that contextual and manipulative approaches can meet different learner preferences effectively. Within this framework, the study examines how these strategies—contextual and manipulative learning—affect the performance in chemistry of Grade 12 STEM students, with the ultimate goal of preparing them for global competence.

Statement of the problem

The main purpose of this study was to determine and compare the effect of contextual and manipulative learning approaches on Performance in Chemistry of Grade 12 STEM students in Filamer Christian University, Roxas City, Capiz for the school year 2024-2025. Specifically, this study sought to answer the following questions:

1. What is the performance in chemistry of Grade 12 STEM students in the pre-tests and post-tests of the contextual and manipulative learning approaches?
2. Is there a significant difference on performance in chemistry of Grade 12 STEM students in the pre-tests of the contextual and manipulative learning approaches?
3. Is there a significant difference on performance in chemistry of Grade 12 STEM students between in the pre-tests and the post-tests of the contextual and manipulative learning approaches?
4. Is there a significant difference on performance in chemistry of Grade 12 STEM students in the post-tests of the contextual and manipulative learning approaches?

METHODOLOGY

This study aimed to determine the effect of contextual and manipulative learning approaches on the performance in chemistry of Grade 12 Science, Technology, Engineering, and Mathematics (STEM) students at Filamer Christian University during the second semester of the school year 2024–2025. It employed a quasi-experimental pre-test and post-test design, as described by Best and Kahn (cited in Catorce, 2020), which is similar to a true experimental design but does not involve the random assignment of participants. The independent variables were the contextual and manipulative learning approaches, while the dependent variable was the students' performance in chemistry as measured by a researcher-made multiple-choice test. In the contextual approach, chemistry concepts were taught by linking them to real-life situations and contexts, while the manipulative approach involved hands-on activities, experiments, and the manipulation of materials to explore concepts. The pre-test and post-test design was implemented for both groups, with pre-tests (O1 for the contextual group and O2 for the manipulative group) administered before the intervention and post-tests (O3 and O4, respectively) administered after. The data gathered were analyzed using descriptive and inferential statistics, with all inferential tests set at a 0.05 level of significance.

The study was conducted during the first quarter of the second semester of SY 2024–2025 and involved two sections out of seven Grade 12 STEM classes at Filamer Christian University. Participants were divided into two groups: one taught using the contextual approach and the other using the manipulative approach. Group assignment was determined through a coin toss method, but before assignment, students were match-paired based on their General Weighted Average in STEM 7 General Chemistry 1 from the previous semester to ensure collective similarity between groups. Students who chose "heads" were placed in the contextual group, and those who chose "tails" were assigned to the manipulative group.

The Performance in Chemistry Test, a 60-item researcher-made multiple-choice instrument, was used for both the pre-test and post-test. It covered four topics—kinetic molecular theory of solids and liquids, properties of solids, properties of liquids, and phase changes—each taught over one week during the four-week experimental period in STEM 7 General Chemistry 1. Each topic was assessed through a 15-item multiple-choice test, and the total score for all four topics was computed out of 60 points. Scores were then averaged, and performance was interpreted using the following scale: 48.01–60.00 as "Outstanding," 36.01–48.00 as "Very Good," 24.01–36.00 as "Good," 12.01–24.00 as "Poor," and 0.00–12.00 as "Very Poor." The test underwent content validation and item analysis following pilot testing with Grade 12 students at the university. Items with a difficulty index of .20–.80 and a discrimination index of .30–.80 were retained, while others were revised or discarded, following Teach.ufl.edu (2019) guidelines.

The research was carried out in three phases: pre-experimental, experimental, and post-experimental. In the pre-experimental stage, the researcher secured permission from the principal to conduct the study and oriented the participants. Topics were identified based on the Department of Education's Most Essential Learning Competencies (MELCs) for General Chemistry 2 and distributed across the experimental period. Two sets of lesson plans were prepared for the contextual and manipulative groups. Assessment tools were constructed using a table of specifications to ensure proper coverage of each topic.

