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AI-GENERATED SIMULATION – BASED INSTRUCTIONAL MATERIALS IN TEACHING SCIENCE 10

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ABSTRACT

The study employed a mixed-method design, specifically a quasi-experimental pretest-posttest nonequivalent group design, to examine the effects of AI-Generated Simulation – Based Instructional Materials on students' concept mastery and learning engagement in Science. The sample consisted of 30 students from section Luna were divided into two groups. The control group received Standard Classroom Instruction while the experimental group was taught using the AI – Generated Simulations – Based Instructional Materials. Quantitative data were used to assess changes in mastery and engagement, while qualitative data explored students' perceptions of the AI tool. The results revealed that both groups improved in concept mastery and engagement. A statistically significant difference was found in the learning engagement between two groups, favoring the experimental group. However, no significant difference in posttest mean scores was observed, and no significant relationship was found between concept mastery and learning engagement. Qualitative responses showed that students generally perceived the AI-Generated Simulation – Based Instructional Materials as a learning enhance, rather than a distractor. Overall, the AI-Generated Simulation – Based Instructional Materials served as a useful instructional tool that enhanced student engagement and help build conceptual understanding, even though its measurable impact on mastery may require further studies to establish stronger statistical evidence.

Keywords: *science, ai-generated simulation, concept mastery, engagement*

INTRODUCTION

In recent years, technology has significantly transformed how science is taught and learned. One of the most promising innovations is the integration of Artificial Intelligence (AI) in education. Globally, AI tools such as intelligent tutoring systems, adaptive simulations, and virtual laboratories have made learning more interactive and personalized (Holmes et al., 2019; Garzón et al., 2025). In chemistry education, particularly in topics such as chemical reactions, students often find it difficult to develop mental representations of processes occurring at the microscopic level, including atomic and molecular interactions and bond formation and breaking. Previous studies have shown that computer simulations and animations can help address misconceptions and support the learning of abstract chemical concepts (Sanger & Greenbowe, 2000).

While AI-supported learning demonstrates strong potential, its effectiveness largely depends on proper implementation. Holmes et al. (2022) emphasized that AI tools may not perform effectively in real classroom settings when teachers lack adequate training, when resources are limited, or when AI features are not aligned with learners' needs. This suggests that AI alone does not guarantee improved learning outcomes. Instead, appropriate instructional design, sufficient support, and contextual adaptation are necessary to ensure meaningful learning.

In the Philippine context, efforts to integrate technology into education continue to expand. However, many schools, particularly in rural areas, still rely on traditional teaching approaches due to limited internet access, outdated equipment, inadequate facilities, and insufficient training opportunities (Madida et al., 2019). As a result, students often struggle to understand complex chemistry concepts that require visualization and interaction.

Recent local studies highlight the growing interest in the use of AI in Philippine science education, demonstrating its potential to enhance student engagement and emphasizing the need for teacher preparedness in AI integration (Gantalao et al., 2025). However, the practical use of AI tools—particularly adaptive simulations that provide personalized feedback—remains limited in rural public schools. Earlier studies focused primarily on virtual simulations (Pyatt & Sims, 2012; Tatli & Ayas, 2013) without fully examining how AI can simultaneously improve both concept mastery and student engagement, especially in public secondary schools. Moreover, many international studies have been conducted in higher education settings in developed countries (Bazie et al., 2024), resulting in limited empirical evidence from local and rural contexts.

These gaps highlight the need for context-specific studies that examine the effectiveness of AI-based instructional tools in improving both conceptual understanding and learning engagement among secondary school students. Addressing this gap is essential in guiding teachers, school leaders, and policymakers in implementing effective AI-supported science instruction.

Therefore, this study examined the effects of AI-generated simulation-based instructional materials on Grade 10 students' concept mastery and learning engagement in Chemical Reactions at Nan-od National High School. By focusing on a rural public-school setting, the study aimed to provide practical insights into how AI-supported instruction could be implemented effectively to improve science learning outcomes and enhance student engagement in Filipino classrooms.

Research Questions

This study aimed to determine the effects of AI-generated simulation-based instructional materials on students' concept mastery and learning engagement in Science among Grade 10 students at Nan-od National High School during the School Year 2025–2026.

Specifically, it sought to answer the following questions:

1. What are the pretest and posttest scores on students' concept mastery in Chemical Reactions in terms of:
    - 1.1. within groups, and
    - 1.2. between groups?
2. What are the levels of engagement in Science between the control and experimental group?
3. Is there a significant difference in the posttest mean scores of students' concept mastery between the control and experimental groups?
4. Is there a significant difference in the learning engagement of students between the control and experimental groups after the intervention?
5. Is there a significant relationship between students' concept mastery and their learning engagement following the implementation of AI-Generated Simulation?
6. How does AI-Generated Simulation function as a learning enhancer or distractor, as perceived by the students during the classroom implementation?
7. Based on the findings, what Enhanced AI-Generated Simulation – Based Instructional Materials can be developed?

