Journal of Research in Environmental and Science Education
ISSN 3062-8660 (online) & 3062-8431 (print)
July 2026, Vol. 3, No. 2, pp. 195–208

Research Article

# Laboratory Engagement and Conceptual Mastery in Chemistry

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**Abstract**
Optimizing science pedagogy within the K–12 STEM curriculum requires identifying the practical drivers of academic achievement, which remains a vital educational priority. This study examines the relationship between laboratory engagement and conceptual mastery in chemistry among Science, Technology, Engineering, and Mathematics students. Using a descriptive-correlational design, the research surveyed 347 students from selected private institutions in Valencia City, Bukidnon, during the 2024–2025 and 2025–2026 school years. Data were collected through two researcher-made, expert-validated, 30-item questionnaires—the Chemistry Laboratory Engagement Questionnaire and the Conceptual Mastery Questionnaire—both of which demonstrated high internal consistency. These data were subsequently analyzed using descriptive statistics and Pearson correlation analysis. Descriptive results indicate that students maintain a moderate level of laboratory engagement overall (3.91). Within this domain, collaborative learning received the highest rating (4.18), followed by technology integration (3.82) and hands-on experimentation (3.73). Similarly, students' conceptual mastery in chemistry was rated as very satisfactory overall (3.81); while problem-solving skills yielded the highest performance (4.07), the lower scores for conceptual change (3.68) and knowledge application (3.67) highlight specific opportunities for targeted instructional improvement. Pearson correlation analysis demonstrated a significant positive linear relationship between laboratory engagement and conceptual mastery ($r$ = .445, $p$ < 0.05), leading to the rejection of the null hypothesis. The study concludes that active and effective laboratory participation is crucial for promoting deeper conceptual understanding and academic performance in chemistry. It recommends that educational institutions prioritize robust laboratory programs emphasizing hands-on learning and structured collaborative practices.

**Keywords:** Engagement, Conceptual Mastery, Hands-on Learning, Chemistry Education, Academic Performance

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**Received**
December 12, 2025
**Accepted**
June 25, 2026
**Published**
July 1, 2026

**Citation**: Alarcon, J. L. P., & Paglinawan, J. L. (2026). Laboratory engagement and conceptual mastery in chemistry. *Journal of Research in Environmental and Science Education, 3*(2), 195–208.

DOI: 10.70232/jrese.v3i2.64



## 1. INTRODUCTION

Teaching chemistry is vital for developing students' scientific literacy and problem-solving skills. Fundamental to this approach is laboratory engagement, which utilizes diverse techniques to enhance comprehension of chemical concepts. Well-designed laboratory experiences significantly bolster students' conceptual mastery, particularly in facilitating conceptual change, knowledge application, and problem-solving.

Despite the recognized importance of laboratory engagement in chemistry education, a significant gap remains in understanding how specific facets such as hands-on experimentation, collaborative learning, and technology integration contribute to students' conceptual mastery. Research indicates that while students frequently participate in laboratory activities, their conceptual understanding varies in depth (Anggraeni & Moersilah, 2024). This inconsistency necessitates further investigation into optimizing these forms of engagement to enhance students' mastery of chemistry concepts. Specifically, shifting from traditional, rigid laboratory protocols toward inquiry-based learning and virtual visualization tools has been shown to improve spatial reasoning and conceptual retention by significant margins (Makhsudovich, 2026).

Research in the Philippines demonstrates that active participation in laboratory activities significantly enhances students' academic performance and scientific process skills. Uche and Eze (2018) found that hands-on engagement improves both attitudes and retention among senior secondary students. Similarly, Alarcon (2025) emphasized the value of collaborative learning in fostering scientific inquiry, while Alarcon et al. (2022) highlighted how technologies, such as video feedback, enhance the practical skills of science students.

Global research has identified key factors influencing laboratory engagement and conceptual mastery in chemistry. For instance, Haw and Wong (2022) observed that a supportive laboratory environment fosters student motivation and involvement, which leads to a greater mastery of concepts. Likewise, Diwakar et al. (2023) review indicated that virtual labs can enhance intrinsic motivation and academic success. Collectively, these studies underscore that effective laboratory engagement encompassing hands-on experiments, collaboration, and the integration of technology is vital for improving students' conceptual mastery in chemistry.

This study explored the relationship between laboratory engagement and conceptual mastery in chemistry of the Science, Technology, Engineering, and Mathematics (STEM) students of selected private education institutions in Valencia City, Bukidnon, in the School Year 2024-2025 and School Year 2025-2026. Specifically, this study aimed to:

1. Assess how the students are engaged in the laboratory in terms of:
   a. Hands-on experimentation
   b. Collaborative Learning
   c. Technology Integration
2. Examine the extent of student conceptual mastery in chemistry in terms of:
   a. Conceptual Change
   b. Problem-Solving Skills
   c. Knowledge Application
3. Find out if there's a significant relationship between laboratory engagement and conceptual mastery, and their sub-variables

### 1.1. Research Paradigm

The relationship between the independent variable and the dependent variable is presented in Figure 1.