During the experimental stage, both groups received instruction according to their assigned approach for four weeks. In week one, the topic was the kinetic molecular theory of solids and liquids. The contextual group analyzed photos, answered guide questions, conducted research, discussed real-life scenarios, applied principles from their experiences, and completed evaluations before taking the post-test. The manipulative group demonstrated KMT in a bottle, manipulated marbles, water, and balloons to observe particle behavior, engaged in guided discussion, completed worksheets, and took the post-test.

In week two, the topic was properties of solids. The contextual group analyzed photos, brainstormed everyday experiences involving solids, classified materials as hard and rigid or flexible and moldable, watched videos, sorted crystalline and amorphous solids, and completed evaluations before the post-test. The manipulative group examined crystalline and amorphous solids, manipulated materials by breaking crystalline solids and stretching amorphous solids, watched videos, conducted classification tasks, and completed the post-test.

In week three, the topic was properties of liquids. The contextual group analyzed images and scenarios, discussed properties such as surface tension, viscosity, boiling point, vapor pressure, and molar heat of vaporization, and participated in a group game to identify properties before the post-test. The manipulative group shook water bottles to observe liquid behavior, conducted the "Quick Liquid Challenge" laboratory activity, engaged in guided discussions, answered critical questions, and took the post-test.

In week four, the topic was phase changes. The contextual group analyzed photos, watched videos, discussed scenarios, matched puzzle pieces to phase change descriptions, and took the post-test. The manipulative group observed ice cubes in a cup, conducted group laboratory activities, analyzed and demonstrated experiments, matched puzzle pieces to phase changes and particle behavior, and took the post-test. In all cases, the teacher supervised, monitored, and provided feedback throughout the activities.

In the post-experimental stage, responses from both groups were collected, recorded, tabulated, and encoded using Microsoft Excel. The data from the pre-tests and post-tests were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, specifically the mean, were used to determine the level of chemistry performance, while the standard deviation assessed the homogeneity or heterogeneity of scores. A t-test for independent samples determined the difference between the performance of the contextual and manipulative groups in both the pre-test and post-test. Both tabular and textual forms were used in presenting the results, with all analyses conducted at a 5% alpha level of significance.

RESULTS AND DISCUSSION

Performance in chemistry of Grade 12 STEM students

The descriptive analysis focuses on the performance in chemistry of STEM students in the pre-tests and post-tests of the contextual and manipulative groups, including the respective means, standard deviations, and qualitative descriptions based on the established performance scale. The inferential analysis determines statistical differences between variables using the t-test, with interpretations grounded in the study's hypotheses.

The descriptive data reveal that students exposed to the contextual approach obtained a pre-test mean score of 25.66 with a standard deviation of 2.30, while those in the manipulative approach obtained a pre-test mean score of 26.00 with a standard deviation of 3.19. Both scores fall within the "Good" category according to the performance scale (24.01–36.00 = Good). This indicates that before the intervention, Grade 12 STEM students demonstrated a foundational level of knowledge and a basic comprehension of chemistry concepts. Such performance may be attributed to prior knowledge and familiarity with the topics from previous lessons. However, their ability to think critically and comprehend lessons in greater depth appeared limited, possibly due to weak retention from limited exposure, insufficient learning activities, or the predominance of traditional teacher-centered approaches.

Difference on the performance in chemistry of Grade 12 STEM students in the pre-tests of the contextual and manipulative learning approaches

After the implementation of the interventions, the post-test results showed a significant improvement. The contextual approach group achieved a mean score of 49.06 with a standard deviation of 1.91, while the manipulative approach group achieved a mean score of 49.94 with a standard deviation of 2.30. Both scores fall within the "Outstanding" category (48.01–60.00 = Outstanding). This improvement suggests that the use of contextual and manipulative approaches deepened students' understanding by building on prior knowledge, connecting simple ideas to more complex and structured concepts, and engaging students in hands-on and real-world applications. The direct and empirical nature of these learning experiences made the lessons more engaging and relevant, increasing students' interest and potentially contributing to their improved performance. These findings are consistent with Reyes (2023), who reported that the implementation of contextual and manipulative learning approaches led to significant improvements in students' science performance, surpassing expected learning outcomes.

