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Virtual science learning application and student performance in anatomy and physiology

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Abstract

The primary purpose of this innovative research was to investigate the influence of virtual science learning applications and student engagement and performance in Anatomy and Physiology courses at Abuyog Community College. Recognizing the increasing integration of digital tools in education, this study sought to determine how such applications could enhance student learning experiences and outcomes compared to traditional methods. Several key research questions drove this study. These questions were: How do virtual learning applications impact student engagement in Anatomy and Physiology courses? What effects do these tools have on students' performance and understanding of the subject matter? How do students perceive virtual learning applications relative to conventional teaching methods? Which components of these applications correlate most strongly with improved learning outcomes? To address these questions, an experimental research design was employed, involving 30 students divided equally into control and experimental groups. The control group followed traditional learning methods, while the experimental group utilized virtual learning applications. Data collection methods included pre-tests and post-tests to measure academic performance, as well as Likert scale surveys and open-ended questions to capture student perceptions and experiences. The intervention featured the introduction of innovative interactive virtual learning tools. These tools were specifically designed to teach complex anatomical and physiological concepts through engaging, visual, and hands-on experiences. They provided unique features such as 3D models, real-time simulations, and immediate feedback mechanisms. The findings revealed that students in the experimental group showed significant improvement in both engagement and academic performance. The Likert scale results indicated that the virtual learning applications increased student motivation and active participation. Open-ended responses highlighted that student found the interactive features and visual aids particularly beneficial for understanding difficult concepts and maintaining interest. These results suggest that virtual science learning applications can be a powerful tool in enhancing student engagement and learning outcomes in Anatomy and Physiology. The study supports the integration of such digital tools into the curriculum to foster a more interactive and effective learning environment, providing practical insights for educators and curriculum developers. Future research should explore the long-term impacts of these applications and their potential in other educational contexts.

Keywords: Virtual Learning Applications; Student Engagement; Anatomy and Physiology; Educational Technology; Interactive Learning

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1. Introduction

Over the years, learning through technology has steadily risen in educational settings, offering tools that aim to enhance student success and engagement—particularly in content-heavy and visually demanding disciplines like anatomy and physiology. Traditional methods often fall short in delivering the kind of interactive, immersive experience these complex subjects require, leading to calls for more dynamic teaching solutions. Virtual science tools present an alternative approach, though their specific effects on student learning outcomes remain underexplored. Several concerns in anatomy and physiology education have emerged from both external and internal assessments. Externally, rapid technological evolution exposes the limitations of static, lecture-based teaching (Staci, 2023; Gamit et., al, 2024), while internally, students and educators report low engagement and weak retention when relying solely on textbooks and passive instruction (Sarah, 2023). Given the complexity of these subjects—requiring both structural and functional understanding—a shift to more auditory and interactive methods is necessary. The ideal anatomy and physiology instruction is one where students are actively engaged and can retain complex concepts over time, supported by questioning, visuals, and interactive tools. However, current practices fall short of this standard, with students often disengaged and struggling to retain critical knowledge. Misalignments in pedagogical transitions from secondary to tertiary education also highlight the need for tools that bridge knowledge gaps and predict student success (Amaal, 2022). Innovative strategies like 3D modeling, online modules, and educational games have been tested to address these issues (Yue, 2022), but widespread adoption remains limited. Engagement and retention are the primary differentiators between average and above-average learning outcomes. Students subjected to passive, one-size-fits-all instruction often show reduced test scores, low participation, and poor conceptual understanding. Meanwhile, brief online modules have been shown to improve study strategies and exam performance, and integrating anatomy and physiology into a systems-based model may aid in better retention of core concepts. Among the many identified challenges, the most pressing and actionable is the need to enhance engagement and retention through interactive learning tools. Virtual science learning apps have emerged as promising supplements to traditional methods, offering simulations, 3D models, and multimedia features that increase understanding and interaction (Christian, 2023; Binaluyo et al 2025). Research supports that VR technology in physiology and anatomy can enhance active learning, curiosity, problem-solving, and visualization (Chun-Wai, 2023). While some evidence suggests students benefit from a combination of physical specimens and virtual models, others report higher achievement and lower cognitive load with mobile learning tools (Berin, 2023). Virtual apps shift students' perspectives and learning approaches by offering personalized, immersive opportunities that cater to various learning styles. Corinna Martarelli (2023) highlighted the effectiveness of integrating VR into educational games, noting improved engagement and performance. VR also helps students grasp complex topics—like the water cycle or anatomical systems—with immersive, multimodal methods, even supporting multilingual learners on par with native speakers (Ai-Chu, 2023). Moreover, augmented reality, gamification, and serious games have been linked to improved motivation, academic achievement, and cognitive development in science education (Georgios, 2023; Ortiz et. al. 2025). VR tools also foster authenticity and influence students' intention to continue using them in the classroom (Dadan Sumardani, 2023). These applications support active learning and critical thinking, encouraging deeper comprehension of complex topics. Despite their potential, more empirical evidence is needed to confirm the link between virtual apps and improved performance in anatomy and physiology. This research seeks to fill that gap, especially as few studies focus on the implementation of such tools in undergraduate science education. Abuyog Community College presents an ideal setting for this research due to its openness to educational innovation. The 3rd-year BSEd Science students, having foundational knowledge, are positioned to benefit from enhanced learning tools in their anatomy and physiology course. The study addresses key challenges in science education—engagement, motivation, comprehension, and accessibility—where traditional methods often fall short. Virtual science apps offer interactive 3D environments that can be tailored to different learning styles and paces, available remotely, and capable of delivering real-time feedback. These features may help students pinpoint weaknesses and improve learning efficiently. Ultimately, this research aims to contribute to the growing evidence base supporting educational technology by evaluating the impact of virtual science learning applications on the academic performance of BSEd Science students. It will also provide insights that could guide curriculum development and instructional practices at Abuyog Community College and similar institutions, strengthening anatomy and physiology education through the strategic integration of digital tools.

1.1. Theoretical Background

This action research is largely based on the (a) (Jean Piaget) Constructivism Learning Theory, expanded by (Lev Vygotsky), (b) Cognitive Load Theory developed by (John Sweller), (c) Multimedia Learning Theory established by (Richard Mayer), (d) Self-determination Theory developed by (Edward et al.) as well as (e) Technology Acceptance Model (TAM) which was proposed by (Fred Davis).

