

Effects of the VIMCC (Visual, Interactive, and Meaning-Centered Conceptualization) Approach on Students' Conceptual Understanding, Learning Engagement, and Insights in Subatomic Particles

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Abstract. This action research focused on improving Grade 8 students' performance in differentiating subatomic particles by strengthening their conceptual understanding of atomic structure through the VIMCC (Visual, Interactive, and Meaning-Centered Conceptualization) approach. The study was conducted in a public high school in Leyte, Philippines, among selected Grade 8 students who had difficulty differentiating subatomic particles. Initial observations and pre-test results revealed that students had weak prior knowledge of atomic structure, which affected their understanding of subatomic particles. To address this problem, the researchers implemented the VIMCC Approach embedded in a 7E's lesson plan. This approach integrated Visual tools (YouTube video presentations, color-coded learning materials, and 3D atomic models), Interactive activities (game-based matching task and model manipulation), and Meaning-Centered strategies (concept maps and the Frayer Model). The study employed participatory action research using formative assessments, classroom observations, and focus group discussions as data sources. Results showed significant improvements in students' conceptual understanding and academic performance, with increasing post-test mean percentage scores in both Cycle 1 and 2. Normalized gain scores and paired t-test results indicated positive learning gains in both cycles. Observations revealed high levels of effort and initiative, accompanied by low levels of disruptive and inattentive behaviors. Focus group discussions further revealed that students perceived the VIMCC-based activities as enjoyable, engaging, easier to understand, and more interesting. The findings highlight the effectiveness of the VIMCC Approach in strengthening secondary students' conceptual understanding of atomic structure, thereby improving their ability to distinguish among subatomic particles and enhancing their confidence in learning science.

Keywords: conceptual understanding; atomic structure; subatomic particles; VIMCC approach; action research

INTRODUCTION

Background and Importance of Subatomic Particles

Subatomic particles—protons, neutrons, and electrons—are the fundamental building blocks of atoms that determine an element's identity, stability, and reactivity. In science education, mastering

these particles are essential for understanding core chemistry topics such as atomic structure, chemical bonding, the periodic table, and chemical reactions. Under the Philippine MATATAG Curriculum, students are expected to develop scientific reasoning and problem-solving skills by exploring how these particles function and applying this knowledge to real-world contexts (Department of Education, 2023). These competencies prioritize conceptual understanding over rote memorization. It directly aligns with the spiral progression approach mandated by Republic Act No. 10533, ensuring that foundational concepts are securely mastered before students advance to more complex chemical principles in higher grade levels. A clear understanding of subatomic particles is also essential in developing students' scientific reasoning and problem-solving skills. Understanding how protons, neutrons, and electrons interact helps students apply scientific concepts to the real world.

Learning Challenges and Performance Gaps in Subatomic Particles

However, at the research site, the researchers observed that students continued to experience significant learning difficulties with this topic. Many students continued to struggle with subatomic particles due to the topic's abstract and highly conceptual nature, which often leads to misconceptions and weak academic performance (Kaya, 2023; Fitriza & Gazali, 2018). Classroom observations, learner interviews, and analysis of student outputs revealed that many learners struggled to accurately identify and explain the mass, charge, symbol, and location of subatomic particles.

Empirical findings in chemistry education further indicate that a weak understanding of atomic structure hinders learning later topics like bonding and reactions. Without a solid grounding in atomic theory and atomic model, students develop fragmented knowledge and rely on memorization rather than conceptual understanding (Dela Cruz et al., 2025; Fitriza & Gazali, 2018). As a result, students may recall factual information but fail to explain why chemical phenomena occur, limiting their ability to apply concepts in problem-solving and real-life situations. In particular, the 2022 Programme for International Student Assessment (PISA) and the 2024 National Achievement Test reported below-average performance, highlighting ongoing challenges in improving scientific literacy within the Philippine education system (Organisation for Economic Co-operation and Development, 2023; Second Congressional Commission on Education (EDCOM) II, 2024).

To systematically examine these learning difficulties, a problem analysis was conducted. This structured process maps a core problem, its causes, and its effects (UNECA, n.d., Chapter 8), providing a basis for designing targeted interventions by identifying root causes (Debesa, 2025). To operationalize this process, with participants' consent, the researchers used meta-cards and follow-up questions to identify learning difficulties. These issues were organized into a problem tree (see **Figure 1**) to map hierarchical causes and effects, highlighting the most influential and addressable factors. Through this analysis with struggling learners, the core problem emerged: students' poor performance in differentiating among subatomic particles. The difficulty may stem from the abstract and unobservable nature of submicroscopic concepts, requiring students to rely on mental visualization, which can hinder their understanding and lead to misconceptions (Laohapornchaiphan & Chenprakhon, 2024; Susilaningih & Aprilia, 2022). Despite inquiry-based learning, students still struggle with subatomic particles in terms of student motivation, suggesting that improving their confidence may require additional strategies beyond content mastery (Azizoglu, 2022). This main problem was split into three key sub-problems: (1) lack of conceptual understanding of atomic structure, (2) poor skills in identifying subatomic particles, and (3) lack of interest (see Figure 1). Researchers prioritized the first branch—lack of conceptual understanding—because it serves as a prerequisite for mastering subatomic particles and heavily influences a student's ability to interpret atomic models, relate particle properties, and apply scientific reasoning. Studies show that the misconceptions and lack of comprehension of this topic are due to limited prior knowledge leading to poor understanding of subatomic particles (Jusgado, 2024). More importantly, this cause was

considered the most feasible and manageable to address through classroom-based instructional interventions and available data sources.