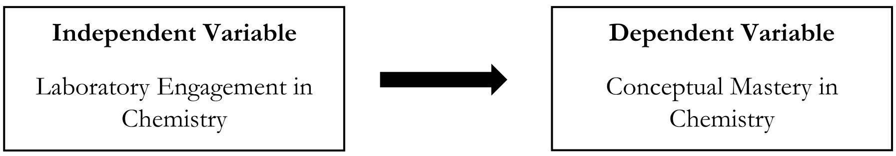


**Figure 1.** The Relationship between Independent and Dependent Variables

### 1.2. Hypothesis of the Study

From the figure shown above, a null hypothesis was formulated:

$H_0$: There is no significant difference between the laboratory engagement and conceptual mastery in chemistry.

## 2. METHODOLOGY

### 2.1. Research Design

This study employed a descriptive-correlational design to investigate the relationship between laboratory engagement and conceptual mastery in chemistry. This approach allowed the researchers to quantify students' involvement in laboratory activities and assess their corresponding levels of conceptual understanding. By analyzing the current state of engagement, the study provided insights into how such involvement influences the mastery of key chemistry concepts, ultimately contributing to a deeper understanding of effective educational practices in the field.

### 2.2. Locale of the Study

The study was conducted at selected private educational institutions in Valencia City, Bukidnon, Philippines, that offer a STEM strand. Data were collected from 347 students during the 2024-2025 and 2025-2026 school years. Drawing on a diverse cohort of STEM students, this research aimed to explore the relationship between their engagement in laboratory activities and their understanding of chemistry concepts. The institutional environment and resources provided an ideal setting for examining these educational dynamics.

### 2.3. Research Instruments

The study employed two researcher-developed survey instruments: the 30-item Chemistry Laboratory Engagement Questionnaire and the 30-item Conceptual Mastery Questionnaire. Both instruments underwent a rigorous validation process by three field experts, followed by pilot testing with 30 STEM students to assess usability and effectiveness. Reliability was confirmed using Cronbach's Alpha, which yielded high coefficients of 0.882 for the Chemistry Laboratory Engagement Questionnaire and 0.806 for the Conceptual Mastery Questionnaire, indicating strong internal consistency for both measures.

The Chemistry Laboratory Engagement Questionnaire (CLEQ) is designed to assess student engagement in laboratory settings with 30 indicators divided equally across three key areas: Hands-on Experimentation, Collaborative Learning, and Technology Integration. By utilizing a series of statements, students reflect on their experiences and attitudes towards laboratory activities. The following rating scale was used to understand the data better:

**Table 1.** Rating Scale, Parameter, and Qualitative Interpretation for the Chemistry Laboratory Engagement Questionnaire (CLEQ)

| Scale | Interval | Description | Qualitative Interpretation |
|---|---|---|---|
| 5 | 4.21 – 5.00 | Strongly Agree | Highly Engaged |
| 4 | 3.41 – 4.20 | Agree | Moderately Engaged |
| 3 | 2.61 – 3.40 | Not Sure | Fairly Engaged |
| 2 | 1.81 – 2.60 | Disagree | Seldom Engaged |
| 1 | 1.00 – 1.80 | Strongly Disagree | Not Engaged |

The Conceptual Mastery Questionnaire aims to evaluate the extent of student conceptual mastery in chemistry, with 30 indicators divided equally across the three critical dimensions: Conceptual Change, Problem-Solving Skills, and Knowledge Application. Through this set of statements, students express their understanding and application of chemistry concepts, as well as their ability to solve problems effectively. The following rating scale was used to understand the data better:

**Table 2.** Rating Scale, Parameter, and Qualitative Interpretation for the Conceptual Mastery Questionnaire

| Scale | Interval | Description | Qualitative Interpretation |
|---|---|---|---|
| 5 | 4.21 – 5.00 | Strongly Agree | Outstanding |
| 4 | 3.41 – 4.20 | Agree | Very Satisfactory |
| 3 | 2.61 – 3.40 | Not Sure | Satisfactory |
| 2 | 1.81 – 2.60 | Disagree | Fairly Satisfactory |
| 1 | 1.00 – 1.80 | Strongly Disagree | Poor |

### 2.4. Statistical Technique

In this study, descriptive statistics and Pearson correlation analysis were employed to examine the relationship between laboratory engagement and conceptual mastery in chemistry, with data processed using SPSS and validated by a statistician. We calculated means to summarize student engagement and conceptual understanding, providing insight into students' laboratory experiences. To investigate the association between these variables, we utilized Pearson's correlation coefficient (r) to assess the strength and direction of the linear relationship. This analysis sought to determine whether higher laboratory engagement correlates with improved conceptual mastery, thereby yielding insights into effective teaching practices in the discipline.