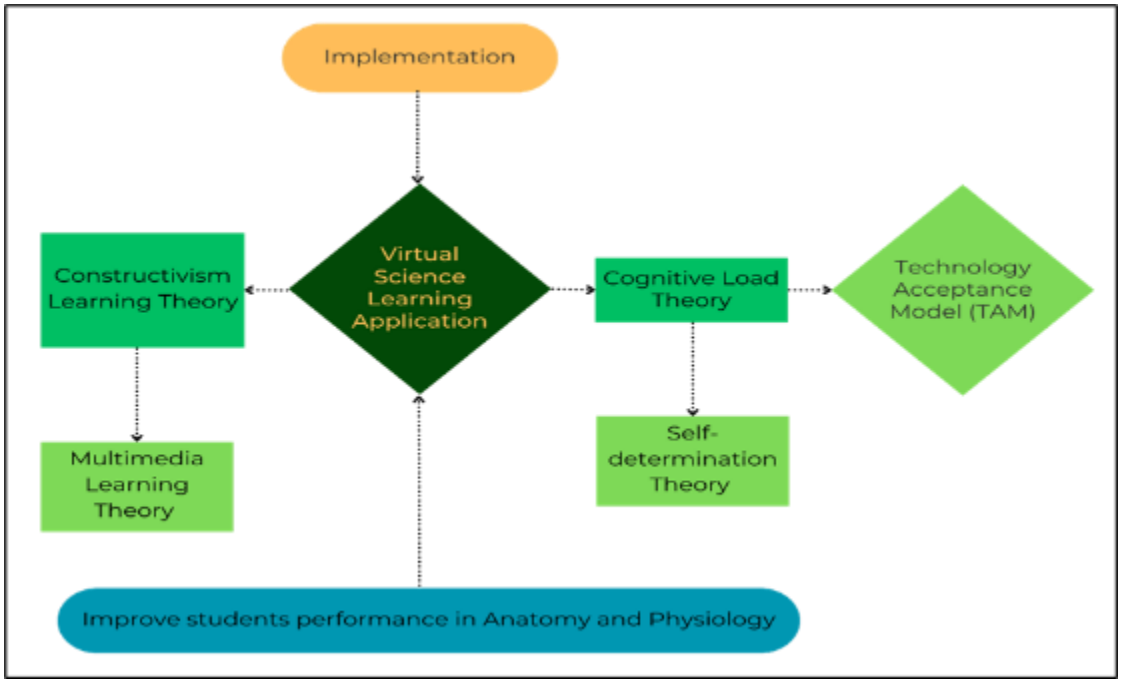

Figure 1 The Theoretical Framework Diagram

This diagram offers a visual analysis of how the different theories and learning models used in the study can be applied to enhance students' learning, particularly in the context of anatomy and physiology study, using a virtual science learning application.

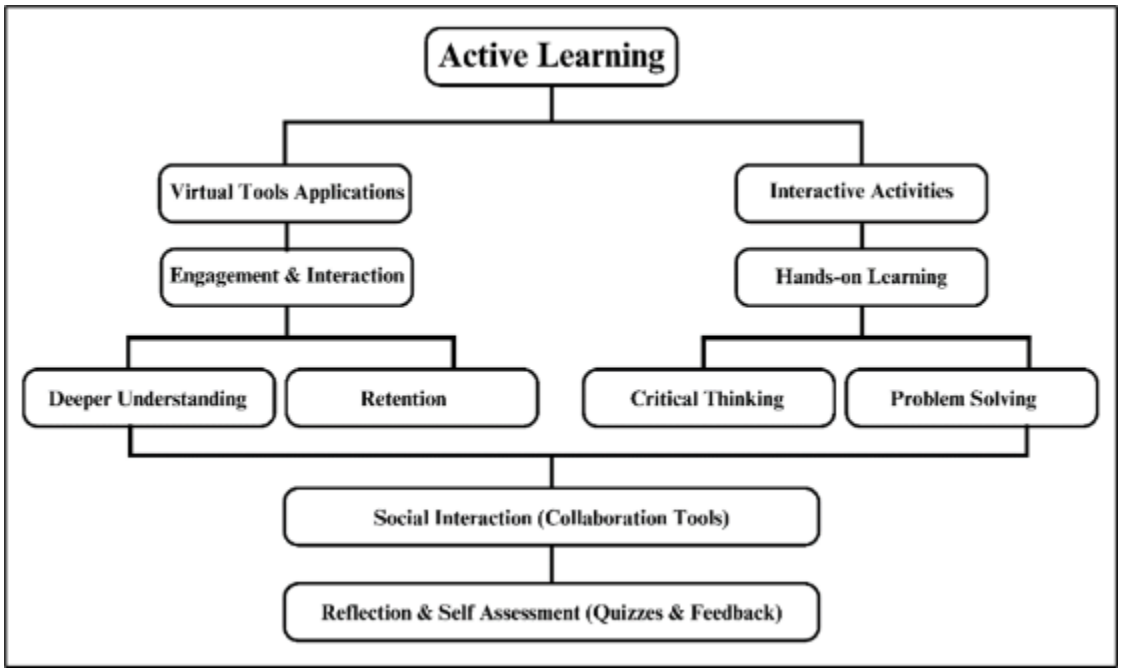

Figure 2 A diagram of Constructivism Theory in the Virtual Science Learning Process

(a) The Theory of Constructivism, first formulated by (Jean Piaget) and later developed by (Lev Vygotsky), emphasizes how important it is for learners to build meanings for themselves through reflective activities and experiential learning in the sense that learners play a central role in making their knowledge.

This theory is considered fundamental to challenging traditional educational paradigms, as argued by (Brau, 2020) and (Pundir, 2016), who noted that education should provide an environment within which students are active rather than

passive participants. It is divided into two main ideas: radical and social constructivism. Radical constructivism focuses on the individual's internal process of knowledge construction, emphasizing personal interpretation and meaning making. In contrast, social constructivism, as highlighted by (Brau, 2020), places significant importance on the role of social Interaction and cultural context in the learning process *(see figure 1.3)* (McLeod, 2020). This contrast is meant to show that learning encompasses individualistic undertakings and a collective act built on both personal experiences and societal engagements.