METHODOLOGY

Research Design

This study employed a mixed-method approach using a quasi-experimental pretest–posttest nonequivalent group design with a qualitative descriptive component. The quantitative phase examined the effects of AI-generated simulation-based instructional materials on students' concept mastery and learning engagement, while the qualitative phase explored students' perceptions of its use. Due to the use of an intact Grade 10 class, participants were divided into control and experimental groups. The control group received standard classroom instruction, while the experimental group was exposed to AI-generated simulations with adaptive questioning and feedback.

Both groups took a pretest and posttest to measure concept mastery, while learning engagement was assessed after the intervention through a questionnaire. The independent variable was the instructional method, and the dependent variables were concept mastery and learning engagement, measured using the Science Concept Mastery Test (SCMT) and Student Engagement Questionnaire (SEQ).

Research Environment

The study was conducted at Nan-od National High School in Sierra Bullones, Bohol, one of four public secondary schools in the district offering Junior and Senior High School programs under the K to 12 curriculum. The school serves learners from diverse socioeconomic backgrounds. The site was selected based on the District School Monitoring, Evaluation, and Adjustment (DSMEA) report, which identified the school as having the highest proportion of students rated “Fairly Satisfactory” in proficiency, indicating a need to improve mastery, particularly in Science.

The school has adequate technological resources, including laptops and stable internet access, making it suitable for implementing AI-generated simulations. Its single-section structure and supportive environment also made it appropriate for a quasi-experimental design. This setting provided a relevant context for examining the use of AI-based instructional materials in enhancing students’ concept mastery and learning engagement.

Research Participants

The participants were 30 Grade 10 students from the Luna section at Nan-od National High School during the School Year 2025–2026. Total population sampling was employed, and all students provided signed parental consent and assent.

To ensure comparable groups, students were ranked based on pretest scores and paired accordingly. Each pair was then randomly assigned to either the control or experimental group, resulting in 15 students per group. The control group received standard classroom instruction, while the experimental group was exposed to AI-generated simulation-based instruction.

The sample size is consistent with classroom-based quasi-experimental studies, where 15–30 participants per group are considered sufficient to obtain meaningful results while maintaining class integrity.

Table 1. Distribution of Participants

Group	Number of Participants	Percentage
Control (Traditional lecture-base Instruction)	15	50%
Experimental (AI-generated simulation)	15	50%
Total	30	100%

Research Instrument

The study utilized four instruments: researcher-made lesson plans, the Science Concept Mastery Test (SCMT), the Student Engagement Questionnaire (SEQ), and an open-ended questionnaire to gather both quantitative and qualitative data.

The lesson plans, developed using the 5As instructional model (Activity, Analysis, Abstraction, Application, Assessment), guided the implementation of instruction on Chemical Reactions. These were validated by a panel of experts, including a Science teacher, a school principal, and a District Science Coordinator.

The SCMT was a 30-item multiple-choice test designed to measure students' concept mastery in Chemical Reactions. It was developed based on Grade 10 curriculum competencies and guided by a Table of Specification (TOS). Content validity was established through expert evaluation, yielding a Scale-Level Content Validity Index (S-CVI) of 1.00. Reliability testing using KR-20 resulted in a coefficient of 0.81, indicating good internal consistency. The SCMT was administered as both pre-test and post test.

The SEQ, a 15-item researcher-developed instrument, measured students' cognitive, behavioral, and emotional engagement using a 5-point Likert scale. It was validated by experts with an S-CVI of 1.00 and demonstrated high reliability with a Cronbach's alpha of 0.89. The questionnaire was administered after the intervention to assess students' engagement under each instructional condition.

An open-ended questionnaire was also administered to the experimental group to explore students' perceptions of AI-generated simulations as a learning enhancer or distractor. Responses were analyzed using thematic analysis to identify common patterns.

Collectively, these instruments ensured valid and reliable measurement of concept mastery and learning engagement, providing a comprehensive basis for evaluating the effects of AI-generated simulation-based instruction.