## 3. RESULTS AND DISCUSSION

This section presents findings on laboratory engagement and conceptual mastery in chemistry, beginning with a summary of key descriptive statistics, such as mean scores for student engagement and conceptual understanding. It subsequently examines the correlation between these variables, highlighting significant relationships identified through Pearson analysis. These results are interpreted within the context of existing literature to determine how laboratory engagement influences the understanding of chemical concepts, thereby offering insights into effective teaching strategies to enhance student learning and engagement.

**Table 1.** Level of Chemistry Laboratory Engagement in terms of Hands-on Experimentation

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| I take responsibility for their roles during group experiments. | 4.51 | Strongly Agree | Highly Engaged |
| I report increased retention of information through hands-on learning experiences | 4.27 | Strongly Agree | Highly Engaged |
| I reflect on their hands-on experiences to enhance understanding of concepts. | 3.84 | Agree | Moderately Engaged |
| I actively participate in conducting experiments during laboratory sessions. | 3.75 | Agree | Moderately Engaged |
| I collaborate with peers to design and execute experiments. | 3.74 | Agree | Moderately Engaged |
| I am able to apply theoretical concepts to practical situations in the lab. | 3.63 | Agree | Moderately Engaged |
| I demonstrate proficiency in using laboratory equipment and tools. | 3.52 | Agree | Moderately Engaged |
| I show enthusiasm when involved in hands-on activities. | 3.5 | Agree | Moderately Engaged |
| I express curiosity about the outcomes of their experiments. | 3.38 | Not Sure | Fairly Engaged |
| I am engaged in manipulating materials to observe scientific phenomena. | 3.16 | Not Sure | Fairly Engaged |
| Overall mean | 3.73 | Agree | Moderately Engaged |

### 3.1. Descriptive Analysis for the Chemistry Laboratory Engagement Level

#### 3.1.1. Hands-on Experimentation

Table 1 presents the level of chemistry laboratory engagement in terms of hands-on experimentation. It also reveals the overall mean score of 3.73, which is interpreted as moderately engaged. Among the indicators, two of which attained the highly engaged, namely: "I take responsibility for their roles during group experiments" (4.51), and "I report increased retention of information through hands-on learning experiences" (4.27). It is followed by seven indicators that attained moderately engaged interpretation namely: "I reflect on their hands-on experiences to enhance understanding of concepts" (3.84); "I actively participate in conducting experiments during laboratory sessions" (3.75); "I collaborate with peers to design and execute experiments" (3.74); "I am able to apply theoretical concepts to practical situations in the lab" (3.63); "I demonstrate proficiency in using laboratory equipment and tools" (3.52); "I show enthusiasm when involved in hands-on activities" (3.50). Lastly, two indicators attained an interpretation of fairly engaged, namely: "I express curiosity about the outcomes of their experiments" (3.38) and "I am engaged in manipulating materials to observe scientific phenomena" (3.16).

The result presented in Table 1 implies that while students are participating in laboratory activities, there is significant room for improvement. The high scores for responsibility during group experiments and retention of students through hands-on experimentation suggest that students value collaborative and experiential learning approaches. On the other hand, the lower scores for curiosity and active manipulation of materials highlight areas for improvement. To enhance student engagement further, educators may consider integrating collaborative, interactive, and inquiry-based activities that stimulate curiosity and encourage exploration of scientific phenomena.

Recent literature supports the idea that collaborative and experiential learning approaches are crucial for improving student outcomes in science education. The study of Ogbeba and Ajayi (2016) emphasizes that students who participated in hands-on activities achieved significantly higher results compared to those taught using traditional demonstration methods. Hands-on activities not only enhance immediate academic performance but also improve retention of knowledge over time, as evidenced by higher retention scores for students engaged in these interactive learning experiences. Similarly, Agwu and Nmadu (2023) found that students who engage in collaborative laboratory work exhibit greater motivation and curiosity, which can lead to improved academic performance. However, Snetinová et al. (2018) found that while both hands-on experimental work and demonstration shows were employed, there were no significant differences in student interest and perceived usefulness between the two methods. These findings imply that a nuanced pedagogical approach, which carefully integrates diverse laboratory modalities, is essential for cultivating deep student engagement and long-term academic efficacy.

### 3.1.2. Collaborative Learning

Table 2 reveals the results for the level of chemistry laboratory engagement in terms of collaborative learning. It shows the overall mean of 4.18, which is interpreted as moderately engaged. Among the indicators, four of which are interpreted with highly engaged remark namely: "I celebrate group successes, fostering a positive learning environment" (4.42); "I exhibit respect for diverse perspectives during collaborative tasks" (4.40); "I participate in peer teaching, explaining concepts to classmates" (4.32); and "I contribute equally to group assignments and experiments" (4.21). It is followed by six indicators interpreted as moderately engaged. These indicators are "I demonstrate improved communication skills through collaborative efforts" (4.19); "I engage in discussions that deepen their understanding of the subject matter" (4.15); "I can work effectively in teams to solve problems during laboratory activities" (4.15); "I feel comfortable expressing their thoughts and questions within their groups" (4.10); "I share ideas and insights with peers to enhance group learning" (3.94), and "I provide constructive feedback to each other during group projects" (3.89). The findings imply that implementing structured collaborative learning approaches in chemistry laboratories can significantly enhance student engagement, comprehension, and interpersonal skills.