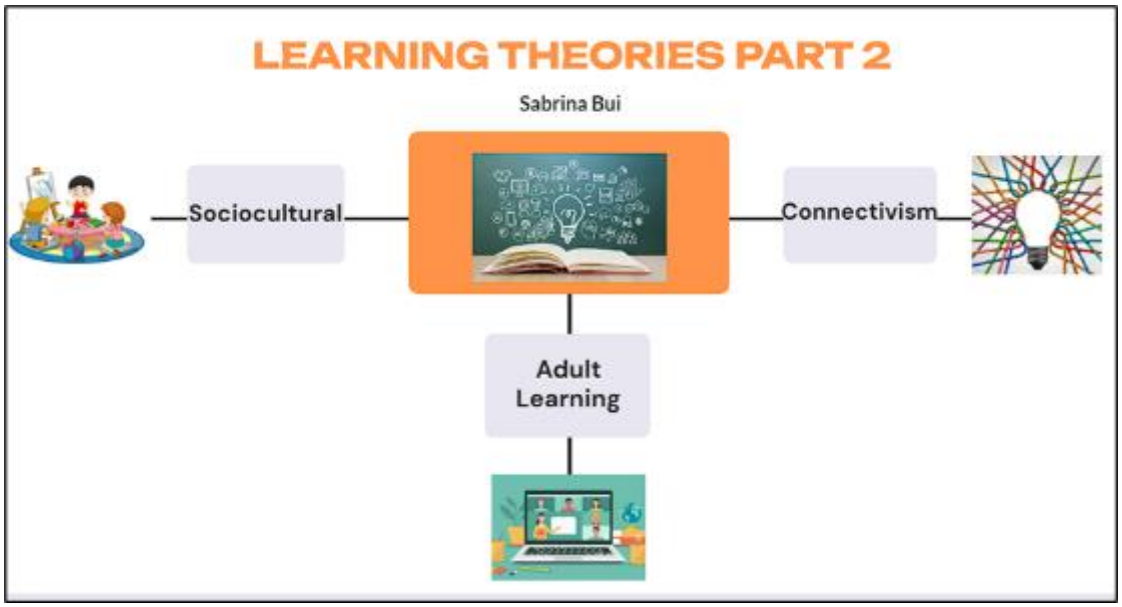

Figure 3 The Learning Theories

A constructivist classroom causes changes in the teaching-learning process. The learners become more active and engaged in various activities aimed at promoting their critical thinking and problem-solving abilities. This also means that teachers transition from being the main sources of knowledge to facilitators who supervise student's progress in learning. This shift in roles is essential for creating an environment conducive to active learning and knowledge construction (Kalpana, 2011).

However, in this study on the impact of Virtual Science Learning applications on students' performance in anatomy and physiology, the constructivism learning theory offers sound background information. It is definitely feasible to design virtual learning applications with reference to the principles of constructivism since such applications would enable learners to engage themselves in active, critical, and collaborative ways. The applications that the researchers implement can model the real physical and physiological systems and anatomies and so on and give students the chance to play the part, fiddle around with their learning experiences, and then self-reflect in cyberspace.

When using the approaches of radical constructivism and social constructivism, it is possible to address the learners in order to meet their individual needs and, at the same time, avoid depriving them of opportunities for cooperation. Thus, when applying both the radical constructivist approach and the social constructivist one, the learners can be addressed to enhance individual learners' requirements. In contrast, the identified approaches will exclude depriving the learners of the possibility to cooperate. In that manner, it enhances students' understanding of blurred concepts not only as separate elements but also guides students' valuable perspective, which connects their learning process with individual and social aspects of constructing knowledge.

The context for the study is constructivist learning theory, particularly owing to its features that include active, reflective, and social learning. Thus, it advocates for the adoption of virtual science learning applications as instruments that can help increase the student's interest, comprehension, and achievement in anatomy and physiology by applying the concepts of active and experiential learning.

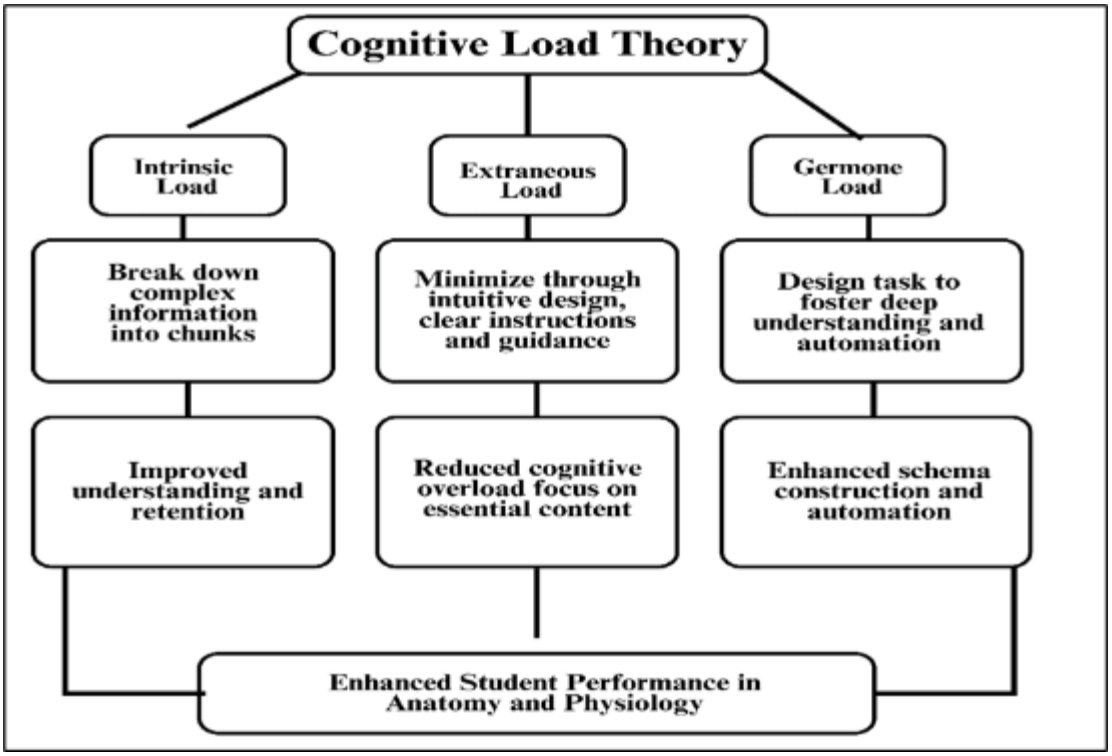

Figure 4 The process of Cognitive Load

(b) Cognitive Load Theory (John Swellers') deals with working memory and conveys that for effective learning, cognitive load in a course has to be managed properly. As noted by (Jong, 2010), this theory is very useful in avoiding the problem of cognitive load by deliberately designing the instructions in a manner that fits the working memory's capacity. In reference to this theory, (S. Feinberg, 2000) applied the use of a minimal cueing strategy in web-based instruction and established that instructional modules should focus on noble content, which should pose a lesser challenge to working memory and with less non-relevant information.