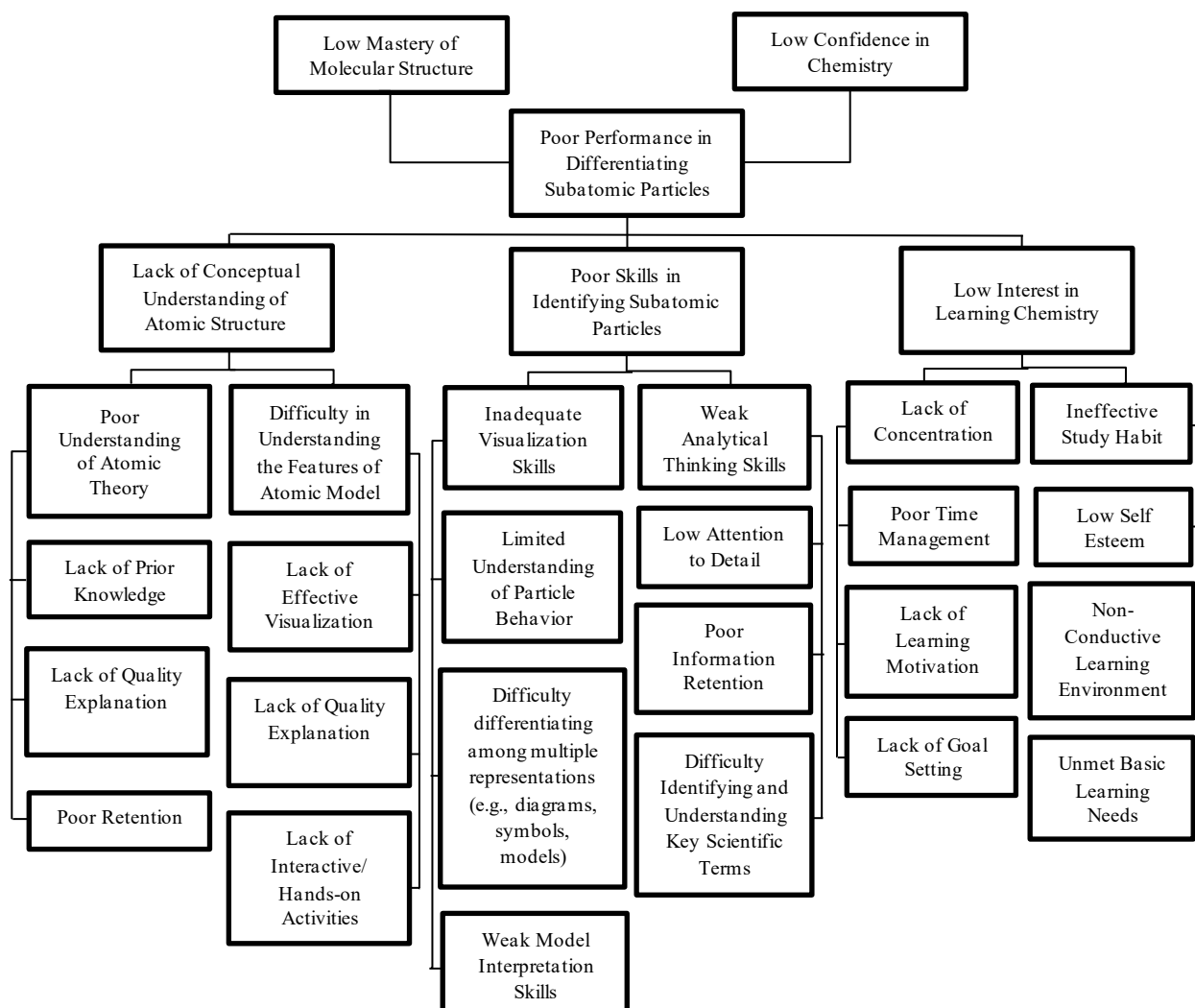


Figure 1: Problem Tree

Instructional Intervention

Stronger conceptual learning correlates directly with advanced scientific reasoning, providing a logical framework for problem-solving while driving behavioral and academic growth (Bautista, 2024). To address conceptual gaps regarding subatomic particles, the researchers implemented the VIMCC (Visual, Interactive, and Meaning-Centered Conceptualization) approach. Because atomic structure exists at an abstract, submicroscopic level and cannot be directly observed, this combined strategy engages learners through seeing, doing, and making sense of ideas, preventing rote memorization and misconceptions.

Visual-based strategies present concepts in clear, structured forms to help students organize and retain information. For example, concept maps visually display relationships between ideas to support deeper understanding, memory, and critical thinking. Concept mapping enhances knowledge representation by allowing learners to actively connect new information with prior knowledge (Narang & Lata, 2024). Similarly, video presentation was used to introduce concepts through animations, images, and guided explanations, supporting student engagement and comprehension. Video-supported discovery learning can promote active participation and improve understanding in

science classes (Koto, 2020). Additionally, 3D models let students observe atomic structures from multiple perspectives to make abstract ideas concrete, while color-coded materials highlighted patterns and categories. The role of visual design in strengthening memory retention and comprehension, ensuring that learning experiences are both engaging and conceptually rich.

Interactive interventions encouraged active student involvement and experiential learning. A key activity was the Atomic Model Matching Game, a game-based classroom task requiring real-time matching and problem-solving. This approach aligns with the findings of Pacturan et al. (2024), who reported that gamification can enhance academic performance and inform more responsive teaching strategies. The use of 3D models also served an interactive function, as students could manipulate and explore the models hands-on, enabling them to better grasp spatial relationships and structural features of atomic components (Astuti, 2020).

Meaning-centered interventions focus on developing a deep and lasting understanding rather than simple memorization. The Frayer Model strategy guided students in defining key concepts, identifying their characteristics, and providing examples and non-examples. Sacapaño and de Castro (2022) found that this approach significantly improves secondary learners' science vocabulary and conceptual clarity. Concept maps further supported this process by encouraging students to link related ideas in meaningful ways, reinforcing the cognitive benefits identified by Narang & Lata (2024).

By synthesizing these possible interventions, the researchers developed an integrative, unified approach termed the VIMCC (Visual, Interactive, and Meaning-Centered Conceptualization). The combination of visual, interactive, and meaning-centered interventions was intentionally designed to address the different challenges associated with learning subatomic particles. Visual strategies helped students see or visualize the concepts, interactive strategies allowed them to experience and explore the concepts, and meaning-centered strategies enabled them to understand and internalize the concepts. Together, these approaches created a complementary learning process that supported conceptual understanding, reduced misconceptions, increased engagement, and promoted meaningful science learning.

Theoretical Foundations

Effective interventions for teaching atomic structure require a strong theoretical basis. This study utilizes the VIMCC approach, which draws on established learning theories to support students' conceptual understanding, with each component grounded in specific educational frameworks.

The visual component of VIMCC uses diagrams, models, and illustrations to help students grasp complex concepts, a strategy strongly supported by Allan Paivio's Dual Coding Theory. By processing information through both verbal and visual channels, students recognize patterns and structures that text alone cannot reveal, leading to deeper conceptual understanding (Paivio, 1986). This is further backed by Richard E. Mayer's Multimedia Learning Principles, which state that learners understand concepts better when words and visuals are presented together rather than separately (Mayer, 2021). Additionally, John Sweller's Cognitive Load Theory highlights that integrating visuals with clear explanations minimizes extraneous cognitive load, allowing students to process complex topics like atomic structure more efficiently.

The interactive component of the VIMCC Approach actively engages students through collaboration, discussion, and hands-on activities. This element is underpinned by Lev Vygotsky's Sociocultural Theory, which emphasizes that social interaction and guided instruction within the Zone of Proximal Development (ZPD) allow students and teachers to co-construct knowledge for better retention. Complementing this, progressivist educational philosophy emphasizes "learning by doing." These interactive, hands-on experiences promote critical thinking and active participation, enabling students to engage meaningfully with scientific concepts rather than passively receiving information.

The meaning-centered component ensures a solid conceptual foundation by connecting new information to prior knowledge and essential scientific terms. Bartlett's Schema Theory highlights how learners organize and retain new information by linking it to existing schemas, making

comprehension faster and more meaningful (Bartlett, 1932; Iran-Nejad & Winsler, 2000). This is complemented by the essentialist philosophy, which emphasizes the accurate understanding of key concepts, helping students reduce misconceptions and grasp the fundamental principles of atomic structure (Bagley, 1938).