Recent studies emphasize the benefits of collaborative learning in chemistry education, particularly regarding student engagement and academic performance. For example, research by Priyambodo et al. (2020) shows that using collaborative learning strategies significantly boosts students' motivation and understanding of acid-base chemistry concepts. The study found that students working together not only achieved better grades but also developed critical thinking skills while solving real-world problems. In a similar vein, a quasi-experimental study by Niyonsaba et al. (2022) revealed that students who learned through collaborative methods performed better than those taught through traditional lectures. This suggests that collaborative learning approaches enhance students' retention and understanding of chemistry content.

However, not all findings are entirely positive. A study by Amo-Saus et al. (2016) takes a more cautious view, indicating that while collaborative learning can increase engagement, its success may depend on the specific context and how it is implemented. They pointed out that some students might struggle in group settings, feeling overshadowed or less motivated, which could lead to varied learning results. This underscores the importance of considering group dynamics and individual differences when applying collaborative learning techniques in chemistry education. Consequently, the broader implication for curriculum designers and educators is the necessity of a nuanced implementation strategy. Rather than viewing collaborative learning as a universal solution, instructors should prioritize the design of structured group tasks that incorporate clear roles and support systems. This balanced approach can mitigate potential disparities in participation and ensure that the cognitive and social benefits of peer interaction are equitably accessible, ultimately strengthening the effectiveness of chemistry instruction.

**Table 2.** Level of Chemistry Laboratory Engagement in terms of Collaborative Learning

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| I celebrate group successes, fostering a positive learning environment. | 4.42 | Strongly Agree | Highly Engaged |
| I exhibit respect for diverse perspectives during collaborative tasks. | 4.40 | Strongly Agree | Highly Engaged |
| I participate in peer teaching, explaining concepts to classmates. | 4.32 | Strongly Agree | Highly Engaged |
| I contribute equally to group assignments and experiments. | 4.21 | Strongly Agree | Highly Engaged |
| I demonstrate improved communication skills through collaborative efforts. | 4.19 | Agree | Moderately Engaged |
| I engage in discussions that deepen their understanding of the subject matter. | 4.15 | Agree | Moderately Engaged |
| I can work effectively in teams to solve problems during laboratory activities. | 4.15 | Agree | Moderately Engaged |
| I feel comfortable expressing my thoughts and questions within groups. | 4.10 | Agree | Moderately Engaged |
| I share ideas and insights with peers to enhance group learning. | 3.94 | Agree | Moderately Engaged |
| I provide constructive feedback to others during group projects. | 3.89 | Agree | Moderately Engaged |
| Overall mean | 4.18 | Agree | Moderately Engaged |

### 3.1.3. Technology Integration

Table 3 shows the results for the level of chemistry laboratory engagement in terms of technology integration. It reveals the overall mean score of 3.82, which is interpreted as moderately engaged. Nine indicators are interpreted as moderately engaged namely: "I can utilize digital tools to enhance their laboratory experiences" (4.11); "I report that technology integration makes laboratory work more engaging" (4.10); "I can collaborate through digital platforms for project management and communication" (4.09); "I can reflect on how technology enhances their understanding of scientific concepts" (4.06); "I can participate in technology-based presentations of their findings" (3.82); "I can access online resources to supplement their laboratory work" (3.81); "I can engage with simulations or virtual labs as part of their learning process" (3.79); "I can demonstrate the ability to troubleshoot technical issues independently" (3.71); and "I can use technology to collect and analyze data during experiments" (3.52), then one indicator is interpreted as fairly engaged, the "I express confidence in using technology for scientific inquiry" (3.17).

This suggests that while students recognize the benefits of digital tools in enhancing laboratory experiences, there remains scope to improve their confidence and proficiency, as highlighted by the score of 3.17 regarding confidence in using technology for scientific inquiry. These findings imply that instructional approaches should go beyond merely incorporating technology in lab settings; they should also actively cultivate student confidence and technical competence.

Recent research highlights the advantages of educational technology, particularly in enhancing student engagement and learning outcomes. For example, a literature review by Larisang (2023) underscores how technology integration boosts motivation and fosters an interactive, collaborative learning environment. This facilitates personalized learning experiences, enabling students to engage with materials tailored to their specific needs and interests. Additionally, Ryan (2019) discusses how augmented reality and scenario-based learning in chemistry labs can enhance student preparation and encourage a research-focused approach. Conversely, some studies highlight challenges regarding technology integration. For instance, Akram et al. (2021) note that many teachers face obstacles such as limited technological skills, poor internet connectivity, and insufficient infrastructure. These issues complicate effective implementation and limit the potential benefits of technology for teaching and learning.