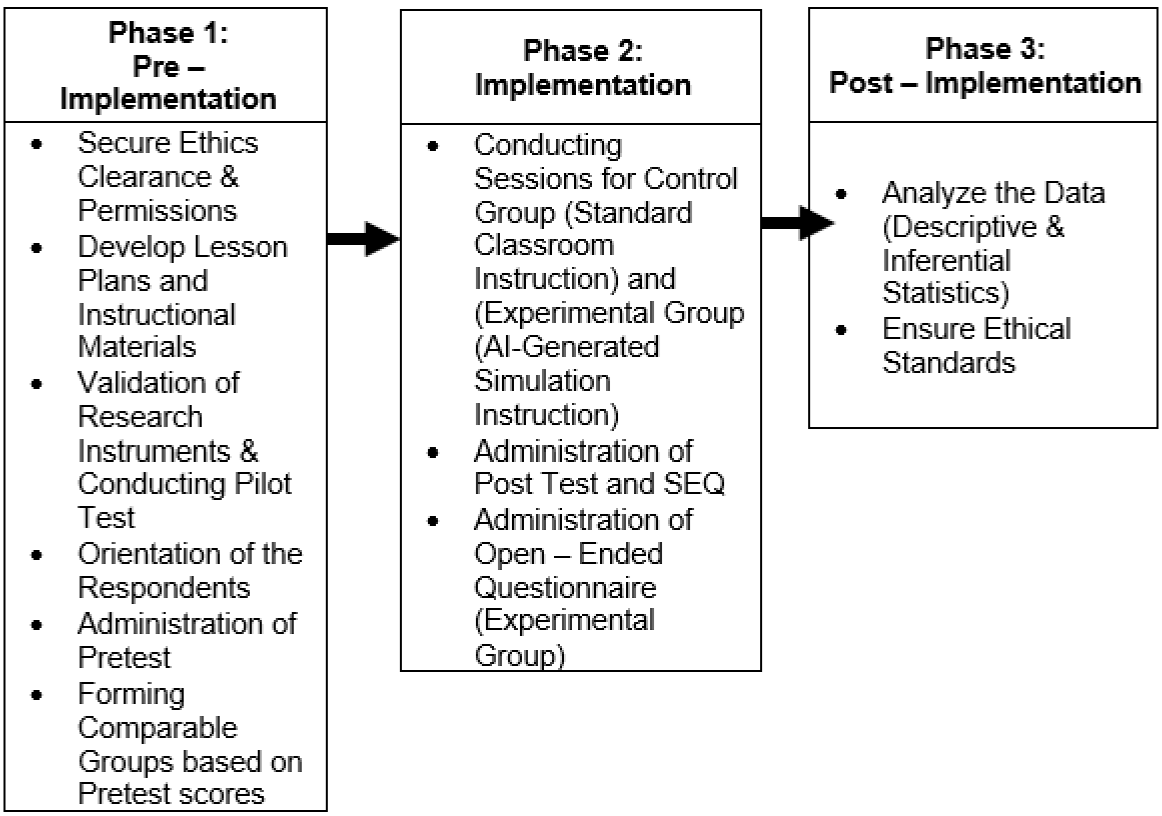
Research Procedure

Data collection followed three phases: pre-implementation, implementation, and post-implementation.

In the pre-implementation phase, ethical clearance was secured from the Holy Name University Ethics Review Board, along with permissions from school authorities and parents. Informed consent and assent were obtained from all participants. Lesson plans and research instruments were prepared, validated by experts, and pilot-tested for reliability. A pre-test was administered, and students were grouped using stratified random assignment based on their scores.

During the implementation phase, both groups underwent a four-week intervention with equal instructional time. The control group received standard classroom instruction using lectures, presentations, and videos, while the experimental group was exposed to AI-generated simulation-based instruction using interactive and adaptive tools. After the intervention, both groups completed the post-test and Student Engagement Questionnaire (SEQ), while the experimental group additionally answered an open-ended questionnaire. Data collection was conducted during class hours under the supervision of the researcher.

In the post-implementation phase, the collected data were encoded and analyzed using Excel and SPSS. Results from both groups were compared to determine the effectiveness of the intervention. To ensure fairness, the control group was later given access to the AI-generated simulations. Ethical standards were strictly observed throughout the study, with voluntary participation and confidentiality maintained.



Research Procedure

Data Analysis

Data were analyzed using Microsoft Excel and SPSS, with a significance level set at 0.05 (Creswell & Creswell, 2017). Results were presented in tabular form with corresponding interpretations.

Descriptive statistics (mean and standard deviation) were used to summarize students' concept mastery and learning engagement. Mean scores described average performance, while standard deviation measured score variability within groups.

An independent samples t-test was employed to determine significant differences in posttest scores of concept mastery and learning engagement between the control and experimental groups. The computed p-values were compared against the 0.05 level of significance to test the hypotheses.

To examine the relationship between concept mastery and learning engagement, Spearman's rank-order correlation (rho) was used. This nonparametric test determined the strength and direction of association between the two variables.

For the qualitative data, responses from the open-ended questionnaire were analyzed using thematic analysis (Braun & Clarke, 2006). Responses were coded, grouped into themes, and interpreted based on frequency patterns (Miles et al., 2014).

Quantitative and qualitative findings were integrated to inform the development of the proposed Work Action Plan.

RESULTS

This section presents, analyzes, and interprets the quantitative and qualitative data collected using the research instruments to determine students' concept mastery and learning engagement in Science 10, as well as their perceptions of AI-generated simulation-based instructional materials in learning Chemical Reactions and Collision Theory. The presentation is organized into four parts: (1) students' concept mastery, (2) students' learning engagement, (3) the relationship between concept mastery and learning engagement, and (4) students' perceptions of AI-generated simulation-based instruction.

Table 2. Pretest and Posttest Results Within and Between Groups

Performance Level	Percentage Equivalent	Score Range (30 points)	Control Group				Experimental Group			
			Pre-test		Post-test		Pre-test		Post-test	
			Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Advanced	90–100	27–30		-	2	13%		-	4	27%
Proficient	85–89	25–26		-	1	7%		-	3	20%
Approaching Proficiency	80–84	24		-	-	-		-	1	7%
Developing	75–79	18–23	1	7%	1	7%	2	13%	2	13%
Beginning	Below 75	0–17	14	93%	11	73%	13	87%	5	33%
Total			15	100%	15	100%			15	100%
			Mean: 70	SD: 0.72	Mean: 76	SD:2.75	Mean: 71	SD: 0.80	Mean: 82	SD: 2.75
Description			Beginning		Developing		Beginning		Approaching Proficiency	

Table 2 presents the pretest and posttest results on students' concept mastery in both the Standard Classroom Instruction (control group) and AI-Generated Simulation (experimental group).