Challenges arising from cognitive load are inevitable since the teaching profession involves an area of concentration that is content-dense, this being when teaching anatomy and physiology, challenges are bound to arise. These difficulties can be solved by Virtual learning applications, which have been developed with consideration of the Cognitive Load Theory, where knowledge is presented in small pieces that are manageable and interactive. Elements like 3D models and animations, together with guided tutorials, are most helpful for this process because they help in minimizing one's extraneous cognitive load.

These interactional components have the advantage of improving the learning process in approaches that deal with anatomical structures and physiological processes. For instance, the use of models in three dimensions is effective in enhancing the students' spatial skills when learning and helping them retain more information as they manipulate the whole anatomical parts. Physiologic activities or processes can be presented as moving pictures to give enhanced comprehension of the function and relation of activities within the body. Model teachers are especially helpful because they provide detailed instructions and explanations as to what is being done and why, thus preventing the students from getting lost in a large number of tips.

According to Cognitive Load Theory, in the design of virtual learning applications, it is possible to increase learners' performance and optimize knowledge storage in long-term memory. This is particularly appropriate in anatomy and physiology, where simple and detailed information is required for academic and professional achievements. When the cognitive load is properly managed, students are likely to have better outcomes than when they are so stressed by the process of learning in a virtual environment.

Thus, Cognitive Load Theory, which focuses on working memory management and avoidance of cognitive overload, is central to the analysis of virtual learning applications in the context of anatomy and physiology. Thus, being designed to include elements predictive of reduced extraneous cognitive load, these applications can improve learning outcomes and students' knowledge retention, therefore boosting their performance and better understanding of the topics

discussed. This theoretical approach is useful in fostering the creation of instructional aids that help to enhance learning, especially in areas where there is much content, for instance, in the fields of anatomy and physiology.

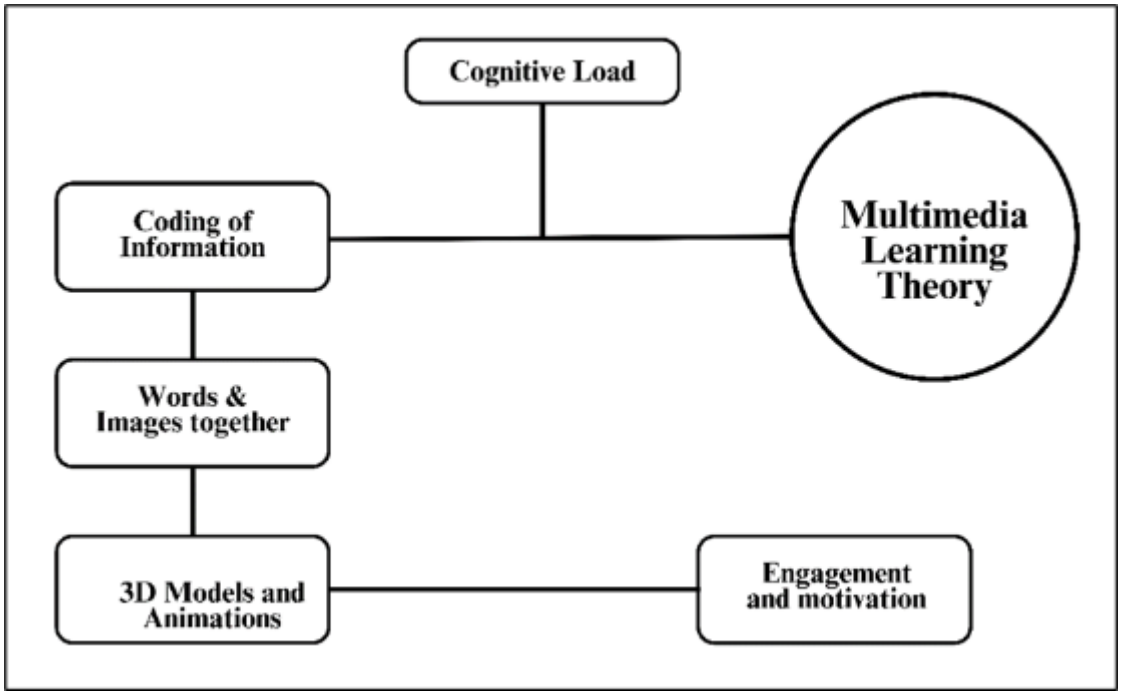

Figure 5 A diagram illustrating how multimedia learning theory works in virtual science learning

(c) Multimedia Learning Theory, developed by (Richard Mayer), knowledge acquisition will be more effective if the instructions involve both words and pictures at one level than at another. It is operationalized by the principles postulated in Mayer's cognitive theory of multimedia learning, which comprises dual channel processing, limited capacity, and active processing principles that comprehensively recommend learning through both presenting visuals and audio simultaneously.

1.1.1. (Mayer, 2021) identifies five cognitive processes crucial to multimedia learning

- Picking up words suitable for the discussed concept
- Developing necessary words and images into meaningful conceptual and pictorial models
- Mapping these models into prior knowledge

According to the multimedia principle of this theory, a person learns better through words combined with pictures than by using words alone (Fletcher, 2005). However, Mayer noted that the procedure of adding photographs to words does not work in this case and that the method used to present such information must correspond with how the human mind processes information.

Based on this analysis, teaching anatomy and physiology Virtual Science Learning applications belong to Multimedia Learning Theory. These applications combine texts, graphics, and multimedia features such as animations, diagrams, and simulations to reveal the details of the human body and biochemical activities. This style of learning makes it easier to understand content and retain information than the traditional one that involves only the use of text.

For instance, when teaching about human physiology, the effect of using 3D animation as a way of displaying the process can be easily seen. That is; by showing how various systems in the body work in harmony, students are easily able to comprehend. Diagrams can decompose complex structures into sections that can be understood easily while employing applications like procuring anatomical models, which means that the student gets a practical sense of the structure being learned besides having enhanced retention due to actual manipulation.

According to the (Mayer, 2021) principles, these virtual learning tools enhance the cognitive operations related to multimedia learning. They assist students in identifying appropriate information and channeling this into

comprehensible mental schemes that would complement what they already know. This way not only is the reception of information improved but so is their long-term retention in the memory.

Furthermore, stressing the connection between vision and hearing guarantees the effective application of virtual learning in anatomy and physiology. With the fundamentals of multimedia incorporated in these applications, learning engagement, comprehension, and memory of the scientific concepts employed by students can be effectively enhanced, boosting learning effectiveness. These contexts explain the notion and creation of effective and efficient educational technologies that are in harmony with how brains are formed in terms of knowledge processing.