**Table 3.** Level of Chemistry Laboratory Engagement in terms of Technology Integration

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| I can utilize digital tools to enhance their laboratory experiences. | 4.11 | Agree | Moderately Engaged |
| I report that technology integration makes laboratory work more engaging. | 4.10 | Agree | Moderately Engaged |
| I can collaborate through digital platforms for project management and communication. | 4.09 | Agree | Moderately Engaged |
| I can reflect on how technology enhances their understanding of scientific concepts. | 4.06 | Agree | Moderately Engaged |
| I can participate in technology-based presentations of their findings. | 3.82 | Agree | Moderately Engaged |
| I can access online resources to supplement their laboratory work. | 3.81 | Agree | Moderately Engaged |
| I can engage with simulations or virtual labs as part of their learning process. | 3.79 | Agree | Moderately Engaged |
| I can demonstrate the ability to troubleshoot technical issues independently. | 3.71 | Agree | Moderately Engaged |
| I can use technology to collect and analyze data during experiments. | 3.52 | Agree | Moderately Engaged |
| I express confidence in using technology for scientific inquiry. | 3.17 | Not Sure | Fairly Engaged |
| Overall mean | 3.82 | Agree | Moderately Engaged |

3.1.4. Summary of the Results from the Chemistry Laboratory Engagement Levels

Table 4 presents the findings regarding chemistry laboratory engagement, yielding a mean score of 3.91 and reflecting a generally positive student experience. Analysis of specific categories provides further insight: hands-on experimentation scored 3.73, suggesting that while students appreciate practical work, the integration of these activities could be refined. Collaborative learning received a higher score of 4.18, underscoring that students value peer interaction as a program strength. Finally, technology integration scored 3.82, indicating that students find digital tools beneficial yet perceive potential for improvement. Overall, these results imply that while the current laboratory engagement is effective, strategic enhancements to hands-on experimentation and technology use could further enrich the student experience.

**Table 4.** Summary of the Results for Chemistry Laboratory Engagement

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| Hands-on Experimentation | 3.73 | Agree | Moderately Engaged |
| Collaborative Learning | 4.18 | Agree | Moderately Engaged |
| Technology Integration | 3.82 | Agree | Moderately Engaged |
| Overall Mean | 3.91 | Agree | Moderately Engaged |

Recent studies illustrate the evolution of chemistry laboratory education, with a growing emphasis on student engagement and effective pedagogy. For instance, Badilles (2024) demonstrated that virtual chemistry laboratories significantly enhance student learning and engagement, underscoring the vital role of technology in modern education. Findings indicated that students utilizing virtual labs achieved superior performance, suggesting that interactive, technology-driven methods foster a more compelling learning experience. Seery et al. (2024) support this perspective, emphasizing the necessity of evidence-based teaching practices within laboratory settings. They advocate for structured activities designed to strengthen students' hands-on skills while simultaneously promoting teamwork and critical thinking.

## 3.2. Descriptive Analysis for the Conceptual Mastery of the Students in Chemistry

### 3.2.1. Conceptual Change

Table 5 shows the level of conceptual mastery of the students in chemistry in terms of conceptual change. It shows the overall mean of 3.68, which is interpreted as Very Satisfactory. Among the indicators, seven of which are interpreted as very satisfactory. These indicators are: "I reflect on my learning experiences to identify areas for improvement in chemistry" (3.98): "I can explain how my previous misconceptions about chemistry have changed" (3.98); "I engage in discussions that challenge my current understanding of chemistry" (3.96); "I actively seek feedback on my understanding of chemistry concepts" (3.93); "I am open to revising my ideas about chemistry based on new evidence" (3.81); "I utilize resources to clarify and deepen my understanding of chemical concepts" (3.75); "I feel motivated to continue learning and changing my perspectives in chemistry" (3.68); and followed by three indicators interpreted as satisfactory namely: "I recognize when my understanding of a chemistry concept has improved" (3.23); "I can articulate the reasons for changes in my understanding of chemistry topics" (3.23); and "I feel confident in discussing my evolving understanding of chemical principles" (3.23). The lowest mean scores are from the indicators related to articulation and confidence in understanding chemistry concepts. This result implies that while students may possess a moderate belief in their capability to learn chemistry, this confidence does not translate into a solid understanding of fundamental concepts.

**Table 5.** Level of Conceptual Mastery in Chemistry in terms of Conceptual Change

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| I reflect on my learning experiences to identify areas for improvement in chemistry. | 3.98 | Agree | Very Satisfactory |
| I can explain how my previous misconceptions about chemistry have changed. | 3.98 | Agree | Very Satisfactory |
| I engage in discussions that challenge my current understanding of chemistry. | 3.96 | Agree | Very Satisfactory |
| I actively seek feedback on my understanding of chemistry concepts. | 3.93 | Agree | Very Satisfactory |
| I am open to revising my ideas about chemistry based on new evidence. | 3.81 | Agree | Very Satisfactory |
| I utilize resources to clarify and deepen my understanding of chemical concepts. | 3.75 | Agree | Very Satisfactory |
| I feel motivated to continue learning and changing my perspectives in chemistry. | 3.68 | Agree | Very Satisfactory |
| I recognize when my understanding of a chemistry concept has improved. | 3.23 | Not Sure | Satisfactory |
| I can articulate the reasons for changes in my understanding of chemistry topics. | 3.23 | Not Sure | Satisfactory |
| I feel confident in discussing my evolving understanding of chemical principles. | 3.23 | Not Sure | Satisfactory |
| Overall Mean | 3.68 | Agree | Very Satisfactory |