By integrating visual representations, interactive engagement, and meaning-centered learning, the VIMCC approach enables students to understand atomic structure more deeply and accurately. This framework aligns with Multimodal Learning Theory, which emphasizes that learning is enhanced when students process information through multiple modes like visual, verbal, and kinesthetic experiences (Mayer, 2021). It also reflects Constructivist Theory, where learning is an active process of constructing knowledge through meaningful interactions with materials, peers, and prior experiences (Piaget, 1952; Vygotsky, 1978). Together, these foundations create a cohesive framework that fosters an engaging, supportive environment to improve science education.

RESEARCH QUESTIONS

This study aims to answer the central question: How does enhancing Grade 8 students' conceptual understanding of atomic structure in public schools improve their ability to differentiate subatomic particles using the VIMCC Approach?

Specifically, this study seeks to answer the following questions:

1. To what extent does the VIMCC approach improve students' conceptual understanding, as indicated by the difference between pre-test and post-test results?
2. What is the level of students' engagement when the VIMCC approach is implemented as an intervention?
3. What insights do students gain regarding how the VIMCC approach facilitated their understanding of atomic structure?

METHODOLOGY

PAR Cycle

The researchers conducted the study using the participatory action research (PAR) method. Participatory Action Research (PAR) was a cyclical approach involving planning, action, observation, and reflection (Kendon et al., 2007). PAR improved learning by enabling ongoing adjustments based on effective strategies and stood out by actively involving participants as partners rather than treating them only as research subjects (Feekery, 2023).

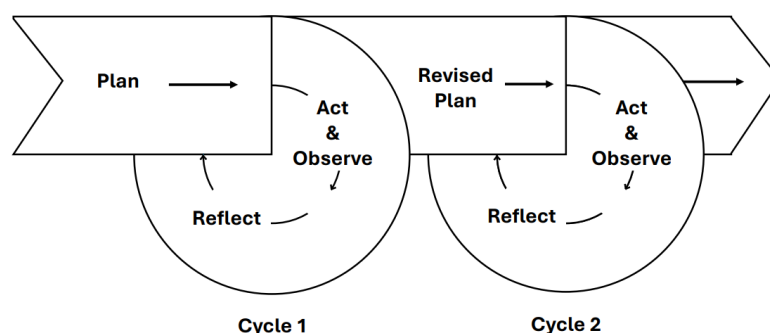


Figure 2: Steps of the Action Research Process

- (1) Planning Phase - Through problem analysis, the researchers identified the learning challenges of struggling Grade 8 students using meta-cards, follow-up questions, and thematic grouping. They mapped these issues into a cause-and-effect problem tree, which was then translated into an objective tree to define clear goals. These goals guided the development of targeted lesson plans, which three science teachers validated before implementation.

- (2) Action Phase - Researchers collaborated with students, parents, administrators, and teachers to implement the interventions. After securing parental consent, students attended an orientation and participated in a two-session, hour-long remedial program during Cycle 1. Following a pre-test, lessons covered Atomic Theory on Day 1 and Atomic Models on Day 2, with student engagement monitored using the SEOC checklist. Finally, a focus group discussion gathered student insights, a post-test assessed learning gains, and participants received tokens of appreciation.
- (3) Observation Phase - During the instructional process, one researcher served as the demonstration teacher, acted as observers to ensure objective monitoring—one handling documentation—and another functioned as a class facilitator to support students.
- (4) Reflection Phase - The researchers analyzed assessment results, classroom observations, and FGD responses to evaluate the effectiveness, long-term viability, and to identify possible learning gaps of the VIMCC Approach.

This process unfolds across two cyclical phases (**Figure 2**). In Cycle 2, the researchers used findings and limitations from Cycle 1 to refine the interventions. These revised strategies were implemented with the same Grade 8 participants across two sessions using the 7Es model (see **Table 2**), incorporating formative reviews, physical demonstrations, guided visuals, and structured group work (see **Table 6**). Data collection mirrored Cycle 1, utilizing pre- and post-tests, quizzes, the SEOC checklist, and a Focus Group Discussion (FGD) alongside lesson observations to monitor engagement and gather student feedback.

Research Locale

This study was conducted at Baybay National High School, a public secondary school located in Baybay City, Leyte, Philippines, during the first quarter of the Academic Year 2025–2026. The participants were Grade 8 students enrolled in the school during the same academic year.

Participants

Participants were selected through purposive sampling based on their first-quarter Science 7 scores on the phases of matter. With the adviser's consent and guidance, the scores were used to identify struggling learners scoring 70% or below. Thirteen Grade 8 students were initially selected; however, only 8 students participated in the study, as the remaining students were not permitted by their parents to take part. These selected students then received the interventions from the researchers.

The participants of the study were assessed using the Student Engagement Observation Checklist (SEOC) by the four researchers, none of whom were the participants' science teachers, thereby minimizing observer bias. Before conducting the observations, the researchers were oriented on the purpose, indicators, and proper use of the SEOC to ensure consistent and objective implementation throughout the study.

Research Tools

The study employed a variety of research tools to gather data on students' academic performance, engagement, and perceptions of the intervention. These included pre-tests, post-tests, quizzes, the Students' Engagement Observation Checklist (SEOC), and Focus Group Discussions (FGD), as shown in **Table 1**.

Table 1: Research Instruments Used

Tools	Description	Purpose
Pre-test/Post-test	20- item multiple - choice test on subatomic particle differentiation	Measure conceptual understanding gains
Formative Assessments (Session Quizzes)	10- item MCQs after each 7Es Lesson Plan	Assess immediate learning from VIMCC activities
SEOC Checklist	18-item observation scale (1-5: effort, initiative, disruptive, inattentive)	Document behavioral engagement patterns
FGD Guide	7 open-ended questions on intervention experiences	Gather qualitative student reflections

To ensure content validity, the pre-test, post-test, and quizzes were reviewed by three master science teachers with over 5 years of experience. They evaluated the items for clarity, appropriateness, and exact alignment with Grade 8 learning competencies, and revisions were made based on their feedback. Reliability was supported through item review. Daily short quizzes monitored students' developing conceptual understanding. Because intervention components varied by session (see **Table 2**), these quiz results reflect snapshots of understanding for that day's concepts, providing evidence of student progress to help explain the differences between the pre-test and post-test.