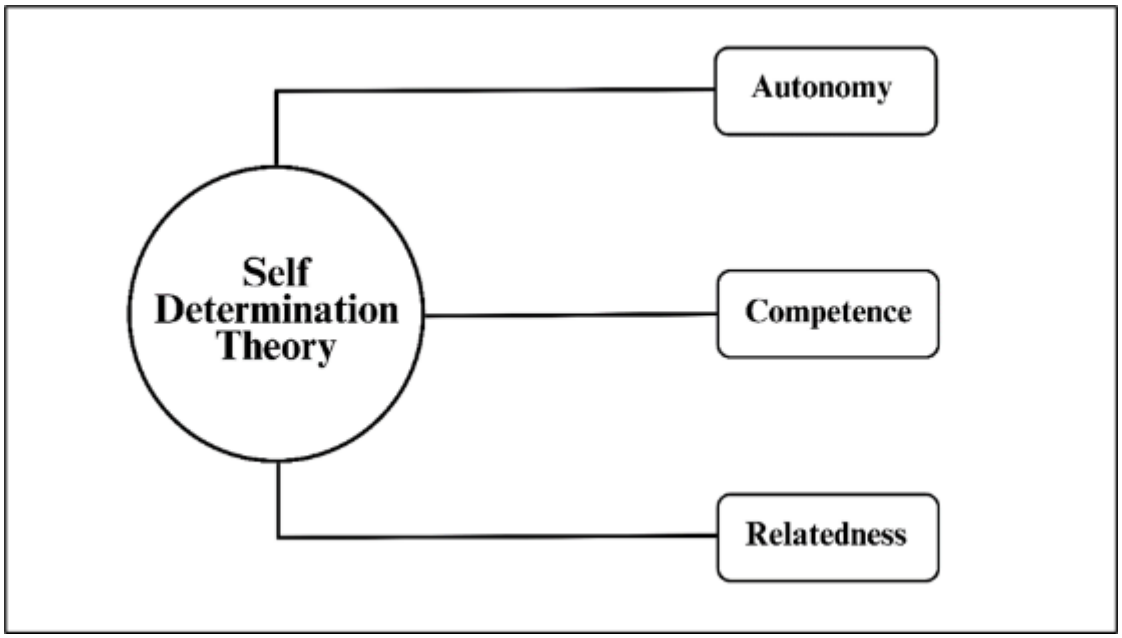

Figure 6 Diagram of Self-Determination Theory (SDT)

(d) Self-Determination Theory (SDT), invented by (Edward et al.) focuses on the importance of intrinsic motivation in influencing people's actions, promoting activity, and supporting learning. As outlined by (Martela, 2020), SDT set forth that individuals are naturally curious and inclined toward growth, and their motivation is significantly influenced by the satisfaction of three fundamental psychological needs: *(a) Autonomy- This is literally a self-explanatory concept as the phrase implies the importance the independence people feel regarding their actions. From experience, when a learner is allowed to make choices in regard to his learning activities, then he or she incurs intrinsic motivation. (b) Competence- This has to do with the ability to accomplish the activities that one undertakes. Thus, when learners have a performance achievement, their intrinsic motivation is boosted. (c) Relatedness: This refers to the process of having to belong to a group of people. A better right-hand assistant for students is if students engage in positive dialogue teaching interactions with one another and between teachers.*

SDT points out more that the concrete environment influences whether a person will become its supporter or detract from his intrinsic motivation. A school environment that nurtures and supports these psychological needs can result in a better education experience and a well-constructed person. This study, which is about the influence of virtual science learning applications on students' understanding of anatomy and physiology, SDT pro, is a very useful framework to explain the ways in which these tools can improve learning activities.

Hence, Virtual learning apps can create a driving force and a more enjoyable and effective learning environment that the learners themselves will want to get into by fulfilling the needs of autonomy, mastery, and connection of learners. This line of reasoning coheres with the Self-Determination Theory. This psychosocial model posits motivational self-regulation as the result of finding the learning process to be gratifying and interesting among students. Virtual learning apps are able to achieve this end by being designed in such a way as to allow students to walk through learning processes at their own pace, ensuring that, at the same time, they are truly involved in the learning process.

Moreover, Virtual learning apps can stimulate intrinsic motivation by providing a learning process that is both engaging and enjoyable. By including features such as gamification, immediate feedback, and interactive challenges, it is possible

to raise students' interest and motivation to learn. This principle is solid because if students look at the learning process as a fun activity, they are more likely to continue and become successful.

