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Improving Conceptual Understanding of the Endocrine System: The Role of Animation and Simulations for Grade 10 Learners

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ABSTRACT

This study assessed changes in Grade 10 learners' conceptual understanding of the endocrine system following instruction integrating animations and simulations and used the findings to inform lesson plan enhancement. Employing a quantitative, one-group pretest–posttest quasi-experimental design, the study involved 30 purposively selected learners at Cangawa National High School, Buenavista, Bohol, during School Year 2025–2026. Adapted, expert-validated instruments assessed five endocrine competencies and learners' perceptions of instructional usability and engagement; descriptive statistics and t-tests were used for analysis. Pretest understanding was low in hormone action and very low in feedback mechanisms, specific glands and hormones, regulation and homeostasis, and endocrine disorders. Posttest scores increased significantly across all five competencies (all $p < .001$), including hormone action ($M = 2.20$ to 8.67) and specific glands and hormones ($M = 0.67$ to 6.93). Learners also rated the instructional materials highly for usability and engagement (overall $M = 4.60$). These findings indicate that the instructional sequence was associated with improved conceptual understanding and favorable learner experiences. The study recommends incorporating guided animations, interactive simulations, and targeted formative assessments into an enhanced Grade 10 Science lesson plan, supported by teacher development and appropriate digital resources. Its small, single-school sample and absence of a comparison group limit generalizability and causal inference. The findings provide locally grounded evidence for technology-supported Biology instruction and educational sustainability, contributing to Sustainable Development Goal 4 (Quality Education) through improved opportunities for conceptual learning.

Keywords: *Animation-Based Instruction, Biology Education, Conceptual Understanding, Endocrine System, Interactive Simulations, Lesson Plan Enhancement*

1. INTRODUCTION

The endocrine system is an essential component of Biology that regulates growth, metabolism, reproduction, and homeostasis through coordinated hormonal activities. However, learners often encounter difficulties understanding endocrine processes because hormonal interactions, feedback mechanisms, and physiological regulation cannot be directly observed. Research on conceptual change in Biology emphasizes the persistence of misconceptions and the importance of instructional interventions that develop coherent scientific understanding (Aleknavičiūtė et al., 2023). Animations and simulations offer opportunities to visualize abstract biological processes and engage learners through interactive representations. Bouali et al. (2022) demonstrated improved achievement through animation-supported Biology instruction, while Almasri (2022) identified positive learner engagement and satisfaction associated with science simulations. Similarly, Sritha et al. (2023) reported improved scientific conceptions of the endocrine system through interactive learning activities. In response to these findings, the present study examined the use of animations and simulations to improve Grade 10 learners' conceptual understanding of the endocrine system at Cangawa National High School, Buenavista, Bohol, during School Year 2025–2026. The findings served as the basis for enhancing the Science lesson plan.

Research Problem

Understanding the endocrine system requires learners to connect the functions of glands, hormones, feedback mechanisms, homeostasis, and endocrine disorders. These interconnected processes present instructional challenges because learners must interpret dynamic physiological relationships rather than memorize isolated concepts. Aleknavičiūtė et al. (2023) emphasized that misconceptions and fragmented prior knowledge can hinder conceptual understanding in Biology. Similarly, Eviota et al. (2026) identified learning difficulties involving homeostasis and feedback mechanisms among Filipino learners, highlighting the need for interactive instructional resources. Research suggests that animations and simulations may address these difficulties by providing visual and interactive learning experiences. Mou (2023) reported positive learner attitudes and improved understanding through animation-supported science instruction, while Wu et al. (2024) examined the effectiveness of simulation-based approaches in endocrinology education. However, evidence from these settings does not automatically establish effectiveness among Grade 10 learners at Cangawa National High School. Therefore, the study sought to determine learners' initial conceptual understanding, examine changes in pretest and posttest performance following animation- and simulation-supported instruction, assess perceptions of usability and engagement, and develop an enhanced lesson plan addressing identified learning difficulties.