Table 2: 7Es Lesson Plans for Day 1 and 2

7Es Step	Day 1		Day 2	
	Lesson: Atomic Theory	Description	Lesson: Atomic Model	Description
Elicit	Application of Concept Map ^{a,c}	Match phrase strips and identify characteristics of states of matter using a concept map.	Atom Drawing Reflection	Review and explain previous atom drawings.
Engage	Activity: What's inside?	Observe and guess the contents of an object to introduce atomic structure.	Activity: Guess the Scientist Riddle	Solve riddles to identify scientists and their contributions.
Explore	Activity: Which Theory came First?	Arrange atomic theories in chronological order.	Gamified Classroom Activity: Atomic Model Matching Game ^b	Match scientists, models, and images in a group game.
Explain	Multimedia Presentation: YouTube Video ^a	Watch a video on the development of atomic theory to strengthen initial understanding and respond to the accompanying guide questions.	Utilization of 3D Model ^{a,b}	Observe and manipulate 3D atomic models.
Elaborate	Color-Coded Learning Materials ^a	Arrange and group color-coded cards of atomic theories.	Frayer Model Strategy ^c	Define and describe subatomic particles, including their characteristics, examples, and non-examples.
Evaluate	Short Quiz	Answer questions about atomic theory.	Short Quiz	Answer questions about subatomic particles and models.
Extend	Draw an atom	Draw and label the parts of an atom.		

Intervention Legend: *a* = Visual Interventions; *b* = Interactive strategies; *c* = Meaning-Centered strategies

The SEOC tool, a validated checklist adopted from Cassar & Jang (2010), was used to assess students' engagement using a 5-point Likert scale (1 – Never, 2 – Rarely, 3 – Sometimes, 4 – Often, 5 – Always). The checklist included indicators under four subscales: Effort (E), Initiative (I), Disruptive Behavior (D), and Inattentive Behavior (N). Effort refers to persistence and task completion. Initiative reflects active participation and willingness to engage. Disruptive behavior includes actions that interrupt learning. Inattentive behavior refers to lack of focus or withdrawal during class activities.

Lastly, Focus Group Discussions (FGD) were conducted using an expert-reviewed, standardized protocol to gather students' experiences. The guide questions were focused on their learning, helpful

activities, difficulties, and interest in science. Responses were recorded, transcribed, and analyzed to identify common themes. The following were the guide questions used for the FGD.

1. Throughout the implementation process, can you describe your overall experience with the 6 interventions used?

2. Do you believe that the interventions applied enhanced your learning experience compared to the traditional teaching methods? If yes, in what way and what specific intervention/s? If not, explain why.

3. Can you share what specific intervention/s that were applied that helped deepen your understanding of subatomic particles? What made it effective for you?

4. Were there any difficulties or challenges you faced during the implementation, and how did those experiences contribute to your overall learning process?

5. What was your initial understanding of subatomic particles before the intervention, and how did it change after?

6. In your opinion, what is the most intriguing about the ideas of subatomic particles that inspired you to participate?

7. Throughout each activity, do you find the topic of subatomic particles more interesting? If yes, what made you want to learn more about this topic? If not, why not?

Data Collection

Data collection followed a triangulation approach, combining formative assessments (pre/post-tests, quizzes), classroom observations (SEOC), and Focus Group Discussions (FGDs) to validate findings and minimize bias. The researcher collected the data according to the following steps in figure 3.

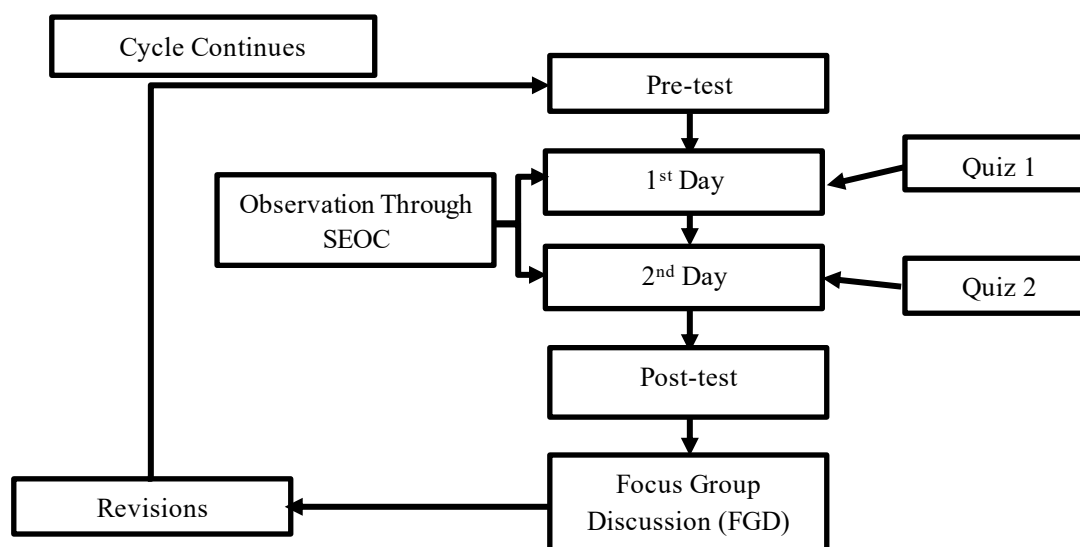


Figure 3: Flowchart of the Data Collection Process

The iterative process begins with a pre-test to establish baseline knowledge, followed by two days of instructional interventions with formative quizzes to monitor progress, and a post-test to measure overall learning. During implementation, four researchers observe student engagement using the SEOC tool. Afterward, participants provide qualitative feedback via a Focus Group Discussion (FGD). This qualitative feedback, combined with assessment and observation data, is analyzed to evaluate the intervention's effectiveness and guide revisions for a continuous cycle of improvement.

Ethical Standards

Ethical standards were strictly upheld following approval from the Visayas State University Health Ethics Review Committee (VSU HERC) under protocol number 2025-130-FTE. Informed parental consent and student assent were secured, emphasizing that voluntary participation could be withdrawn at any time without penalty. To ensure confidentiality under the Data Privacy Act of 2012 (RA 10173), data were anonymized using participant codes (e.g., P1) and stored securely for a five-

year retention period. The researchers declared no conflicts of interest and minimized bias by conducting sessions after class hours, maintaining clear researcher boundaries, and thoroughly familiarizing themselves with the SEOC checklist before data collection. Lastly, potential risks were mitigated by fostering a supportive, non-coercive environment that actively addressed student anxiety.

Limitations

While this study offers valuable insights into the VIMCC approach, several limitations apply. The small sample size from a single school limits the generalizability of the findings across other institutions, grade levels, or regions. Additionally, the short-term intervention may not reflect long-term retention. Data collection—relying on tests, quizzes, observation checklists, and feedback—might not capture all facets of conceptual understanding, and uncontrolled variables like prior knowledge, learning styles, and resource access could have influenced the results. Nevertheless, the study establishes a foundational baseline for future research.