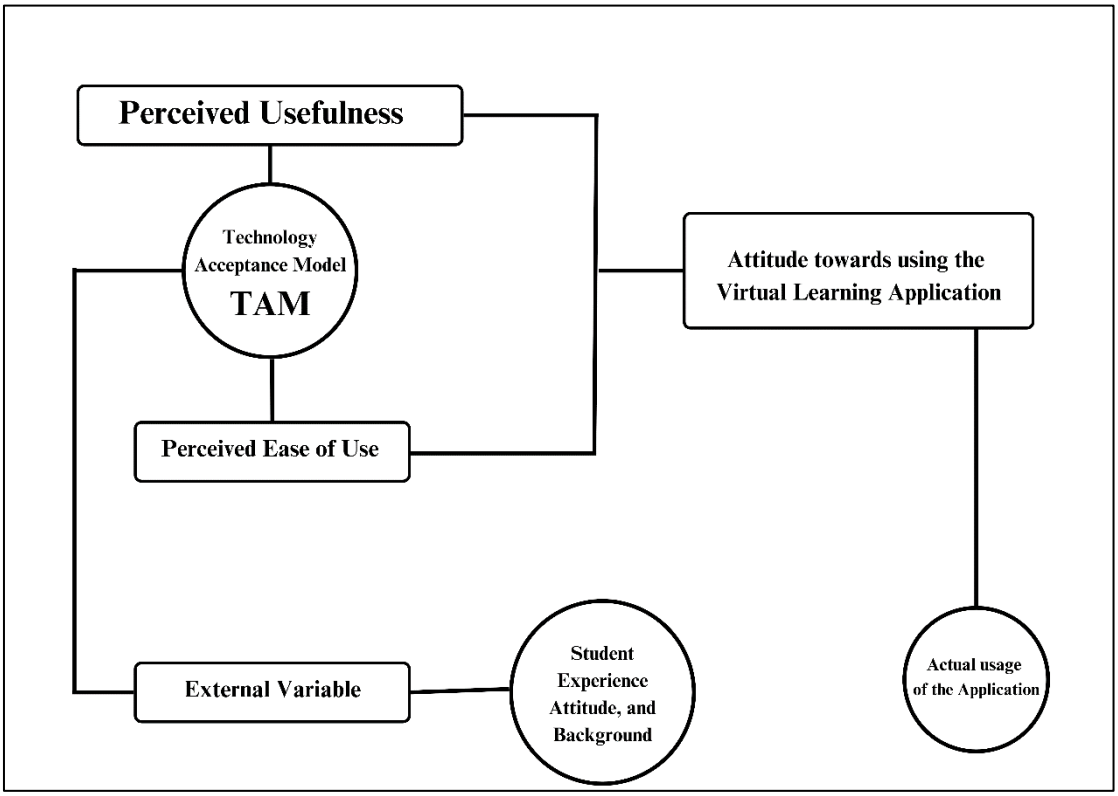

Figure 7 Diagram of Technology Acceptance Model

(e) The Technology Acceptance Model (TAM), formulated by (Fred Davis) presents the mechanism through which users accept and start using technology. At the heart of (TAM) are two major factors: perceived usefulness (The degree to which an individual believes that using a particular system would improve his or her performance) and ease of use (perceived effortlessness associated with obtaining more functionality from technology). Central to understanding how new technologies are adopted and used is gaining insight into the forces that shape users' perceived intentions.

From the perspective of virtual reality (VR) or virtual science applications, many studies have scrutinized and extended TAM. These pointers can be used to understand better the application of anatomy and physiology in educational environments by focusing on virtual learning applications. According to this study, (Camille Sagnier, 2020) points out that perceived usefulness and ease of use are crucial elements for VR acceptance in accordance with TAM's basic principles. This means that students must perceive virtual science learning applications as helpful to their learning experiences and easy to use.

Examining further the acceptance of VR, (Camille Sagnier, 2020) expanded TAM with additional variables relevant to VR, such as cybersickness, which has been found to have a significant effect on intention towards using VR. The essence of this extension is important because it underscored other factors that should be taken into account when developing and implementing virtual learning applications in order to ensure a good user experience.

(K. T. Manis, 2019) expanded TAM to incorporate perceived enjoyment and the factors influencing the acceptance of VR hardware. This expansion supports the model's applicability to virtual learning environments by emphasizing the role of enjoyment in technology adoption. This aspect is particularly relevant as engaging and enjoyable learning experiences can enhance students' motivation and willingness to use virtual science applications. (Shih-Chih Chen, 2012) Provided a comprehensive overview of TAM's application across various information technology domains, indicating its broad relevance and potential for application in virtual science learning. This suggests that TAM can serve as a robust framework for assessing the acceptance of virtual learning technologies in diverse educational settings.

The TAM framework aids in understanding and evaluating students' acceptance of these tech`nologies for use in virtual science learning in the context of this study and how they influence student performance in anatomy and physiology.

This can be done by assessing factors like perceived usefulness, ease of use, enjoyment, and possible barriers like cybersickness. Hence, this research can provide insight into how these applications are viewed and what influences their adoption.

The reasons behind such design must be clear from sharing. If students believe that they would benefit from using the applications for their studies with ease, they are more likely to adopt them, which would lead to better learning performance. Furthermore, the integration of fun elements and addressing probable inadvertent unpleasantness further advocates acceptance as well as continuous usage.

In assessing virtual learning applications' acceptance in anatomy and physiology, the Technology Acceptance Model (TAM) is built on perceived usefulness together with pleasurable use. The study can also include additional factors such as enjoyment or cybersickness so as to come up with a holistic understanding of the determinants influencing technology adoption, hence facilitating the design of more effective and user-friendly educational technologies.

The complications cited in this investigation are rooted in overloaded learning content and students' declining motivation due to the pressure of memorizing complex material in anatomy and physiology. These issues are especially prevalent among undergraduate students, whose learning capacity is stretched by traditional teaching approaches reliant on lengthy lectures and text-heavy resources. The lack of interactive tools contributes to disengagement and reduced knowledge retention. This action research aims to address these problems by evaluating the effectiveness of Virtual Science Learning Applications (VSLA) in enhancing student engagement, comprehension, and performance. These applications are grounded in educational frameworks such as Cognitive Load Theory, Multimedia Learning Theory, Self-Determination Theory, and the Technology Acceptance Model. Specifically, the study seeks to answer the following questions: (1) In what ways do virtual science learning applications influence the level of students' engagement in the anatomy and physiology courses? (2) How do virtual science learning applications affect the performance and understanding of knowledge in anatomy and physiology among the students? (3) What is the student's perception of the applications of virtual science learning as compared to the conventional methods of learning? (4) Due to the vast areas of teachers' practices that have been affected by virtual learning applications, it is crucial to establish what components of those applications have the strongest correlation with the enhanced learning outcomes in students taking anatomy and physiology classes. The hypothesis presumes that integrating VSLAs can significantly boost student interest and academic performance by promoting immersion and interaction. The quantitative hypothesis includes: Null Hypothesis (H0): One must note that there is no significance difference in the students' performance in Anatomy and Physiology when they use Virtual Science Learning Applications as compared to those groups of students who do not use Virtual Science Learning Applications. Alternative Hypothesis (H1): The use of virtual science learning applications will indicate higher achievements in anatomy and physiology learning among students than those students who fail to apply the said learning tool. The qualitative hypothesis states that participants who complete the virtual applications will have a significantly better learning experience than the ones who do not complete the virtual science learning applications regarding anatomical and physiological structures. These hypotheses aim to bridge the gap between outdated educational methods and modern student needs by investigating how technology can support science education. The significance of this study lies in its potential to address long-standing challenges in anatomy and physiology education by offering interactive, accessible, and student-centered learning tools. Traditional teaching methods often fail to engage students or simplify complex scientific material, leading to low performance and interest. This study proposes that virtual learning applications can provide a more dynamic and effective learning environment. The goal is to validate the use of these tools and provide evidence that supports their integration into science curricula. The outcomes could inform educational practice and policy, particularly in leveraging ICT for improved academic achievement and reduced dropout rates. The findings are expected to benefit multiple stakeholders: students may experience more engaging and comprehensible learning; teachers can adopt more effective instructional strategies; and school administrators may use the data to support broader technological reforms. Ultimately, this research supports efforts to enhance the overall quality and relevance of science education, preparing students for professional success in health and science fields. The study's relevance is in its potential to shift traditional teaching approaches toward more innovative, technology-based methods that align with contemporary learning needs. As for the scope and delimitations, this study will focus on third-year BSEd Science students enrolled in the Anatomy and Physiology course at Abuyog Community College during the Academic Year 2023–2024. The intervention will involve the use of interactive virtual learning tools, including 3D models, animations, simulations, and immediate feedback features, to support student understanding of complex topics. The study will span three months and will evaluate both quantitative outcomes—such as test scores—and qualitative insights, such as student feedback on usability and effectiveness. However, the study is delimited to a specific educational level, course focus, and geographic location: it only applies to third-year BSEd Science students in the Anatomy and Physiology course at Abuyog Community College and does not extend to other subjects, educational levels, or institutions.