Assumptions of the Study

The study was guided by the premise that learners' conceptual understanding of the endocrine system could be assessed through their knowledge of hormone action, feedback mechanisms, specific glands and hormones, regulation and homeostasis, and endocrine disorders. It further recognized that animations and simulations could provide instructional opportunities for visualizing complex biological processes and supporting active learning. These premises are consistent with multimedia learning principles emphasizing coordinated visual and verbal representations (Mayer, 2024) and research on interactive instructional approaches (Adeyele, 2024). The study did not presume that the intervention would necessarily improve conceptual understanding. Instead, it tested the null hypothesis that no significant difference existed between learners' pretest and posttest scores following the integration of animations and simulations, using a 0.05 significance level.

Objectives of the Study

The primary objective of the study was to assess the effectiveness of animations and simulations as instructional tools for improving Grade 10 learners' conceptual understanding of the endocrine system at Cangawa National High School, Buenavista, Bohol, during School Year 2025–2026. Specifically, it aimed to determine learners' initial understanding of hormone action, feedback mechanisms, specific glands and hormones, regulation and homeostasis, and endocrine disorders; establish whether a significant difference existed between their pretest and posttest performance following the instructional intervention; assess learners' perceptions of the usability and engagement of integrated animations and simulations; and develop an enhanced lesson plan based on the findings.

Theoretical or Conceptual Basis

The study was anchored in the Cognitive Theory of Multimedia Learning, Cognitive Load Theory, and Constructivist Learning Theory. Mayer (2024) explained that meaningful multimedia learning involves processing visual and verbal information through separate but interconnected cognitive channels. This provides a basis for using animations to represent endocrine processes that are difficult to observe directly. Cognitive Load Theory further emphasizes the importance of organizing instructional materials to manage learners' limited working-memory capacity. Aalioui et al. (2022) examined cognitive load in physiology video instruction, highlighting the relevance of instructional presentation and design to learning. Constructivist principles support active knowledge construction through interaction and exploration, consistent with Adeyele (2024), who investigated interactive multimedia and simulation-based approaches in science education. The study was also informed by the Department of Education's MATATAG Curriculum implementation guidelines, which provide a policy context for competency-focused and learner-responsive instruction (Department of Education, 2024). Conceptually, integrated animations and simulations constituted the instructional intervention, while learners' conceptual understanding of the endocrine system represented the principal learning outcome. Understanding was assessed through pretest and posttest scores across the identified endocrine competencies. Learners' perceptions of usability and engagement provided additional information on the instructional experience. The findings served as the basis for developing an enhanced lesson plan integrating visual, interactive, and competency-aligned learning activities. This framework is supported by research demonstrating the educational relevance of multimedia learning, interactive science instruction, and endocrine-specific learning interventions (Bouali et al., 2022; Sritha et al., 2023; Wu et al., 2024).

The study primarily aligns with Sustainable Development Goal 4 (Quality Education), particularly Target 4.1, which emphasizes effective and equitable learning outcomes in primary and secondary education. By examining animations and simulations as instructional tools, the study contributes evidence for improving conceptual understanding and supporting technology-enhanced Science education. UNESCO (2023) emphasized that educational technologies should be selected according to learner needs, instructional relevance, accessibility, and sustainability rather than technology adoption alone. Similarly, Eviota et al. (2026) demonstrated the potential of interactive digital resources to address difficult biological competencies. The study also has a secondary connection to SDG 3 (Good Health and Well-Being) through its educational focus on hormonal regulation, homeostasis, and endocrine disorders, which form part of foundational human health literacy. However, it did not directly assess health behaviors or health outcomes. Its principal sustainability contribution lies in educational and technological sustainability through the development of an enhanced lesson plan that teachers may use and refine to support continued Biology instruction. By identifying conceptual learning difficulties and

assessing the instructional value of digital resources, the study provides a localized basis for more responsive and sustainable Science teaching practices.

2. METHODOLOGY

Research Design

The study utilized a quantitative, quasi-experimental one-group pretest–posttest design to determine changes in learners' conceptual understanding of the endocrine system following the integration of animations and simulations. A pretest assessed learners' initial understanding, followed by the instructional intervention and a posttest to measure changes in performance. A descriptive component also examined learners' perceptions of the instructional tools in terms of usability and engagement. This design enabled the assessment of learning outcomes before and after the intervention within the same group of participants.