Data Analysis

The data analysis in this research was categorized into three parts in accordance with the triangulation method (see **Table 3**), as outlined below:

- (1) Formative Assessments: Pre-tests, post-tests, and quizzes' scores were analyzed through mean percentage scores (MPS), bar graphs with error bars, paired t-test, and normalized gain by Hake (1998), $g = \frac{(posttest)-(pretest)}{100-(pretest)}$, to determine the effectiveness of the VIMCC Approach in promoting conceptual understanding and the students' improvement before, during, and after the implementation.
- (2) SEOC (Classroom Observation): SEOC results were examined using mean percentage scores (MPS) and bar graphs with error bars, guided by the adopted descriptive scale ranges (Lingling, 2023) to measure students' engagement and behavior, while also illustrating the variability and dispersion of data.
- (3) FGD (Focus Group Discussion): Students' perceptions and reflections after the implementation were recorded, transcribed, and analyzed using Braun & Clarke's (2006) 6-step thematic analysis: familiarization (transcribe/read), coding (inductive/deductive), theme generation/review, definition/naming, reporting linked to objectives.

Cycle comparisons were analyzed via graphs/tables to confirm VIMCC effectiveness.

Table 3: Data Collection and Analysis in each Research Question

Research Question:	Data Collection Method (Triangulation Approach)	Data Analysis
Q1: Performance	Pre-test and Post-test, Quizzes	Bar Graph with Error Bars, Mean Percentage Score (MPS), Normalized Gain, Paired t-test
Q2: Student Engagement	Observational tool SEOC	Mean Percentage Score (MPS), Bar Graph with Error Bars, Adopted Descriptive Scale Range (Lingling, 2023)
Q3: Students' perceptions	Focus Group Discussion	Braun & Clarke's (2006) 6-Step Thematic Analysis

RESULTS AND DISCUSSION

Following the triangulation method, this section will discuss the findings from formative assessments, classroom observations, and student responses in Cycle 1 in analyzing the effectiveness of the VIMCC approach, along with the adjustments made in the interventions that led to Cycle 2.

CYCLE 1 FINDINGS

Formative Assessment Results (Findings for Research Question 1)

Low pre-test scores in **Table 4** showed that students had limited understanding of subatomic particles, indicating the need for targeted instructional interventions. This might be because students find atomic concepts difficult due to their abstract nature and limited concrete representation in traditional teaching (Clamohoy et al., 2025). For instance, junior high school students in Philippine public schools demonstrated weak prior knowledge in chemistry concepts, particularly those involving atomic models, due to their limited visualization and conceptual scaffolding (Dela Cruz et al., 2025). In response to this challenge, the results showed a clear improvement in student performance (see **Table 4**). The mean score rose from 13.875 in the pre-test to 17.25 in the post-test, while the Mean Percentage Score (MPS) increased from 69.38% to 86.25%. This shift moves students from an "approaching proficiency" level to a "proficient" level of understanding, demonstrating that the instructional intervention effectively enhanced their mastery of the concepts.

The paired-samples t-test further confirmed that the improvement was statistically significant, $t(7) = -4.00, p = 0.005$. Because the p-value is less than 0.05, the null hypothesis is rejected, indicating the score increase is due to the intervention rather than chance. Furthermore, Cohen's d yielded an effect size of -1.41, representing a very large, meaningful impact on learning outcomes. This significant gain highlights the effectiveness of using interactive, visual-based instructional interventions to improve conceptual understanding in science, matching findings that tools like concept mapping, strategic intervention materials, and activity-based learning heavily enhance mastery of abstract concepts (Borabo & Dio, 2025).

Table 4: Paired t-test for Pre-test and Post-test Scores in Cycle 1

Test	Mean	Mean Percentage Score	t-statistic	df	p	Cohen's d	Normalized Gain
Pre-test	13.875	69.38	-4.00	7	0.005	-1.41	0.55
Post-test	17.25	86.25					

Additionally, the normalized gain score of 0.55 indicates a moderate improvement in students' conceptual understanding. This shows that learners achieved more than half of their potential learning gains, developing a deeper understanding of atomic structure. While the interventions proved effective, the results suggest that further instructional refinement is needed to address remaining misconceptions and fully deepen mastery.

Table 5: Quiz Mean Percentage Scores (MPS) Per Day in Cycle 1

	MPS (Mean Percentage Score)	Mean Difference
Day 1: Atomic Theory	82.5%	12.5%
Day 2: Atomic Models	95%	

Table 5 shows a 12.5% increase in mean scores from Day 1 to Day 2, indicating improved retention and a deeper understanding of atomic concepts as instruction progressed. This aligns with the spiral progression approach mandated by the Enhanced Basic Education Act of 2013 (Republic Act No. 10533), which emphasizes reinforcing prerequisite concepts before introducing more complex subjects. This growth demonstrates that students' science performance improves significantly when strategic intervention materials and formative assessments are used to consolidate foundational ideas (Borabo & Dio, 2025). Building this solid baseline is critical for understanding subatomic particles, as it provides the necessary context for how protons, neutrons, and electrons are structured and interact (Department of Education, 2020). Additionally, Filipino learners develop a stronger grasp of chemistry when instruction continually revisits key ideas using varied representations rather than treating topics as isolated lessons (Dela Cruz et al., 2025).

Participants' Engagement Through SEOC (Findings for Research Question 2)

The SEOC results for Cycle 1 described the students' behaviors during the two-day implementation. The mean scores in **Figure 4** show that Effort and Initiative were consistently high, while Disruptive and Inattentive behaviors remained low across both days.

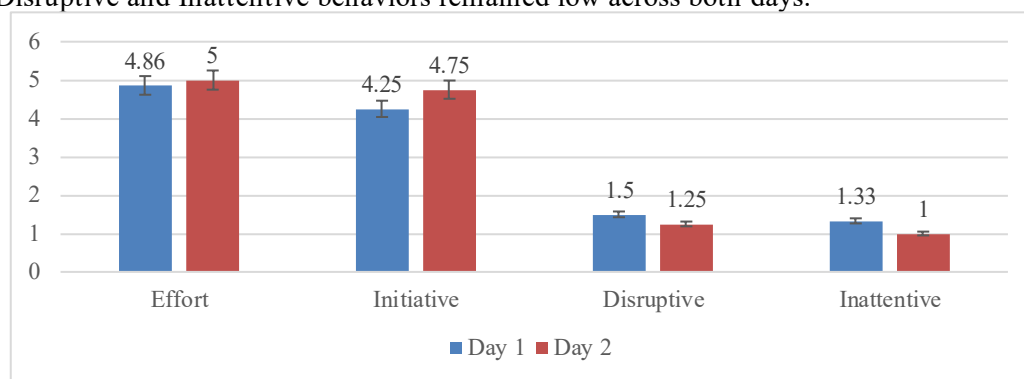


Figure 4: Mean Scores of SEOC Scale for Cycle 1

The high Effort and Initiative mean scores indicate that students were actively engaged and willing to participate in tasks, which strongly aligns with the improved learning outcomes. This engagement can be attributed to the interventions, which fostered active involvement. Interventions supporting student autonomy encourage learners to take initiative and become more proactive (Reeve et al., 2020). The findings further show that students demonstrated a high commitment to completing tasks, particularly those requiring less intensive manipulation (Al Mamun & Lawrie, 2023), and sustained effort typically enhances overall educational outcomes (Berhanu et al., 2025). These interactive activities likely strengthened effort and initiative, contributing to the reduction of disruptive and inattentive behaviors.