Recent research in chemistry education emphasizes the significance of innovative pedagogical methods, particularly inquiry-based learning, in fostering student engagement and conceptual understanding. A systematic review by Vega (2024) demonstrates that cooperative and inquiry-based strategies can substantially enhance both cognitive and emotional learning outcomes. This finding aligns with the work of Popova (2024), who advocates for research-practice partnerships to bridge the gap between educational research and classroom implementation. Such collaborations facilitate the application of evidence-based strategies that assist students in mastering complex chemical concepts.

Furthermore, a comprehensive review by Furtak et al. (2012) indicates that inquiry-based approaches deepen conceptual understanding while bolstering student motivation and confidence. Collectively, these studies underscore that innovative teaching practices are essential for optimizing student performance. Conversely, some research provides a more nuanced view; Hercules et al. (2016) argue that the efficacy of inquiry-based learning varies across contexts and student populations. They observe that some learners may struggle with the self-directed demands of these methods, potentially leading to knowledge gaps in the absence of adequate teacher support. Ultimately, these findings suggest that the success of innovative pedagogy depends heavily on the specific educational environment and individual student needs.

3.2.2. Problem-Solving Skills

Table 6 shows the results for the level of conceptual mastery of the students in terms of problem-solving skills. It reveals the score of 4.07, which is interpreted as very satisfactory. Among the indicators, four of them are interpreted as outstanding, namely: "I often use multiple strategies to tackle complex chemistry problems" (4.28); "I persist in finding solutions even when faced with difficult chemistry questions" (4.27); "I can identify the relevant information needed to solve chemistry problems" (4.25); and "I often reflect on the problem-solving process to improve my skills in chemistry" (4.25). Additionally, the remaining six indicators are interpreted as very satisfactory, namely: "I analyze the results of my problem-solving efforts critically" (4.16); "I collaborate with peers to find solutions to challenging chemistry problems" (4.09); "I approach chemistry problems systematically and logically" (4.05); "I feel confident in applying mathematical concepts to solve chemistry-related issues" (3.96); "I utilize technology and tools effectively to assist in solving chemistry problems" (3.96); and "I can connect theoretical knowledge to practical problem-solving in chemistry" (3.66). These findings imply that students are not only equipped with effective problem-solving techniques but are also resilient when faced with difficulties, which is crucial for mastering complex subjects like chemistry. Additionally, the data reflect a positive trend in students' problem-solving abilities, indicating a strong potential for further development through targeted instructional strategies.

**Table 6.** Level of Conceptual Mastery in Chemistry in Terms of Problem-Solving Skills

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| I often use multiple strategies to tackle complex chemistry problems. | 4.28 | Strongly Agree | Outstanding |
| I persist in finding solutions even when faced with difficult chemistry questions. | 4.27 | Strongly Agree | Outstanding |
| I can identify the relevant information needed to solve chemistry problems. | 4.25 | Strongly Agree | Outstanding |
| I often reflect on the problem-solving process to improve my skills in chemistry. | 4.25 | Strongly Agree | Outstanding |
| I analyze the results of my problem-solving efforts critically. | 4.16 | Agree | Very Satisfactory |
| I collaborate with peers to find solutions to challenging chemistry problems. | 4.09 | Agree | Very Satisfactory |
| I approach chemistry problems systematically and logically. | 4.05 | Agree | Very Satisfactory |
| I feel confident in applying mathematical concepts to solve chemistry-related issues. | 3.96 | Agree | Very Satisfactory |
| I utilize technology and tools effectively to assist in solving chemistry problems. | 3.69 | Agree | Very Satisfactory |
| I can connect theoretical knowledge to practical problem-solving in chemistry. | 3.66 | Agree | Very Satisfactory |
| Overall mean | 4.07 | Agree | Very Satisfactory |

Recent research highlights the importance of problem-solving skills in education, particularly in improving student learning outcomes. A systematic review by Ajani (2022) discusses various strategies to enhance problem-solving abilities among pre-service teachers, emphasizing the effectiveness of teaching methods like Problem-Based Learning (PBL). This review summarizes studies showing that when students engage with real-world problems, they develop critical thinking and collaboration skills, which lead to better problem-solving abilities. Additionally, Almulla (2023) supports this view by demonstrating that students who participate in a constructivist learning approach improve their problem-solving skills but also gain more confidence in using these skills across different subjects. Their findings suggest that ongoing exposure to real-life problem-solving situations significantly aids students' cognitive growth and adaptability.