Research Locale or Study Setting

The study was conducted at Cangawa National High School in Buenavista, Bohol, Philippines, during School Year 2025–2026. The school provided an authentic classroom setting for integrating animations and simulations into Grade 10 Science instruction. The intervention was implemented within regular learning activities, allowing the assessment of learners' conceptual understanding and perceptions of technology-supported instruction.

Participants or Data Sources

The study involved 30 learners identified as Grade 10 students enrolled in Science at Cangawa National High School during School Year 2025–2026. Participants were selected through purposive sampling based on their enrollment and exposure to the targeted Science competencies. The selected learners participated in the instructional intervention and completed the assessments used to evaluate their conceptual understanding and perceptions of animations and simulations.

Research Instruments or Materials

The study employed adapted research instruments consisting of the Endocrine System Concepts Inventory (ESCI) and the Animation and Simulation Evaluation Questionnaire (ASEQ). The ESCI assessed learners' understanding of hormone action, feedback mechanisms, specific glands and hormones, regulation and homeostasis, and endocrine disorders through pretest and posttest assessments. The ASEQ measured learners' perceptions of the instructional materials in terms of usability and engagement, including clarity, accessibility, interactivity, and sustained participation. The adapted instruments underwent expert content validation, and necessary revisions were incorporated before administration.

Data Gathering Procedure

Data collection began with the preparation and approval of the research proposal and instruments by the appropriate university authorities. The researcher subsequently secured institutional endorsements and permission from concerned school authorities. Following instrument validation, informed consent and assent were obtained from participants and their parents or guardians. The researcher coordinated with school personnel to schedule the assessments and instructional activities. Learners completed a pretest to determine their initial conceptual understanding, participated in lessons integrating animations and simulations, and subsequently completed a posttest. Their perceptions of usability and engagement were also gathered through the adapted questionnaire. Completed instruments were checked for completeness, encoded, and organized for statistical analysis.

Data Analysis

The collected data were analyzed using descriptive and inferential statistics. Frequency and percentage were employed to summarize categorical data, while weighted mean was used to assess learners' perceptions of the usability and engagement of animations and simulations. Standard deviation measured variability in assessment scores and responses. A t-test was utilized to determine the statistical significance of differences between learners' pretest and posttest scores in conceptual understanding. Hypothesis testing was conducted at the 0.05 level of significance.

Ethical Consideration

The study observed established ethical principles to protect participants' rights, privacy, and welfare. Necessary institutional permissions were secured, and informed consent and assent were obtained after explaining the study's objectives and procedures to learners and their parents or guardians. Participation was voluntary, with respondents permitted to decline or withdraw without penalty. Confidentiality and anonymity were maintained through coded responses and secure handling of collected information. All data were used exclusively for academic purposes, and the researcher ensured that participation did not disrupt regular classroom instruction or expose learners to unnecessary risks.

3. RESULTS AND DISCUSSION

3.1 Initial Conceptual Understanding of the Endocrine System

3.1.1 Baseline Understanding Across Endocrine Competencies

The pretest results revealed low to very low conceptual understanding across the five assessed competencies. Hormone Action obtained a mean of 2.20 (SD = 1.63), interpreted as Low. Feedback Mechanisms recorded a mean of 0.37 (SD = 0.56), Specific Glands and Hormones obtained 0.67 (SD = 0.76), Regulation and Homeostasis recorded 0.60 (SD = 0.77), and Endocrine Disorders obtained 0.47 (SD = 0.57), all described as Very Low. These results indicate limited prior knowledge of hormonal functions, physiological regulation, and endocrine disorders. The findings highlight the need for instructional approaches that support conceptual understanding of abstract biological processes. Eviota et al. (2026) identified similar learning difficulties involving homeostasis and feedback mechanisms among Filipino learners. Carvalho et al. (2025) demonstrated the relevance of visual representations in explaining hormonal signaling and negative feedback, while Mekonnen et al. (2024) emphasized the potential of animation-supported instruction for addressing scientific misconceptions. These studies support the use of appropriately designed multimedia resources to address the conceptual difficulties identified in the pretest.