Conversely, the low mean scores for Disruptive and Inattentive behaviors suggest a supportive learning environment with fewer interruptions and better focus. Clear structure and guided activities naturally minimize these behaviors (Berhanu et al., 2025). Despite this, the non-zero mean scores reveal that some students still exhibited occasional off-task behaviors and relied on teacher guidance to begin, showing that independent engagement was inconsistent. This pattern often stems from fluctuations in engagement as task difficulty increases, which can temporarily reduce attention among certain learners (Heemskerk & Malmberg, 2020).

The increased effort and initiative demonstrated by the students suggest that the interactive, visual, and meaning-centered activities effectively enhanced their engagement in learning. By making the concepts more meaningful and easier to understand visually, these activities encouraged students to participate more actively in classroom tasks. As a result, disruptive and inattentive behaviors were minimized during classroom instruction.

Students' Insights About the Used Interventions (Findings for Research Question 3)

As part of the triangulation process, a focus group discussion was conducted to validate and explain the results obtained from formative assessments and classroom observations.

Theme 1: Positive Learning Experience

Many learners in Cycle 1 described the activities as fun, comfortable, and engaging, thereby creating a positive classroom atmosphere and encouraging active participation. One participant stated, "*It is fun actually, because there are a lot of activities which I really enjoyed*" (P1), while another shared, "*For me, it was fun and engaging activities that were made, and I love it*" (P2). These responses suggest that interactive tasks increased student involvement and that enjoyment in learning encouraged more active participation and confidence in expressing ideas. Active learning strategies increase student engagement and improve learners' attitudes toward science lessons compared to traditional lecture-based approaches (Yunzal et al., 2023).

Learners also noted that guidance made difficult tasks easier to understand and that support helped them overcome initial confusion. One participant explained, *“There are also questions which I thought were hard, but with the help, it was actually easy”* (P3). This response highlights the importance of scaffolding, where guided instruction helps students build understanding step by step and reduces frustration and cognitive overload. Structured guidance, combined with active learning, improves comprehension and helps students manage complex concepts more effectively (Yunzal et al., 2023).

Theme 2: Interest and Motivation to Learn More

Cycle 1 activities increased learners' interest and motivation to explore abstract scientific concepts. Many participants expressed curiosity about atomic structures and subatomic particles, noting that the activities helped them visualize concepts that cannot be directly observed. One learner shared, *“The interesting point of view of seeing something that can't be seen in our human eyes inspired me”* (P3), highlighting how visualization and interactive approaches stimulated interest. Exposure to unseen concepts made learning more intriguing and meaningful for students. Meaningful and interactive learning experiences promote curiosity and increase students' interest in science, as learners become more actively involved in understanding complex ideas rather than memorizing information (Rosete & Olua, 2024). This indicates that curiosity emerged naturally when students were encouraged to explore abstract content through engaging activities.

Despite experiencing confusion during the learning process, learners remained motivated to continue learning. One participant stated, *“Yes, I want to learn more about the atomic models because I'm confused”* (P4), suggesting that confusion did not discourage learning but instead encouraged deeper inquiry. This response reflects productive confusion, where uncertainty motivates students to seek understanding. Inquiry-based, student-centered approaches support this process by encouraging questions, exploration, and reflection. When students are actively involved in inquiry and problem-based tasks, their interest and engagement increase even when the content is challenging (Sarsale & Langub, 2023). The desire to learn more despite confusion shows that motivation was sustained throughout Cycle 1.

Theme 3: Improved Conceptual Understanding

Implemented interventions supported learners' improved understanding of atomic models and subatomic particles. Several participants shared that the use of 3D models helped them visualize abstract concepts that are usually difficult to imagine. One participant stated, *“The 3D model activity deepened our understanding of subatomic particles by clarifying differences between models”* (P4). Another learner added, *“I was finally able to determine the difference between the models”* (P5). These statements show that visual representations allowed learners to compare atomic models more clearly and meaningfully. Research supports the claim that concrete and visual learning materials help students form clearer mental images, which leads to a better understanding of abstract scientific ideas (Zheng et al., 2022). When learners can see and manipulate representations, they are more likely to connect ideas and recognize differences between scientific concepts.

In addition to 3D models, the timeline activity helped learners understand the sequence of atomic discoveries. One participant shared, *“The timeline activity made it easy to plot and identify the sequence of discoveries”* (P6). These structured activities helped learners logically organize information and grasp the historical development of science. Research confirms that multimedia and structured tools enhance conceptual understanding by helping students link concepts and events rather than memorizing isolated facts (Kaamiño & Hussien, 2024). By integrating visual models and chronological tools, the Cycle 1 interventions successfully helped learners bridge abstract ideas and scientific reasoning.

Theme 4: Learning Difficulties Encountered

Despite the positive learning experiences and increased interest observed during Cycle 1, several learning difficulties were encountered by the learners. Some participants reported difficulty identifying the states of matter, particularly when activities required them to classify pictures. One participant stated, *“The activity I probably struggled with was identifying the picture whether it was a gas, liquid, or solid”* (P7). This difficulty indicates that foundational concepts were not fully

mastered, highlighting a need for clearer explanations, more examples, and guided practice. When foundational concepts are not adequately reinforced before introducing higher-level tasks, learners often struggle to apply them effectively (Del Mundo & Caballes, 2022).

Learners also struggled to remember scientists' names and correctly match them with their atomic models. One participant shared, "*The only thing that is difficult is memorizing the names of scientists because there are so many*" (P8). This challenge reflects the high cognitive demand of remembering multiple unfamiliar names, models, and concepts, which can cause cognitive overload and hinder retention. High cognitive load often interferes with learning when students are still developing conceptual understanding and organizational strategies (Del Mundo & Caballes, 2022). This explains why learners struggled to remember factual details, like scientists' names, despite being actively engaged.

Another difficulty identified by participants was understanding unfamiliar scientific terms used in questions and instructions. One learner stated, "*There are some difficulties I had, like answering questions for which there are other words I didn't know*" (P1). Limited vocabulary hindered some learners' full understanding of the tasks despite their interest in the lesson. While inquiry-based and student-centered approaches increase curiosity and engagement, learners still struggle if scientific language and key terms are not explicitly taught or scaffolded (Sarsale & Langub, 2023). This highlights that interactive strategies must be paired with clear vocabulary instruction and structured guidance to reduce cognitive load and maximize learning.

Transitioning to Cycle 2 Based on Cycle 1 Findings

While the Cycle 1 findings show that the initial intervention effectively enhanced students' conceptual understanding of subatomic particles, the results also highlighted the need for further refinement to address remaining misconceptions. Guided by these insights, the researchers implemented revised interventions in Cycle 2 to target these gaps and strengthen overall conceptual mastery (see Table 6).