The inferential analysis comparing the pre-tests of the contextual and manipulative approaches revealed no significant difference between the two groups, $t(83) = 0.581$, $p = 0.563$

($p > 0.05$). This indicates that prior to the intervention, both groups had similar levels of understanding of chemistry concepts. The comparability of the groups' initial performance can be attributed to the match-pairing procedure, where students were assigned to groups based on their General Weighted Average in STEM 7 General Chemistry 1 from the previous semester, ensuring a homogeneous baseline. This finding implies that students' starting knowledge was not influenced by exposure to either contextual or manipulative strategies before the intervention. The similarity may also reflect learning loss, where students struggle to retain previously learned concepts due to gaps in instruction or insufficient reinforcement. This aligns with Picardal (2022), who found no significant difference in pre-test scores between experimental and control groups in contextualized science instruction, and with Almirol (2018), whose study on competency-based manipulative materials in Grade 12 Chemistry also found comparable pre-test results between experimental and control groups. Based on these findings, the null hypothesis stating no significant difference between the pre-test performance of the contextual and manipulative groups is accepted.

Difference on performance in chemistry of Grade 12 STEM students between the pre-tests and the post-tests of the contextual and manipulative learning approaches

The comparison between the pre-tests and post-tests within each group showed a significant improvement in performance. For the contextual approach, the results were $t(34) = 44.544$, $p = 0.000$ ($p < 0.05$), while for the manipulative approach, the results were $t(34) = 32.499$, $p = 0.000$ ($p < 0.05$). This indicates that both approaches were effective in enhancing students' chemistry performance. The contextual approach allowed students to connect lessons to meaningful real-life experiences, analyze familiar scenarios, and engage in relevant activities, which generated interest and motivation while making lessons more engaging and applicable. The manipulative approach provided opportunities to interact with physical objects, conduct laboratory experiments, and observe particle behavior, thus reinforcing understanding through hands-on experiences. These methods improved retention, strengthened conceptual understanding, and fostered a deeper appreciation of the subject matter. These findings are in line with Capitolina (2023), who reported significant improvements in science performance through context-based science lessons, and Santos (2022), who found considerable enhancement in scientific concept mastery through manipulative learning experiences. Consequently, the null hypothesis stating no significant difference between the pre-test and post-test scores within each approach is rejected.

Difference on performance in chemistry of Grade 12 STEM students in the post-tests of the contextual and manipulative learning approaches

When comparing the post-tests of the contextual and manipulative approaches, the results showed no significant difference, $t(68) = 1.167$, $p = 0.247$ ($p > 0.05$). This suggests that both approaches were equally effective in improving students' performance in chemistry. The contextual approach enhanced learning by linking concepts to real-life situations, while the manipulative approach offered hands-on, interactive learning experiences. These results imply that both strategies foster engagement, comprehension, and critical thinking, and that students were highly adaptable to either instructional method. The "Outstanding" classification of performance in both groups further demonstrates the effectiveness of these methods in closing learning gaps and reinforcing understanding.

The findings are consistent with Yaayin (2024), who demonstrated that contextual learning enhances students' conceptual understanding and performance in chemistry when concepts are grounded in familiar contexts, and with Alcober (2017), who reported that STEM senior high school students perceived manipulative activities positively, associating them with improved comprehension and engagement. However, Mundi (2023) emphasized that contextual learning's effectiveness depends on the integration of context into learning activities, cautioning that mere contextualization without meaningful integration may not ensure deep understanding. Additionally, Vobejda (2015) noted a decline in the use of manipulative learning approaches in American schools, with the percentage of science classes incorporating laboratory exercises dropping from 53% to 39% over a decade, raising concerns about students' readiness for advanced science courses and their development of practical scientific skills.

In conclusion, the study confirms that both contextual and manipulative approaches are effective in improving the chemistry performance of Grade 12 STEM students, with neither approach proving superior to the other. Therefore, the null hypothesis stating no significant difference between the post-test performance of the contextual and manipulative approaches is accepted.