3.2 Changes in Conceptual Understanding Following Animation and Simulation Integration

3.2.1 Hormone Action and Specific Glands and Hormones

The results showed significant improvement in Hormone Action, with the mean increasing from 2.20 (SD = 1.63) to 8.67 (SD = 2.01), $t = 12.88$, $p < .001$. The reported Cohen's d was 2.75, classified as a large effect. Similarly, Specific Glands and Hormones increased from 0.67 (SD = 0.76) to 6.93 (SD = 1.46), $t = 22.78$, $p < .001$, with a reported large effect size of 1.51. These findings demonstrate substantially higher posttest performance in both competencies following the instructional intervention. The improvements suggest that dynamic visualizations may support learners in understanding hormonal functions and relationships among endocrine structures. Bouali et al. (2022) found that animation-supported Biology instruction improved achievement in complex cellular processes. Similarly, Ijaz and Ali (2024) reported improved Biology performance

among secondary learners exposed to computer-generated animations, while Teplá et al. (2022) demonstrated the educational value of dynamic visualizations in Science instruction. These findings provide relevant support for interpreting the observed learning gains.

3.2.2 Feedback Mechanisms and Regulation and Homeostasis

Feedback Mechanisms showed a significant increase from a pretest mean of 0.37 (SD = 0.56) to a posttest mean of 1.83 (SD = 0.46), $t = 11.79$, $p < .001$, with a reported medium effect size ($d = 0.68$). Regulation and Homeostasis likewise improved from 0.60 (SD = 0.77) to 4.30 (SD = 1.32), $t = 16.06$, $p < .001$, with a reported large effect size ($d = 1.26$). These results indicate significant improvements in learners' understanding of endocrine regulation and physiological balance. The findings suggest that visual and interactive instruction may help learners understand the sequential relationships involved in hormonal feedback and homeostasis. Carvalho et al. (2025) demonstrated how instructional visualizations can represent hormonal signaling and negative feedback processes. Eviota et al. (2026) likewise reported improved mastery following the use of an interactive learning module on homeostasis and feedback mechanisms. These studies reinforce the relevance of multimedia-supported instruction for explaining complex physiological relationships.

3.2.3 Endocrine Disorders

Learners' understanding of Endocrine Disorders significantly improved from a pretest mean of 0.47 (SD = 0.57) to a posttest mean of 4.50 (SD = 1.20), $t = 16.34$, $p < .001$. The reported Cohen's d was 1.35, interpreted as a large effect. The results indicate substantially higher posttest performance in identifying and understanding endocrine disorders following the integration of animations and simulations. The improvement suggests that interactive representations may help learners connect abnormalities in hormonal regulation with their physiological consequences. Kumalasari and Anggraito (2023) found that interactive multimedia improved students' conceptual understanding of biological systems. Similarly, Koç and Kanadlı (2025) reported positive cognitive learning outcomes associated with interactive learning environments in Science education. These findings support the instructional relevance of visual and interactive approaches for understanding biological processes, although the present study's one-group design does not establish causality.

3.3 Learners' Perceptions of the Usability and Engagement of Animations and Simulations

3.3.1 Usability and Concept Visualization

Learners reported highly favorable perceptions of the usability of animations and simulations. Ease of understanding obtained the highest mean of 4.80 (SD = 0.48), followed by concept visualization with 4.70 (SD = 0.47). Perceived improvement in understanding received a mean of 4.60 (SD = 0.56), while technical execution and relevance to the learning content obtained means of 4.50 and 4.40, respectively. All indicators were interpreted as Strongly Agree, indicating positive perceptions of the materials' clarity, accessibility, and instructional usefulness. These findings are consistent with Mou (2023), who reported positive learner responses to animation-supported Science instruction, particularly in understanding scientific concepts. Çeken and Taşkın (2022) emphasized the importance of multimedia design principles in supporting meaningful learning, while Teplá et al. (2022) identified positive learner perceptions of dynamic visualizations. The results suggest that the animations and simulations were perceived as accessible supplementary resources for explaining abstract endocrine processes.