For the control group, the pretest results indicate that students started with very low concept mastery, with 93% classified under the Beginning level and a mean score of 70. The low standard deviation (SD = 0.72) suggests that students had similarly limited prior knowledge. After the implementation of standard classroom instruction, there was a slight improvement, as reflected in the increase of the mean score to 76 (Developing level). However, the majority of students (73%) remained in the Beginning category, indicating that the improvement was not substantial. The increase in variability (SD = 2.75) suggests uneven learning gains among students, where only a few demonstrated notable progress. This implies that while traditional instruction contributed to minimal improvement, it was insufficient to significantly elevate overall concept mastery.

In contrast, the experimental group also began with low baseline performance, with 87% of students classified under the Beginning level and a mean score of 71. However, after exposure to AI-generated simulation, a more pronounced improvement was observed. The mean score increased to 82, corresponding to the Approaching Proficiency level. Notably, a considerable number of students advanced to higher proficiency levels, with 27% reaching Advanced and 20% achieving Proficient levels. Although some students remained in the lower categories, the reduction in those classified under Beginning (from 87% to 33%) indicates a substantial shift in learning outcomes. The increased standard deviation (SD = 2.75) further reflects differentiated gains, with several students benefiting significantly from the intervention.

The observed improvement in the experimental group may be attributed to the use of interactive and visual simulations, which help learners better understand abstract scientific concepts. This finding is supported by the study of Sanger and Greenbowe (2000), which found that computer simulations effectively enhance students' understanding of chemical processes by addressing misconceptions and promoting visualization of microscopic interactions. Similarly, Garzón et al. (2020) reported that simulation-based learning significantly improves academic performance and conceptual understanding, particularly in science education, due to its interactive and student-centered nature.

Overall, while both groups showed improvement, the shift from Beginning to Approaching Proficiency in the experimental group demonstrates that AI-generated simulation is more effective than standard classroom instruction in enhancing students' concept mastery in Science.

Students' Learning Engagement

The Students' Learning Engagement was measured after the intervention period to determine its level under each instructional condition (Standard Classroom Instruction and AI – Generated Simulation).

Table 3. Distribution of Students' Engagement Levels Within and Between Groups

Numerical Value	Descriptive Equivalent	Control Group		Experimental Group	
		Frequency	Percentage	Frequency	Percentage
4.21–5.00	Very High Engagement	3	20%	13	87%
3.41–4.20	High Engagement	10	66%	2	13%
2.61–3.40	Moderate Engagement	1	7%		-
1.81–2.60	Low Engagement	1	7%		-
1.00–1.80	Very Low Engagement		-		-
	Total	15	100%	15	100%
	Mean	3.86	High Engagement	4.37	Very High Engagement

Table 3 shows that the control group obtained a mean engagement score of 3.86, interpreted as High Engagement. The majority of students (66%) were classified under high engagement, while 20% reached very high engagement. However, a small proportion of students fell under moderate (7%) and low (7%) engagement levels, indicating some variability in participation and involvement during standard classroom instruction.

In contrast, the experimental group demonstrated a higher mean score of 4.37, corresponding to Very High Engagement. A substantial majority of students (87%) were categorized under very high engagement, while the remaining 13% were under high engagement. Notably, no students were classified under moderate or low engagement levels, suggesting a more consistent and sustained level of engagement among learners exposed to AI-generated simulation.

The higher mean score and the concentration of responses in the very high engagement category indicate that AI-generated simulation was more effective in promoting student engagement compared to standard classroom instruction. The interactive and visual nature of simulations likely enhanced students' behavioral participation, cognitive involvement, and emotional interest during the learning process.

This finding is consistent with the engagement framework of Fredricks et al. (2004), which emphasizes that meaningful learning occurs when students are cognitively, behaviorally, and emotionally involved in classroom activities. Similarly, Bond et al. (2020) found that technology-enhanced learning environments significantly increase student engagement by promoting active participation, interactivity, and sustained attention.

Overall, the results suggest that AI-generated simulation creates a more engaging learning environment, leading to more uniform and higher levels of student engagement.

Table 4. Difference in the Post-test Mean Scores of Students' Concept Mastery between the Control and Experimental Groups

Variables	Mean$\pm SD$	Mean Difference	Computed t-value	P-value	Decision on Ho	Interpretation
Control Group:	76 ± 2.75	5.0	1.45	0.08	Accept Ho	Not Significant
Experimental Group:	82 ± 2.75					

Table 4 presents the comparison of posttest mean scores between the control and experimental groups. The experimental group obtained a higher mean score (M = 82, SD = 2.75) compared to the control group (M = 76, SD = 2.75), with a mean difference of 5.0. This indicates that students exposed to AI-generated simulation demonstrated better academic performance and higher concept mastery than those who received standard classroom instruction.