On the other hand, Harefa & Purba(2020) offer a different perspective, indicating that while problem-solving is crucial for student success, its effectiveness can depend on the teaching methods used.

They argue that traditional teaching approaches can still produce satisfactory results in some situations, especially when they include structured guidance and support. This viewpoint suggests that not all teaching methods are equally effective in developing problem-solving skills, challenging the idea that PBL is always the best approach.

### 3.2.3. Knowledge Application

Table 7 shows the level of conceptual mastery in chemistry in terms of knowledge application. It shows the overall mean of 3.67, which is interpreted as very satisfactory. Among the indicators, eight of them are interpreted as very satisfactory namely: "I am able to predict outcomes based on my understanding of chemical reactions" (3.96); "I use my knowledge of chemistry to make informed decisions in daily life" (3.88); "I feel confident in conducting experiments that demonstrate chemical principles" (3.87); "I can design experiments that test specific hypotheses related to chemistry concepts" (3.86); "I apply my understanding of chemistry concepts to real-world situations" (3.80); "I actively seek opportunities to use my knowledge of chemistry outside the classroom" (3.80); "I recognize the importance of safety and ethics when applying my knowledge of chemistry" (3.65) followed by the two indicators interpreted as satisfactory namely: "I often relate new information in chemistry to what I've learned previously" (3.38), and "I share my knowledge of chemistry with others to enhance their understanding" (2.70). These findings imply that while students are adept at applying their chemistry knowledge, there is a need to enhance their skills in connecting new information with existing knowledge and fostering collaborative learning environments.

**Table 7.** Level of Conceptual Mastery in Chemistry in terms of Knowledge Application

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| I am able to predict outcomes based on my understanding of chemical reactions. | 3.96 | Agree | Very Satisfactory |
| I use my knowledge of chemistry to make informed decisions in daily life. | 3.88 | Agree | Very Satisfactory |
| I feel confident in conducting experiments that demonstrate chemical principles. | 3.87 | Agree | Very Satisfactory |
| I can design experiments that test specific hypotheses related to chemistry concepts. | 3.86 | Agree | Very Satisfactory |
| I apply my understanding of chemistry concepts to real-world situations. | 3.80 | Agree | Very Satisfactory |
| I actively seek opportunities to use my knowledge of chemistry outside the classroom. | 3.80 | Agree | Very Satisfactory |
| I recognize the importance of safety and ethics when applying my knowledge of chemistry. | 3.76 | Agree | Very Satisfactory |
| I can explain how chemical principles relate to everyday life experiences. | 3.65 | Agree | Very Satisfactory |
| I often relate new information in chemistry to what I've learned previously. | 3.38 | Not Sure | Satisfactory |
| I share my knowledge of chemistry with others to enhance their understanding. | 2.70 | Not Sure | Satisfactory |
| Overall mean | 3.67 | Agree | Very Satisfactory |

Recent studies in chemistry education reveal the intricate nature of students' understanding and the implications for teaching methods. Two studies support the idea that effective teaching strategies can significantly improve students' grasp of chemistry concepts. For example, a study highlights the effectiveness of using multimodal teaching approaches, which enhance students' ability to visualize and reason about molecular geometry. This research advocates for incorporating various reasoning strategies in classroom instruction, as they can lead to a deeper understanding and better problem-solving skills (Kiernan et al., 2024). Another study from 2024 presents a meta-analysis showing that cooperative and inquiry-based learning techniques are beneficial for student engagement and cognitive development in chemistry. These methods not only improve students' academic performance but also foster positive attitudes towards learning chemistry, aligning with modern educational goals that emphasize critical thinking and teamwork (Vega, 2024).

On the other hand, a study challenges this optimistic view by pointing out that many students still struggle with achieving a comprehensive understanding of chemistry concepts, despite various teaching methods being employed. The research indicates that students often have difficulty linking different levels of chemical representation—sub-microscopic, macroscopic, and symbolic—which leads to misconceptions and shallow learning experiences. This suggests that even innovative teaching strategies may not fully bridge the gap in students' abilities to integrate and apply their knowledge effectively (Rahmawati et al., 2022). While recent literature emphasizes the potential of diverse teaching methodologies to enhance conceptual understanding in chemistry, it also highlights persistent challenges that educators must address to ensure meaningful learning outcomes for their students.

#### 3.2.4. Summary of the Results from the Conceptual Mastery of the Students in Chemistry

The results summarized in Table 8 indicate that the overall performance in the conceptual mastery of chemistry is very satisfactory, with an average score of 3.81. This suggests that students have a solid understanding of the material and are effectively engaging with the concepts. However, at the individual sub-variables, we see some areas that could use improvement. For instance, while problem-solving skills scored the highest at 4.07, indicating strong capabilities in this area, both conceptual change (3.68) and knowledge application (3.67) received lower scores. This finding implies that while students are good at solving problems, they may struggle with fully grasping conceptual changes and applying their knowledge in practical situations. Therefore, educators should focus on enhancing these specific areas to ensure a more balanced mastery of chemistry concepts, which will ultimately lead to a deeper understanding and better application of the subject in real-world scenarios.