CONCLUSION

This quasi-experimental research investigated the effects of contextual and manipulative learning approaches on the performance in chemistry of Grade 12 STEM students at Filamer Christian University during the second semester of the school year 2024–2025. The study sought to determine the students' performance in chemistry in the pre-tests and post-tests of both approaches, to assess whether there were significant differences between the pre-test results of the two groups, to evaluate differences between their pre-test and post-test scores, and to examine post-test differences between the approaches. The participants consisted of two sections, with thirty-six students from Grade 12 STEM Dalton assigned to the contextual approach and thirty-six students from Grade 12 STEM Aristotle assigned to the manipulative approach. The independent variables were the contextual and manipulative approaches, while the dependent variable was the students' performance in chemistry, measured through a researcher-made, 60-item multiple-choice test administered over four weeks. Descriptive statistics, including mean and standard deviation, were used alongside inferential tests, specifically the t-test, at a 0.05 level of significance.

Findings revealed that in the pre-tests, both groups achieved a "Good" performance in chemistry, with mean scores of 25.66 for the contextual group and 26.00 for the manipulative group. After the interventions, both groups demonstrated an "Outstanding" performance, with post-test mean scores of 49.06 and 49.94, respectively. Statistical analysis showed no significant difference between the pre-test results of the two groups, a significant difference between the pre- and post-tests for both approaches, and no significant difference between the post-tests of the two groups. These results indicate that both approaches were equally effective in improving student performance in chemistry.

The results lead to the conclusion that contextual and manipulative learning approaches can produce measurable improvements in students' mastery of chemistry, enabling a progression from a basic understanding to an advanced level of comprehension. Students' outstanding post-test performance suggests that both strategies support the development of higher-order thinking skills such as analysis, synthesis, and application, which are essential for mastering complex scientific concepts. The active engagement fostered by real-world contexts and hands-on experiences contributed to greater interest, motivation, and participation in lessons, ultimately leading to improved academic outcomes. These approaches promote student-centered instruction, encouraging learners to take a more active role in their own learning journey. This shift can create dynamic and responsive classroom environments where students not only excel academically but also develop a stronger inclination toward STEM-related pursuits and a positive attitude toward problem-solving, experimentation, and the real-life application of scientific knowledge.

The similarity in pre-test scores indicates that both groups began with an equal level of understanding, making the improvements observed in the post-tests a direct result of the interventions. Both contextual and manipulative strategies effectively addressed knowledge gaps and reinforced foundational concepts, enabling students to build upon their prior knowledge. This finding emphasizes the importance of targeted interventions that connect lessons to prior learning while providing opportunities to strengthen conceptual understanding before advancing to more complex topics. The post-test results also reflect how these strategies bridged initial learning gaps by providing tangible and meaningful experiences, making abstract concepts more accessible and relevant.

The significant improvements between pre-test and post-test scores demonstrate that both approaches enhanced students' ability to recall, apply, and integrate chemistry concepts. Contextual learning facilitated connections between theoretical knowledge and everyday experiences, while manipulative learning allowed students to interact directly with materials and observe phenomena, reinforcing their understanding through physical engagement. These experiences not only deepened comprehension but also increased students' confidence and willingness to participate in discussions and collaborative tasks. As students became more competent, they contributed more actively to the classroom environment, fostering a culture of shared learning and mutual support.

Furthermore, both approaches cultivated adaptability among students, as reflected in their consistent performance regardless of the teaching method used. The interactive and relevant nature of the lessons reduced confusion, encouraged independent learning, and enhanced cooperation among peers. The outstanding performance achieved by both groups validates the effectiveness of integrating active, student-centered methodologies into science instruction. This study reinforces the value of combining real-world relevance with hands-on application to create meaningful learning experiences that improve retention, engagement, and critical thinking.

Given these findings, the study affirms that both contextual and manipulative learning approaches are effective tools for improving chemistry performance among senior high school STEM students. Neither method proved superior, suggesting that educators can successfully use either—or a blend of both—depending on instructional goals, available resources, and students' learning needs. The evidence supports the acceptance of the hypothesis that there is no significant difference in the post-test performance between the two approaches. This underscores the adaptability and applicability of these methods in diverse classroom settings, making them valuable strategies for fostering both academic excellence and enthusiasm for science learning.

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