Table 6: Results-Intervention Matrix

Key Findings from Cycle 1	Specific changes/ Improvements Implemented for Cycle 2
Lower quiz scores during Day 1 compared to Day 2	Formative review and guided questioning were added before the Day 1 quiz to reinforce key concepts.
Difficulty identifying states of matter during concept mapping	Real-life physical examples were incorporated during the concept mapping activity to support concrete understanding.
Difficulty remembering scientists and atomic model timelines	Atomic theory timelines were presented as storytelling through an animated YouTube video.
Difficulty understanding and using scientific terms	The Frayer Model was modified to include guided definitions and visual representations.
Increased curiosity about subatomic particles but lingering confusion	Additional enrichment explanations were added during the Elaborate phase to deepen understanding.
Occasional low participation and classroom management concerns	Clear classroom rules and structured group roles were implemented to improve participation and behavior

CYCLE 2 FINDINGS

Following the implementation of the revised VIMCC Approach interventions, Cycle 2 quantitative and qualitative data showed marked improvements in student performance, engagement, and conceptual insights. The results revealed higher quiz and assessment scores alongside increased active participation and more positive student feedback. These findings suggest that the targeted modifications effectively bridged previous learning gaps, maintained student interest, and enhanced overall conceptual understanding.

Formative Assessment Results (Findings for Research Question 1)

As shown in **Table 7**, the Cycle 2 pre-test and post-test results indicate that the enhanced VIMCC interventions further improved students' understanding of subatomic particles. While Cycle 1 demonstrated effective conceptual change, Cycle 2 yielded higher initial and final scores overall. This improvement suggests strong retention of prior learning and confirms that the revised interventions successfully deepened students' conceptual understanding.

The statistical results demonstrate stronger effects in Cycle 2 where the *t*-value slightly increased in magnitude from -4.00 in Cycle 1 to -4.15 in Cycle 2, while the *p*-value decreased from 0.005 to 0.004, indicating a more statistically significant improvement. Moreover, the effect size (Cohen's *d*) increased from -1.41 to -1.47, both of which are interpreted as very large effects, but with Cycle 2 showing a stronger impact.

In addition, Cycle 2 yielded a high normalized gain of **0.79**, indicating that students achieved a significantly larger proportion of their maximum potential learning improvement than in Cycle 1. This substantial gain confirms that the score increases reflect conceptual mastery rather than chance. The consistent growth across mean scores, MPS, statistical significance, effect size, and normalized gain demonstrates that the refined interventions became steadily more effective over time.

Table 7: Cycle 1 and 2 Paired t-test for Pre-test-Post-test Comparison

Cycle	Test	Mean	Mean Percentage Score	t-statistic	df	<i>p</i>	Cohen's <i>d</i>	Normalized Gain Score
1	Pre-test	13.875	69.38	-4.00	7	0.005	-1.41	0.55
	Post-test	17.25	86.25					
2	Pre-test	15.125	75.63	-4.15	7	0.004	-1.47	0.79
	Post-test	19.00	95.00					

The significant improvement in students' test scores across both cycles underscores the VIMCC Approach's potential to effectively enhance conceptual understanding of atomic structure. Because chemistry is inherently abstract, visual representations offer spatial coherence and completeness that help learners process invisible structures more effectively (Bobek & Tversky, 2016). Furthermore, the interactive nature of game-based learning tasks has been shown to boost conceptual retention (Cruz, 2023), while meaning-centered graphic organizers like concept maps and the Frayer model effectively reveal existing knowledge and secure key vocabulary mastery (Ekinci & Şen, 2020; Labajo, 2024; Sacapaño & de Castro, 2022). Collectively, these studies empirically support the positive trends in **Table 7**, confirming the value of the active, visual, and game-based strategies integrated into the VIMCC Approach.

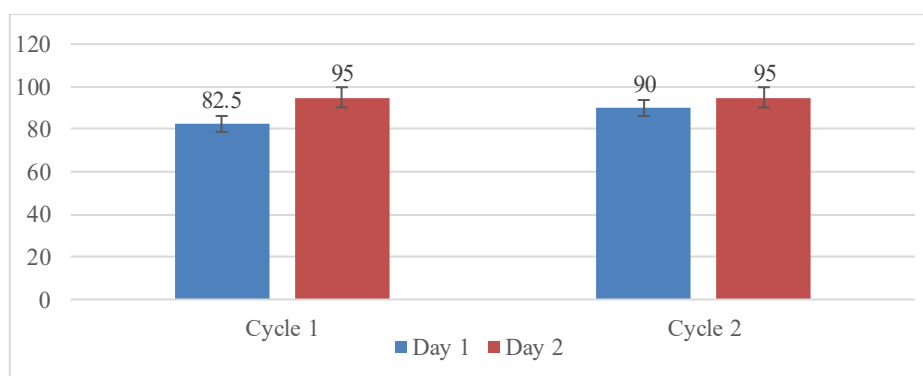


Figure 5: Quiz Mean Score Per Day Comparison of Cycle 1 and 2

In both cycles (see **Figure 5**), quiz scores increased from Day 1 to Day 2, with Cycle 2 maintaining a consistently higher performance baseline of 90%–95%. This sustained performance

indicates improved retention and understanding following the refined VIMCC interventions, culminating in high post-test scores. Overall, the steady progress across both cycles suggests that the daily layout was effective: Day 1 successfully introduced the core concepts, while Day 2 deepened mastery through highly guided and engaging activities.

Participants' Engagement Through SEOC (Findings for Research Question 2)

Cycle 2 SEOC results showed a highly positive shift: Effort and Initiative increased, while Disruptive and Inattentive behaviors dropped or remained low (see **Figure 6**). The increase in Effort and Initiative suggests that clearer conceptual support, explicit terminology scaffolding, and structured activities made students more willing to persist and start tasks independently. Meanwhile, well-defined group roles and clear expectations kept students focused, minimizing Disruptive and Inattentive behaviors. These behavioral improvements demonstrate that the refined VIMCC Approach effectively maintains an environment that fosters a strong understanding of atomic structure.