**Table 8.** Summary of the Results for Conceptual Mastery of the Students in Chemistry

| Indicators | Mean | Descriptive Rating | Qualitative Interpretation |
|---|---|---|---|
| Conceptual Change | 3.68 | Agree | Very Satisfactory |
| Problem-Solving Skills | 4.07 | Agree | Very Satisfactory |
| Knowledge Application | 3.67 | Agree | Very Satisfactory |
| Overall mean | 3.81 | Agree | Very Satisfactory |

Recent literature highlights the complexities of achieving conceptual change in chemistry education, supporting the idea that students often hold misconceptions that hinder their understanding. For instance, a systematic literature review by Suparman et al. (2024) identifies prevalent misconceptions among students regarding key chemistry concepts such as chemical equilibrium and acid-base theory. The study emphasizes that recognizing these misconceptions is crucial for developing effective teaching strategies aimed at facilitating conceptual change and enhancing student comprehension. Additionally, the Dynamic Model of Conceptual Change (DMCC) proposed by Nadelson et al. (2018) underscores the importance of a comprehensive approach to conceptual change, incorporating various factors such as culture and personal epistemology. This model suggests that addressing these diverse influences can significantly improve students' conceptual understanding in science, including chemistry.

On the contrary, Ultay et al. (2015) challenge the effectiveness of singular interventions like conceptual change texts (CCTs) in remedying misconceptions in chemistry. Their research indicates that while CCTs can have some positive impact, they are insufficient on their own to address the complexity of students' alternative conceptions fully. The authors argue for a multifaceted approach that combines various instructional strategies to achieve more substantial and lasting conceptual change. This contradiction highlights the need for educators to employ diverse methods rather than relying solely on one type of intervention to foster deeper understanding in chemistry.

### 3.3. Correlation between Laboratory Engagement and Conceptual Mastery

Table 9 shows the statistical significance between the variables of this study. It revealed that there is a significant relationship that exists between laboratory engagement and conceptual mastery in chemistry.

At a 0.05 significance level, the correlation value is .445 which is significant. Thus rejecting the hypothesis of this study. This finding suggests that students who actively participate in laboratory activities are more likely to achieve a deeper understanding of chemistry concepts. By fostering greater engagement in laboratory settings, they can enhance students' conceptual mastery, ultimately leading to improved academic performance in chemistry. This underscores the importance of practical learning experiences in science education and encourages further investment in laboratory resources and training for both teachers and students.

**Table 9.** Statistical Significance of the Results using Pearson Correlation

| Scale | Conceptual Mastery | Decision | Remarks |
|---|---|---|---|
| Laboratory Engagement | .445* | Reject $H_0$ | Significant |

*. Correlation is significant at the 0.05 level (2-tailed).

Recent studies have shown that engaging in laboratory work significantly boosts students' understanding of chemistry concepts. For example, Iyamuremye et al. (2023) found that hands-on activities in chemistry education enhance critical thinking skills and lead to better academic outcomes. Their research points out that when students participate directly in experiments, they are able to relate theoretical knowledge to practical situations, which helps them grasp chemistry concepts more effectively. Similarly, Okam and Zakari (2016) reported that students who were taught through laboratory methods performed better than those who learned through traditional lectures, reinforcing the idea that practical experience is essential for effective chemistry learning. On the other hand, Smith and Alonso (2020) offer a different viewpoint. They suggest that while students often enjoy their laboratory experiences, these activities do not always translate into a deeper understanding of the material. Their findings indicate that without a clear focus on cognitive learning goals alongside hands-on activities, the benefits of laboratory engagement might not be fully realized. This highlights the need for a balanced approach that integrates both practical engagement and cognitive objectives in laboratory settings.

## 4. CONCLUSIONS

The study on laboratory engagement and conceptual mastery in chemistry has yielded significant insights into the educational dynamics. The major outcome indicates a positive correlation between active laboratory engagement characterized by hands-on experimentation and conceptual mastery in chemistry. This finding underscores the importance of fostering engaging laboratory environments to improve students' understanding and application of chemical concepts, which is crucial for their academic success and future scientific endeavors. This study recommends that educational institutions prioritize the development of strong implementation of laboratory programs that emphasize hands-on learning and collaborative practices. Future research may expand on these findings by exploring diverse educational settings and employing longitudinal designs to assess the long-term impact of laboratory engagement on student mastery in chemistry and other STEM disciplines.

**Acknowledgments.** The authors express their sincere gratitude to all the individuals who provided technical and administrative support throughout the course of this research.

**Research Ethics.** This research adhered to all relevant ethical standards and guidelines, including obtaining informed consent from participants, ensuring anonymity and confidentiality of data, and avoiding any practices that could cause harm or distress. Additionally, the research design was conducted transparently and unbiasedly, and the findings were presented accurately and objectively.

**Data Availability Statement.** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Conflicts of Interest.** The authors declare no conflicts of interest.

**Funding.** This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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