3.3.2 Engagement, Interest, and Learner Acceptance

The findings revealed highly positive perceptions of learner engagement and acceptance. The ability of animations and simulations to sustain attention obtained a mean of 4.70 (SD = 0.54), while enhanced interest in the subject received 4.70 (SD = 0.53). Willingness to recommend the instructional tools to other learners recorded 4.60 (SD = 0.50). Their perceived learning value and superiority over traditional teaching methods both obtained means of 4.50. The overall weighted mean was 4.60, interpreted as Strongly Agree, indicating favorable perceptions of the integrated instructional approach. The findings are consistent with Almasri (2022), who identified positive relationships among engagement, confidence, satisfaction, and simulation-supported Science learning. Reen et al. (2022) likewise demonstrated the educational potential of immersive simulations for challenging biological concepts. Furthermore, Koç and Kanadlı (2025) reported favorable cognitive and affective outcomes associated with several interactive learning environments. These studies support the relevance of incorporating appropriately designed interactive resources to enhance learners' instructional experiences and engagement.

3.4 Implications for the Enhanced Endocrine System Lesson Plan

The findings established that learners initially demonstrated low to very low conceptual understanding across the assessed endocrine competencies but obtained significantly higher posttest scores following the integration of animations and simulations. Learners also expressed highly positive perceptions of the instructional materials' usability and engagement. These findings provided the basis for developing an enhanced Grade 10 Science lesson plan emphasizing hormone action, feedback mechanisms, specific glands and hormones, regulation and homeostasis, and endocrine disorders. The proposed lesson plan enhancement is supported by research demonstrating the instructional relevance of visual and interactive learning resources. Mekonnen et al. (2024) emphasized the value of integrating animations into structured Biology instruction, while Ijaz and Ali (2024) demonstrated improved Biology performance following animation-supported teaching at the secondary level. Similarly, Carvalho et al. (2025) highlighted the usefulness of visual approaches for representing hormonal feedback processes. The enhanced lesson plan therefore provides a research-informed instructional output intended to address the conceptual difficulties identified among the participating learners, although its effectiveness beyond the study setting requires further evaluation.

4. CONCLUSIONS AND RECOMMENDATIONS

The study demonstrated significant improvements in the conceptual understanding of the endocrine system among 30 Grade 10 learners at Cangawa National High School, Buenavista, Bohol, following the integration of animations and simulations. Initial assessments revealed low to very low understanding of hormone action, feedback mechanisms, specific glands and hormones, regulation and homeostasis, and endocrine disorders. Posttest results showed statistically significant improvements across all competencies, with large reported effect sizes in most areas and a medium effect in feedback mechanisms. Learners also expressed highly positive perceptions of the instructional materials, particularly their usability, clarity, visualization capabilities, and ability to sustain engagement. These findings indicate that animation- and simulation-supported instruction was associated with improved conceptual understanding and favorable learning experiences. The study provides an empirical basis for enhancing the Grade 10 Science lesson plan through visual and interactive instructional activities that address identified conceptual difficulties and support meaningful Biology learning.

Science teachers should integrate appropriate animations and simulations into Grade 10 Biology lessons, particularly when teaching abstract endocrine concepts such as hormonal regulation, feedback mechanisms, and homeostasis. Greater instructional emphasis should be placed on competencies where learners initially demonstrated very low understanding, supported by guided visualization, interactive activities, and formative assessments. The enhanced lesson plan developed from the findings should be refined, implemented, and regularly evaluated to ensure alignment with learning objectives and learners' needs. School administrators should provide appropriate digital instructional resources, technical support, and professional development opportunities to strengthen teachers' capacity to implement technology-supported instruction. Learners should be encouraged to participate actively in interactive learning activities, while parents and community stakeholders may support the appropriate use of educational digital resources. The Department of Education may also consider supporting similar instructional initiatives. Future researchers should evaluate the intervention across additional learner groups and educational settings to establish its broader applicability.

The study was limited to 30 Grade 10 learners selected through purposive sampling at Cangawa National High School, Buenavista, Bohol, during School Year 2025–2026. Its one-group pretest–posttest design lacked a comparison group, limiting causal conclusions about the observed learning improvements. The study assessed selected endocrine competencies and relied on adapted assessment instruments and self-reported perceptions of usability and engagement. Consequently, the findings may not be generalizable to other learners, schools, or Science topics. Future investigations may employ larger samples, comparison groups, multiple school settings, and additional assessment procedures to strengthen the evidence regarding instructional effectiveness.

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