2. Review of related literature

Over recent years, the integration of technology in education, particularly in virtual learning applications, has grown significantly. This action research aims to determine the effects of a Virtual Science Learning Application (VSLA) on students' performance in Anatomy and Physiology at Abuyog Community College. Various studies support the use of Virtual Reality (VR) and Augmented Reality (AR) in enhancing student achievement, motivation, and engagement. According to B. G. Sarmiento (2022), students using virtual laboratories in anatomy and physiology achieved higher grades and completed tasks more efficiently than those using traditional methods, attributing these results to the interactive, practical, and repeatable nature of virtual labs. Tandra R Chakraborty (2018) similarly found that iPad applications improved student grades and participation by offering engaging features such as 3D models, quizzes, and diagrams, which enhance spatial orientation and memory retention. Although Christian Moro (2020) found no significant difference in knowledge scores when comparing VR/AR tools to traditional methods, his meta-analysis emphasized that these technologies foster better engagement and cater to diverse learning styles, making them effective supplementary tools. W. B. Vidona (2022) also highlighted the positive perception students have of virtual anatomy applications due to their flexibility and interactivity, though challenges like high mobile data usage and technical issues were noted. Despite these barriers, the overall response remains favorable. The literature thus affirms that virtual laboratories, iPad-based tools, and immersive VR/AR methods are promising alternatives to conventional instruction, and while integration challenges remain, their potential to enhance health science education is clear.

The integration of virtual and augmented reality (VR/AR) into anatomy and physiology education has generated diverse insights regarding its effectiveness compared to traditional teaching methods. Christian Moro (2020) conducted a meta-analysis indicating no significant difference in knowledge outcomes between VR/AR tools and conventional techniques, although these technologies provide complementary value in enhancing engagement and interactivity. M. Kesner (2005) emphasized the advantages of computer-based tutorials and simulations that allow students to explore anatomical structures beyond textbook limitations. D. Cook (2010) highlighted the positive impact of virtual patients on knowledge acquisition and clinical reasoning, showcasing how simulated clinical cases offer safe, experiential learning opportunities. Susan Jang (2017) found that 3D interactive navigation significantly benefits students with low spatial reasoning skills, improving their understanding of structural relationships through active manipulation. Cook (2010) also identified key design elements such as repetition, feedback, and contrast cases, which promote tailored and effective learning experiences. These findings support the use of VR/AR in promoting self-directed, engaging, and meaningful learning in anatomy and physiology, even though they may not always result in higher knowledge scores compared to traditional methods.

In terms of engagement and academic outcomes, various studies demonstrate the nuanced effects of educational technologies. J. Stokes (2020) described digital learning technologies as tools that increase student interest, openness, and knowledge retention. Similarly, Tandra R. Chakraborty (2018) reported that the use of iPads with forensic anatomy apps improved students' grades and comprehension. Conversely, Christian Moro (2017) argued that while immersive technologies like VR/AR heighten engagement, they do not necessarily yield better performance compared to simpler tablet-based apps. Mona Bains (2022) introduced the importance of self-regulated learning paired with instructor guidance, emphasizing that technology's effectiveness depends on how it is used, rather than its presence alone. These perspectives collectively suggest that while technology supports engagement and learning, its impact is shaped by how it is integrated, the level of student autonomy, and the instructional context.

Research also highlights how virtual learning environments (VLEs) can foster improved learning outcomes when designed with pedagogical intent. Moramay Ramírez Hernández (2020) advocated for techno-pedagogical mediation strategies—such as tutoring, structured communication, and diverse learning approaches—to ensure that technology functions as a learning platform rather than a mere tool. Raquel Aguayo (2021) reinforced this by aligning technological features with varied learning styles, ensuring that educational platforms are responsive to student needs. However, Maria Galofré (2008) cautioned that organizational and pedagogical barriers can hinder the effectiveness of VLEs if not properly addressed, pointing to the need for instructor training and curriculum alignment. Ethel Chua (2020) emphasized the strategic role of social media in VLEs, noting its potential to enhance student interaction and engagement when thoughtfully integrated. These findings stress the need for a holistic approach in VLE design—balancing technology, pedagogy, and institutional support—to optimize learning experiences.

While some studies argue that VR/AR technologies do not significantly outperform traditional methods in improving knowledge scores, the literature overwhelmingly supports their value in enhancing student engagement, spatial understanding, and experiential learning in anatomy and physiology. The effectiveness of these tools is highly dependent on thoughtful instructional design, student autonomy, and institutional readiness. Incorporating adaptive learning strategies, real-time feedback, social interaction tools, and personalized support systems into virtual science

learning environments can significantly enhance student outcomes. Therefore, a well-structured blend of technology, pedagogy, and support systems is essential for maximizing the potential of virtual learning applications in anatomy and physiology education.

This study acknowledges several challenges and limitations in implementing virtual science learning applications, particularly in developing countries like the Philippines. The COVID-19 pandemic highlighted these issues as education shifted online. According to Masoomeh Latifi (2022) and Sujata Khobragade (2021), technical difficulties such as unstable electricity, poor internet access, and lack of hardware like computers or tablets significantly hinder effective online learning. Addressing these barriers requires substantial investment in infrastructure, improved internet services, affordable devices, and partnerships with technology firms to bridge the digital divide. Social, cultural, and ethical concerns also emerge, as virtual education is often perceived as inferior to traditional face-to-face learning (Latifi, 2022). Issues such as plagiarism and copyright infringement must be tackled through institutional policies that promote ethical academic behavior. Moreover, Khobragade (2021) and Malik (2023) emphasize the psychological impact of virtual learning, including reduced motivation, lack of discipline, and feelings of isolation due to limited peer and teacher interaction. These factors affect student performance and engagement. Strategies to counteract these effects include using interactive features like gamification, group projects, and virtual social spaces to foster motivation and community. Baburajan (2022) and Khobragade (2021) further note the challenge of limited student-teacher communication, which can weaken instructional support. Incorporating real-time tools such as video conferencing, live chat, and interactive discussions, along with teacher training, can enhance interaction and student engagement. Despite these challenges, virtual learning offers significant benefits, including flexible scheduling, repeatable content access, and the use of advanced tools like 3D models and simulations to support understanding of complex anatomy and physiology concepts (Baburajan, 2022). Latifi (2022) suggests solutions such as infrastructure development, technology standardization, and learning from the practices of developed countries. Malik (2023) also advocates for enhancing student motivation, confidence, and tech proficiency to maximize learning outcomes. Ensuring access to appropriate technology and integrating digital literacy into curricula will help students fully benefit from virtual education. While virtual learning poses technical, cultural, and psychological challenges, these can be mitigated through systemic investments, awareness efforts, teacher-student interaction improvements, and the strategic use of engaging, student-centered digital tools. Continued research and targeted efforts will be vital in realizing the full potential of virtual science learning applications in improving education quality, especially in anatomy and physiology.