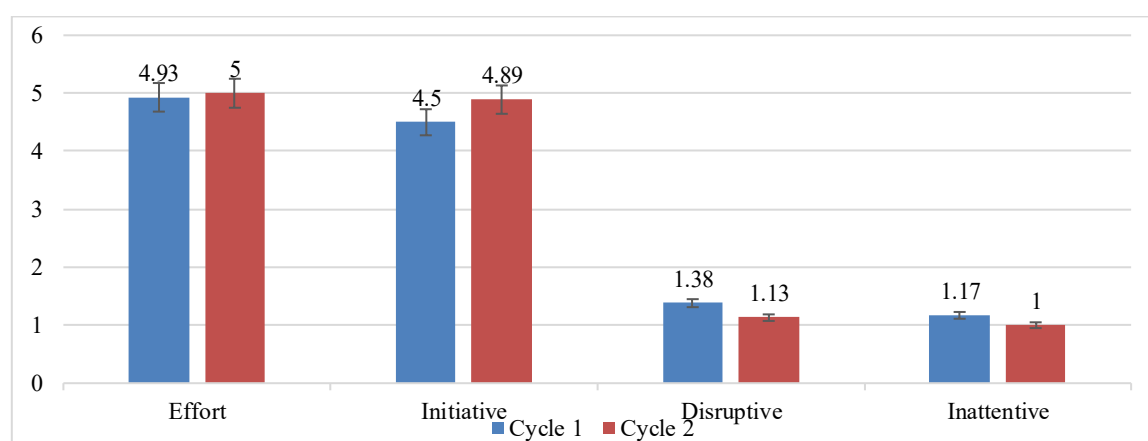


Figure 6: Mean SEOC Results Comparison of Cycle 1 and Cycle 2

This interpretation is consistent with active learning research showing that interactive and student-centered strategies improve student engagement, motivation, and academic outcomes (Alisoy, 2025; Yunzal et al., 2024; Munna & Kalam, 2021). It also aligns with constructivist theory, which emphasizes that learners become more engaged when they actively build knowledge through exploration, interaction, and participation (Zajda, 2021). In addition, Self-Determination Theory explains that when learning supports autonomy, competence, and relatedness, students are more likely to show persistence, attention, and motivation (Ryan & Deci, 2000). Supportive classroom conditions and guided learning may have helped reduce off-task behavior by keeping students focused and involved during instruction (Cebelleros & Buenaventura, 2024). Consequently, clear explanations, structured activities, and improved classroom management in Cycle 2 help learners remain focused during instruction, thereby reducing the likelihood of inattentive and disruptive behaviors.

Students' Insights About the Used Interventions (Findings for Research Question 3)

Theme 1: Increased Engagement and Motivation Toward Learning Atomic Structure

Students found the activities included through the VIMCC Approach as enjoyable and engaging, which encouraged participation and improved focus. One student shared, *"The activities were engaging and fun"* (P1). Another said, *"The activities helped me understand subatomic particles better and made the topic more interesting"* (P2). Several students reported that they participated to deepen their understanding, not merely because the activities were enjoyable (P3, P5). Engagement was driven by both the design of the activities and students' intrinsic motivation. Compared to Cycle 1, Cycle 2 showed increased participation and attention, building on the enjoyable and interactive experiences of the first cycle. Game-based and student-centered strategies increase engagement and

motivation in science learning. A systematic review found that educational games can increase learning motivation and fun, while fostering understanding of chemistry content (Byusa et al., 2022). This finding underscores the importance of optimizing the educational and motivational dimensions of learning activities when studying complex, abstract topics in Chemistry. Furthermore, combining enjoyable activities with curiosity-driven motivation can sustain engagement with complex topics such as atomic structure.

Theme 2: Preference for the Effective Instructional Strategies Used

Students emphasized that the visual and interactive aspects of the VIMCC approach—such as color-coded cards, concept maps, and games—helped them organize ideas, retain concepts, and think critically. One student mentioned, *“The game-based activity helped me think critically and understand the subatomic particles better”* (P4). Another said, *“Color-coded cards helped me understand and remember the differences between the particles”* (P6). Several students noted that these strategies were more effective than traditional teaching methods that rely primarily on slides or lectures (P5, P7). The findings build on Cycle 1, in which visual tools such as 3D models and timelines supported conceptual clarity. Cycle 2 extended these strategies through increased interactivity and gamification. The shift from guided visual tools in Cycle 1 to interactive methods in Cycle 2 shows how scaffolding improves comprehension and critical thinking in science learning.

Theme 3: Improved Conceptual Understanding and Accuracy

Students reported a clearer understanding of subatomic particles, including their roles and locations. One student said, *“At first, I was confused about where electrons are, but after the explanation, I learned that electrons are located in shells outside the nucleus”* (P1). Another shared, *“I now know not only the particles but also the scientists behind each discovery”* (P3). Repeated lessons and scaffolded activities helped students retain information better. They were also more accurate in identifying protons, neutrons, and electrons (P2, P5, P8).

While students in Cycle 1 struggled to memorize names and scientific terms, Cycle 2 demonstrated significant improvements in conceptual clarity and accuracy due to repeated exposure and interactive activities. Active, immersive approaches like gamification heavily enhance conceptual understanding and knowledge retention in science (Al-Muqbali et al., 2026; Tanilong, 2026). This progression underscores that the visual support, interactive learning, and reinforced instruction provided by the VIMCC Approach collectively strengthen learning outcomes, helping students confidently distinguish among protons, neutrons, and electrons.

CONCLUSION AND IMPLICATIONS

This action research demonstrated that improving students’ conceptual understanding of atomic structure enabled them to more effectively distinguish among subatomic particles. The VIMCC approach supported students in developing a clearer and more accurate understanding of how the atom is structured through visual, interactive, and meaning-centered strategies. As a result, students moved beyond memorization and correctly identified the symbols, masses, charges, and locations of protons, neutrons, and electrons. Learners became more confident, participated more actively in class, and showed improved performance in assessments. Misconceptions were reduced as students learned to explain ideas using appropriate scientific terminology and logical connections, thereby making the lessons more meaningful and enjoyable.

The findings suggest that teachers should focus on strengthening students’ basic understanding of atomic concepts before introducing more complex topics. Leveraging visual, interactive, and meaning-centered conceptualization strategies helps make abstract ideas in Chemistry easier to understand and meet learning needs, especially for struggling students. The study supports practical teaching approaches in which students are given opportunities to actively participate in learning and be exposed to effective modes of presenting scientific concepts, while they are facilitated in a learning-focused environment. Teachers are encouraged to reflect on their existing teaching practices and to promote methods that emphasize understanding over memorization to improve students’ engagement, confidence, and overall performance in science.

RECOMMENDATIONS

Based on the findings of this study, science teachers are encouraged to adopt the VIMCC approach and similar learner-centered strategies to improve student understanding of abstract concepts. School leaders should likewise provide professional development opportunities that strengthen teachers' competencies in designing theory-informed interventions, utilizing visual tools, and conducting classroom action research. Furthermore, future researchers are encouraged to replicate this study across different settings, grade levels, and science topics—using larger sample sizes and longer intervention periods—to validate the effectiveness and long-term impact of the VIMCC approach.

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USE OF ARTIFICIAL INTELLIGENCE TOOLS

Artificial Intelligence (AI) tools were used solely to assist with grammar checking, organization, reference formatting, and phrasing suggestions. All research data, findings, and interpretations were derived strictly from classroom observations, pre-tests, post-tests, and focus group discussions. AI was not used to generate data, fabricate results, or replace researcher judgment. The authors assume full responsibility for the accuracy and integrity of the content, having carefully reviewed all AI-assisted outputs to ensure compliance with ethical and copyright standards.

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