The identical standard deviations (SD = 2.75) suggest that both groups had similar variability in performance. This implies that the improvement observed in the experimental group was relatively consistent across students and did not disproportionately benefit only high-performing learners. Instead, the intervention appears to have supported a more uniform improvement in concept mastery.

However, the computed t-value (t = 1.45) yielded a p-value of 0.08, which is greater than the 0.05 level of significance. Thus, the null hypothesis was accepted, indicating that the difference in posttest mean scores between the two groups was not statistically significant. Although the experimental group performed better numerically, the difference was not sufficient to establish statistical significance. This result may be attributed to factors such as the small sample size, limited duration of the intervention, and natural variability among learners.

Despite the lack of statistical significance, the observed mean difference suggests practical or educational significance. In classroom settings, even modest improvements in mean performance may reflect meaningful gains in learning. This finding aligns with the study of Garzón et al. (2020), which reported that simulation-based learning environments can enhance students' understanding and performance, even when statistical differences are not always significant. Similarly, Rutten et al. (2012) found that computer simulations in science education improve conceptual understanding and support learning gains, particularly when used as a supplement to traditional instruction.

Overall, the results suggest that AI-generated simulation serves as an effective enhancement tool that can support concept mastery, although it may not fully replace standard classroom instruction.

Table 5. Significant Difference in Learning Engagement Between Groups

Variables	Mean$\pm SD$	Computed t-value	P-value	Decision on Ho	Interpretation
Control Group:	3.86±0.08	6.38	0.001	Reject Ho	Significant
Experimental Group:	4.37±0.06				

Table 5 presents the difference in students' learning engagement between the control and experimental groups after the intervention. The experimental group obtained a higher mean engagement score (M = 4.37, SD = 0.06) compared to the control group (M = 3.86, SD = 0.08). The low standard deviations in both groups indicate consistent responses; however, the higher mean in the experimental group suggests that AI-generated simulation more effectively enhanced students' engagement.

The independent samples t-test confirmed that this difference was statistically significant (t = 6.38, p = 0.001), which is lower than the 0.05 level of significance. Thus, the null hypothesis was rejected, indicating that the AI-generated simulation had a significant positive effect on students' learning engagement compared to standard classroom instruction.

This finding implies that the interactive, visual, and adaptive features of AI-generated simulation promoted higher levels of behavioral participation, cognitive involvement, and emotional interest among students. Such environments encourage active learning and sustained attention, which are essential components of effective engagement.

The result is supported by the study of Bond et al. (2020), which found that technology-enhanced learning environments significantly increase student engagement through interactivity and active participation. Similarly, Gligorea et al. (2023) reported that AI-based instructional tools improve student engagement by providing immediate feedback, personalized learning experiences, and interactive content. Overall, the findings confirm that AI-generated simulation is highly effective in promoting students' learning engagement and serves as a valuable instructional enhancement in science education.

Table 6. Significant Relationship Between Students' Concept Mastery and Learning Engagement in the Experimental Group

Variables	Computed Spearman Rho	P-value	Decision on Ho	Interpretation
Mastery concept & Learning engagement	-0.179	0.51	Accept Ho	Very small negative relationship, Not Significant

Table 6 presents the relationship between students' concept mastery and learning engagement in the experimental group. The computed Spearman's rho (ρ = −0.179) indicates a very small negative relationship between the two variables. This suggests that variations in learning engagement were not meaningfully associated with changes in concept mastery, and the relationship is negligible in practical terms.

Furthermore, the p-value (p = 0.51) is greater than the 0.05 level of significance, leading to the acceptance of the null hypothesis. This indicates that there is no statistically significant relationship between students' concept mastery and learning engagement following the implementation of AI-generated simulation. In effect, higher engagement did not necessarily result in higher conceptual understanding among the students.

This finding implies that while AI-generated simulation effectively increased students' engagement, engagement alone may not be sufficient to significantly influence learning outcomes. Concept mastery may depend on other factors such as instructional design, prior knowledge, cognitive processing, and teacher facilitation.

The result is consistent with the findings of Lei et al. (2018), who reported that the relationship between student engagement and academic achievement is often small to moderate, indicating that engagement is only one of several contributing factors to learning outcomes. Similarly, Henrie et al. (2015) found that in technology-mediated environments, increased engagement does not always translate into improved academic performance, as learning is influenced by multiple interacting variables. Overall, the findings suggest that AI-generated simulation enhances engagement, but additional instructional supports are necessary to achieve significant improvements in concept mastery.

Table 7. Summary of Students' Perception towards AI – Generated Simulation – Based Instructional Materials

Theme	Keycodes	Sample Responses
Visualizing Abstract Concepts Improves Understanding	Visual learning, Immediate feedback	*R10 "Example, katong collision theory nay gipakita nga video or visuals bato mas dali ko kasabot adto tungod sa movements where if ang heat mo increase mas paspas ang collision."* *R6 "And kung mali ko kay mo red man siya ug correct pd mo green siya. Makabalo rako nga namali diay ko or nasakto."*
Enhanced Emotional Engagement and Intrinsic Motivation	Enjoyment, Excitement,	*R1"Every lesson is entertaining for me because you cannot expect what's next and that makes it more interesting and fun"* *R10 "By making me interested and excited kay mas dali ko maka sabot if murag entertaining ang datingan."*

Support for Independent Learning	Self-paced review, Easier understanding	*R10 "Nakatabang pd ang AI -Generated Simulation kay kung dili ka kasabot pwedi nimo ibalik sa laing page aron maka basa balik."* *R3"AI help me understand tungod sa iyang gi provide nga mga notes."*
Language Barrier to Full Comprehension	Low Comprehension, English Difficulty	*R5 "Dili ako maka sabot sa lesson."* *R1 "Mas prefer nako ang standard teaching kay magbisaya si maam nig explain, magsuwat sa board."*
Adaptability to Minor Technical Difficulties	Copy-paste difficulty, Adaptation	*R3 "When copy pasting the link."* *R1 "At first (referring to difficulty in navigating the simulation), but eventually its easier. It even helps me to engage more on the discussion or topic."*
Balanced View Between AI and Traditional Teaching	Value of teacher explanation	*R10 "If the topic is solving equations for example balancing equation on chemical reaction it is better if it is standard teaching."*

Theme 1: Visualizing Abstract Concepts Improves Understanding. Students reported that the AI-generated simulation improved their understanding of abstract scientific concepts. Students highlighted that simulation and animations helped them visualize microscopic processes that are usually difficult to imagine through Standard teaching alone. One student (R10) stated that "*Example, katong collision theory nay gipakita nga video or visuals bato mas dali ko kasabot adto tungod sa movements where if ang heat mo increase mas paspas ang collision.*" And another student (R6) said, "*Dali rako maka sabot adtong chemical change kay nay picture/ animation and then makit an pod nimo ang ilahang pag change of color.*" Here, students noted that by observing particle collisions and molecular movement through animation representations helped deeper understanding.

The real-time feedback feature also strengthened learning, student (R6) added that "*And kung mali ko kay mo red man siya ug correct pd mo green siya. Makabalo rako nga namali diay ko or nasakto.*"

The findings suggest that visual representations and interactive feedback enhanced students' cognitive engagement, particularly in understanding abstract concepts such as collision theory and reaction mechanisms. According to Reeve (2013), cognitive engagement refers students being committed to learn by actively using ones thinking skills to analyze, solve problems, and deeply process information. The result also aligned with multimedia learning principles, which propose that combining visual and interactive elements enhances comprehension of abstract scientific phenomena (Mayer, 2009).

Theme 2: Enhanced Emotional Engagement and Intrinsic Motivation. Students described the experience as enjoyable and motivating. Some stated as follows; (R1) "*Every lesson is entertaining for me because you cannot expect what's next and that makes it more interesting and fun*." And another student (R12) said; "*It helps me to easily understand. I am excited to answer."* The dynamic and interactive nature of the simulation captured students' attention and reduced boredom, as reflected in the answer of student (R10) "By making me interested and excited kay mas dali ko maka sabot if murag entertaining ang datingan."

These responses reflect strong emotional engagement, consisted with Fredricks et al. (2004), who describe it as students expressed enjoyment, interest, and excitement during the lesson. Reeve (2013) further explained that learning environments that support autonomy and curiosity enhance students' intrinsic motivation. The findings indicate that AI-Generated Simulations can create emotionally supportive learning environments that would result to a positive attitude towards Science learning.

Theme 3: Support for Independent and Self-Regulated Learning. Students appreciated the ability to review content and materials repeatedly and learn at their own pace using the AI-Generated Simulation. These were the few statements of the students; (R7) "*Nakatabang pd ang AI -Generated Simulation kay kung dili ka kasabot pwedi nimo ibalik sa laing page aron maka basa balik*." And student (R3) added that "*AI help me understand tungod sa iyang gi provide nga mga notes*." With this, students experienced revisiting, explanations and trying again tasks when they find it hard, showing students autonomy and persistence to learn.

This theme reflects increased cognitive and behavioral engagement, as students demonstrated effort, persistence, and strategic learning behaviors. Reeve (2013) emphasized that autonomy – supportive learning environments encourage self – regulated learning behaviors, allowing students to take greater responsibility for their learning process. The AI – Generated Simulation's self – paced structure appears to have supported this engagement.

Theme 4: Language Barrier to Full Comprehension. Despite of the positive feedback, a strong counter – theme involved difficulty in understanding English instructions and discussion. Respondents expressed confusion due to unfamiliar words and limited comprehension as reflected in statements such as (R5) "*Dili ako maka sabot sa lesson.*", and (R13) "*Mas prefer nako ang standard teaching kay magbisaya si maam nig explain, magsuwat sa board.*" These responses suggest that students feel more comfortable when instruction is delivered in the students' mother tongue language, indicating that language proficiency plays a crucial role in comprehension and engagement. And that may also affect the students' posttest result.

Research supports this finding by showing that English language proficiency strongly influences academic performance and comprehension. Escala et al. (2025) found that students with higher English proficiency achieved better academic outcomes than those with limited proficiency, suggesting that learners who struggle with English may also struggle to benefit fully from AI-generated simulations delivered in English. In addition, Yulianti et al. (2025) study reveals that unfamiliar words and complex language structures serve as major barriers to comprehension among English as a Foreign Language (EFL) learners. Overall, these studies confirm that language proficiency meaningfully affects students' understanding, engagement, and learning outcomes in AI-supported instructional environments.

Theme 5: Adaptability to Minor Technical Difficulties. Students reported technical difficulties. These were difficulty "*When copy pasting the link.*" According to R3, occasional Wi-Fi problems (R6) and initial navigation confusion as reflected in the answer of R2. However, students indicated that these issues were temporary and manageable as stated by R1 "*At first (referring to difficulty in navigating the simulation), but eventually its easier. It even helps me to engage more on the discussion or topic.*" Also student (R8) said that "*It has arrow where you can follow and you go all the way.*" These responses reflected that AI-generated simulation did not noticeably hinder engagement, suggesting that the technological design was generally user-friendly. Previous technology integration studies indicate that minor technical barriers are common during digital learning implementation but do not necessarily reduce engagement when instructional design remains clear and accessible (Hew & Cheung, 2014).

Theme 6: Balanced View Between AI and Traditional Teaching. While students preferred the AI simulation, there are students who emphasized the importance of teacher continuously explaining. As stated as follows; (R11) "*It is better if teacher teaching you in person*." And another student (R10) said that "*If the topic is solving equations for example balancing equation on chemical reaction it is better if it is standard teaching*." This indicates that while AI – Generated Simulation enhances engagement, teacher guidance remains essential to students particularly for procedural problem-solving tasks.

This finding highlights the complementary role of technology and teacher as facilitator. Reeve (2013) said that effective engagement occurs when instructional tools support and not replace teacher. Likewise, Fredericks et al., (2004) emphasized that engagement develops through structured instructional support combined with meaningful learning activities. Thus, the results emphasized that AI – Generated Simulation function best as supportive tool that enhance rather than replace teacher instruction. A combination of technology and teacher guidance is important to help students stay engaged and learn better.

Overall, the findings align with the three dimensions of student engagement; Cognitive Engagement which focus on deeper understanding, strategic effort, Behavioral Engagement refers to participation, persistence, task completion, and emotional Engagement which focus enjoyment, interest, and excitement. The AI-Generated Simulation appeared to positively influence all these three dimensions, supporting the quantitative findings of increased engagement in the experimental group.

Students' responses reveal that the AI-generated simulation enhanced their engagement and understanding of Chemical Reactions. Visual animations, interactive feedback, and self-paced features contributed to increased motivation and conceptual clarity. Although minor technical challenges were reported, students expressed overwhelmingly positive experiences. These findings suggest that AI-Generated Simulation is an effective supplementary instructional strategy in Science 10.

DISCUSSION

This study aimed to determine the effects of AI-Generated Simulation on students' concept mastery and learning engagement in Science 10. Quantitative data from the SCMT and SEQ, along with qualitative responses, were used to analyze students' performance, engagement levels, and perceptions. The discussion focused on comparing pretest and posttest results within and between groups, determining differences in concept mastery and engagement after the intervention, and examining the relationship between these variables. Students' perceptions were also explored to determine whether AI-generated simulation functioned as a learning enhancer or a distractor.

The findings provided the basis for developing enhanced AI-generated simulation-based instructional materials.

Findings

Based on the analyses conducted, the following are the salient findings of the study.

1. In the standard classroom instruction, most students began with low concept mastery and showed only slight improvement after the lessons. While a there were few advanced to higher proficiency, the majority remained at the beginning level. It indicates that the gains were not enough to significantly raise the overall mastery. On the other hand, the group which are taught with the AI-Generated simulation also started with low mastery but demonstrated more meaningful improvement. The respondents' average performance increased to a level closer to proficiency, with a notable portion of students reaching advanced and proficient categories. Although some still remained at lower levels, the overall shift suggests that the AI-Generated simulation was more effective in enhancing concept mastery compared to standard classroom instruction.

2. In the standard classroom instruction, students generally showed high engagement, with most of the students demonstrate high engagement and a smaller portion of the group had classified themselves in very high engagement level. However, some displayed moderate or low engagement, indicating variability in how students participated. However, the group which are taught using AI-generated simulation exhibited consistently high engagement. The majority reached very high levels of engagement, while the rest maintained high engagement. Notably, no students fell into moderate or low categories, highlighting

the effectiveness of the simulation in showing sustained and uniform engagement among learners.

3. There is no significant difference in the posttest mean scores of students' concept mastery between the control and experimental groups indicating that the observed difference in posttest mean scores between the two groups was not statistically significant.

4. There a significant difference in the learning engagement of students between the control and experimental groups after the intervention. This indicates that the AI-Generated Simulation significantly improved students' learning engagement compared to Standard Classroom Instruction.

5. There is no significant relationship between students' concept mastery and their learning engagement following the implementation of AI-Generated Simulation. This suggests that although the intervention increased engagement, engagement alone was not a significant predictor of students' conceptual mastery.

6. The qualitative findings revealed that students generally perceived the AI-Generated Simulation as a learning enhancer rather than a distractor. Students reported that visual animations and real-time feedback improved their understanding of abstract concepts, increased emotional engagement and motivation, and supported independent and self-regulated learning. Although some students experienced language barriers and minor technical problems, these challenges were manageable. Moreover, many emphasized that teacher guidance remained important; thus, suggesting that the AI-Generated Simulation functioned best as a supportive instructional tool that enhanced, rather than replaced, standard teaching.

Conclusions

The findings of this study show that AI – Generated Simulation – Based Instructional Materials significantly enhanced students' learning engagement and led to noticeable improvement in concept mastery compared to Standard Classroom Instruction, although the difference in mastery was not statistically significant. The students using simulation showed a consistent high engagement however this increased engagement did not significantly relate to the students' concept mastery. Moreover, qualitative responses further reinforced the positive effect of AI – Generated Simulation, as students perceived it as learning enhancer that complemented teacher guidance through visual animations and real – time feedback. Overall, the AI-Generated Simulation served as a useful instructional tool that enhanced student engagement and help build conceptual understanding, even though its measurable impact on mastery may require further studies to establish stronger statistical evidence.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are proposed:

1. Teachers are encouraged to integrate AI-generated simulation-based instructional materials as a supplementary tool to enhance students' learning engagement, while ensuring that instructional guidance remains central in the teaching process.
2. Given that teacher support remains essential, educators should provide structured scaffolding, clear explanations, and timely feedback to maximize the effectiveness of AI-generated simulations in facilitating conceptual understanding.
3. Developers and educators may improve AI-generated simulation materials by incorporating clearer language, localized content, and more user-friendly interactive features to address minor challenges such as comprehension difficulties and technical limitations.
4. Future researchers are encouraged to replicate the study using larger samples and varied educational contexts, and to explore additional variables that may influence concept mastery beyond learning engagement.

Proposed Enhanced AI-Generated Simulation–Based Instructional Materials

Rationale

The findings of the study revealed that AI-generated simulation significantly improved students' learning engagement and showed potential in enhancing concept mastery. However, results also indicated that teacher guidance remains essential, and minor challenges such as language barriers and technical limitations were encountered. Hence, there is a need to develop enhanced AI-generated simulation–based instructional materials that are more structured, accessible, and responsive to students' learning needs. These materials aim to support both engagement and deeper conceptual understanding while complementing, rather than replacing, teacher-led instruction.

Objectives

This enhancement program aims to:

1. Improve students' concept mastery in Science 10, particularly in Chemical Reactions.
2. Sustain and further increase students' cognitive, behavioral, and emotional engagement.
3. Provide clearer, more contextualized, and learner-friendly AI-generated simulations.
4. Strengthen the integration of teacher guidance in simulation-based instruction.
5. Address identified challenges such as language clarity and technical usability.

Mechanics of Implementation

The enhanced instructional materials will be integrated into regular Science 10 classes through a structured approach. Teachers will utilize AI-generated simulations during key lesson phases, particularly in concept introduction, visualization, and application. Each simulation will include guided instructions, simplified language, and interactive elements such as adaptive questioning and immediate feedback.

Teachers will facilitate the learning process by providing explanations, scaffolding activities, and follow-up discussions to reinforce understanding. The materials will be designed using accessible platforms (e.g., Canva AI or similar tools) and will be aligned with curriculum competencies. Prior to implementation, teachers may undergo orientation or training on the effective use of AI-based instructional tools.

Schedule of Implementation

Phase	Activities	Time Frame
Preparation	Development and refinement of enhanced materials; teacher orientation/training	2 weeks
Implementation	Integration of AI-generated simulations in Science 10 lessons	4–6 weeks
Evaluation	Administration of assessments and collection of feedback	1 week
Revision	Improvement of materials based on evaluation results	1–2 weeks

Monitoring and Evaluation System

The effectiveness of the enhanced materials will be monitored through both quantitative and qualitative measures. Students' concept mastery will be assessed using pretest and posttest results, while engagement levels will be measured through a standardized questionnaire. Additionally, feedback from students and teachers will be gathered through open-ended responses and informal reflections to identify strengths and areas for improvement. Data will be analyzed periodically to determine the effectiveness of the materials and guide further refinement. Continuous monitoring will ensure that the instructional materials remain relevant, effective, and aligned with learners' needs.

Compliance with Ethical Standards

This study strictly adhered to established ethical standards in the conduct of educational research. Prior to data collection, ethical clearance was secured from the Holy Name University Ethics Review Board. Permission to conduct the study was also obtained from the school authorities, including the district supervisor and school principal. Participation of the students was voluntary. Informed consent was obtained from parents or guardians, and assent was secured from the student-participants after explaining the purpose, procedures, and potential benefits of the study. Participants were assured that their involvement would not affect their academic standing and that they could withdraw at any time without penalty. Confidentiality and anonymity were strictly maintained throughout the study. Students' identities were protected through the use of code identifiers instead of names, and all collected data were used solely for research purposes. The results were reported in aggregate form to prevent identification of individual participants. Furthermore, the study ensured fairness and equity by providing the control group access to the AI-generated simulation after the intervention. All data were securely stored and handled in accordance with ethical guidelines, ensuring the protection of participants' rights and well-being.

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