3. Methodology

3.1. Research Design

This study adopts a mixed methods research design, integrating both quantitative and qualitative approaches to provide a comprehensive assessment of the impact of virtual science learning applications on students' performance in anatomy and physiology. The decision to employ mixed methods is supported by existing literature emphasizing its value in educational research. Traser (2016) highlights the usefulness of qualitative case studies in anatomy education for capturing complex learning processes and interactions, offering detailed insights into students' experiences. Fillmore (2016) and Caruth (2013) further underscore the strength of combining quantitative and qualitative data, noting that statistical findings alone cannot fully explain how students engage with educational content. By merging numerical data with narrative feedback, researchers can gain a fuller understanding of the effectiveness of teaching methods and materials. Accordingly, this study employs a quasi-experimental design featuring pre-tests and post-tests to gather quantitative data on students' academic performance. Simultaneously, qualitative data is collected through interviews and focus group discussions to explore participants' experiences, perceptions, and emotional responses to the virtual applications. This dual approach ensures that the analysis not only measures learning outcomes but also captures the depth of student engagement and satisfaction, thereby enhancing the validity and relevance of the study's conclusions.

3.2. Research Locale

This study was conducted at Abuyog Community College, located in the municipality of Abuyog in the province of Leyte. Known for its commitment to innovation and quality education, the college provides a conducive environment for educational research, particularly in exploring technological integration in teaching and learning. The institution offers a comprehensive Bachelor of Secondary Education (BSEd) major in Science program, which includes courses like Anatomy and Physiology—making it an ideal setting for this study. The college's openness to technological advancements aligns closely with the research objectives, as it actively incorporates digital tools into its curriculum to enhance instruction. The relevance of Abuyog Community College to this research is evident in several aspects: (a) Curriculum Integration – its inclusion of Anatomy and Physiology in the BSEd Science program demonstrates the importance of interactive and modern teaching tools, supporting the use of virtual science learning applications; (b)

Technological Readiness – the institution is well-equipped and committed to introducing innovative technologies, making it an appropriate and supportive environment for this kind of study; (c) Educational Innovation – by participating in this research, the college reinforces its role as a forward-thinking educational institution, potentially guiding future strategies for broader tech integration in instruction; and (d) Student Engagement – targeting third-year BSEd Science students at a critical stage in their academic journey ensures the research addresses both immediate learning needs and long-term teaching preparedness. Conducting the study within this locale allowed the researcher to evaluate the direct effects of virtual science applications on student performance in anatomy and physiology, offering insights valuable to both the institution and the broader field of technology-enhanced science education.

3.3. Participants of the Study

The participants of this action research consisted of thirty (30) third-year Bachelor of Secondary Education (BSEd) Science students enrolled in the Anatomy and Physiology course at Abuyog Community College. They were evenly divided into two groups: an experimental group and a control group, with fifteen (15) students in each (Abdullah, 2021). The experimental group engaged with virtual science learning applications specifically designed to enhance interactivity and deepen understanding of complex topics in human anatomy and physiology through 3D animations, interactive graphics, and virtual workshops. In contrast, the control group received traditional instruction using conventional methods such as lectures, textbooks, and group discussions. This comparison allowed the study to measure the added value of virtual learning tools over standard teaching practices. Additionally, the course instructor played a supportive role in the research, offering insights on student engagement, instructional effectiveness, and the integration of the virtual tools into the curriculum. The teacher's perspective contributed to evaluating how technology influenced both teaching practices and student learning outcomes.

3.4. Research Instruments

To evaluate the effectiveness of virtual science learning applications on students' performance in anatomy and physiology, this study utilized a mixed-methods approach, incorporating both quantitative and qualitative research instruments. These tools enabled a well-rounded collection of data, offering a deeper understanding of student engagement, perception, and learning outcomes. The primary instruments included pre-tests and post-tests, as well as surveys and questionnaires administered via Google Forms. The formal objective tests, conducted before and after the intervention, measured students' grasp of anatomy and physiology concepts, allowing for a direct comparison of performance to assess the impact of the virtual tools. Meanwhile, surveys and questionnaires collected quantitative data on student participation and attitudes through Likert scale items, gauging levels of agreement with various experience-based statements. Additionally, open-ended questions captured richer qualitative insights, enabling students to elaborate on their experiences and perceptions. Together, these instruments provided a comprehensive view of how virtual science applications influenced both the academic achievement and overall learning experience of the participants.

3.5. Data Gathering Procedures

The data gathering procedure for this study was carefully structured to assess the impact of virtual science learning applications on students' performance in anatomy and physiology. The process began with securing permission from the instructor, whose involvement was essential for both implementation and data collection. This was followed by an orientation session for students and the instructor, where the study's objectives, procedures, and ethical considerations were explained, and informed consent was obtained. Participants were introduced to the virtual applications through a guided demonstration, allowing time for exploration and clarification to ensure familiarity and comfort. A pre-test was then conducted for both control and experimental groups to establish a baseline for evaluating learning gains. The virtual science learning tools were then integrated into the experimental group's lessons, with consistent use monitored and adjusted as needed to maintain effective implementation. Ongoing support and monitoring were provided through regular check-ins, enabling immediate resolution of challenges and reinforcing engagement. After the intervention period, a post-test was administered to both groups to measure improvements in understanding. Alongside this, qualitative feedback was collected via surveys and interviews to capture students' and the instructor's experiences and perceptions of the virtual tools. Data analysis involved statistical testing using SPSS for quantitative results and thematic analysis for qualitative data, ensuring a comprehensive evaluation of the outcomes. Finally, the findings were compiled into a research report detailing the methodology, results, and recommendations for future research or educational practice improvements. This report was shared with stakeholders, particularly the college administration, to support informed decision-making. This entire process was designed to ensure the credibility, relevance, and integrity of the collected data while providing a well-rounded evaluation of the virtual applications' educational effectiveness.

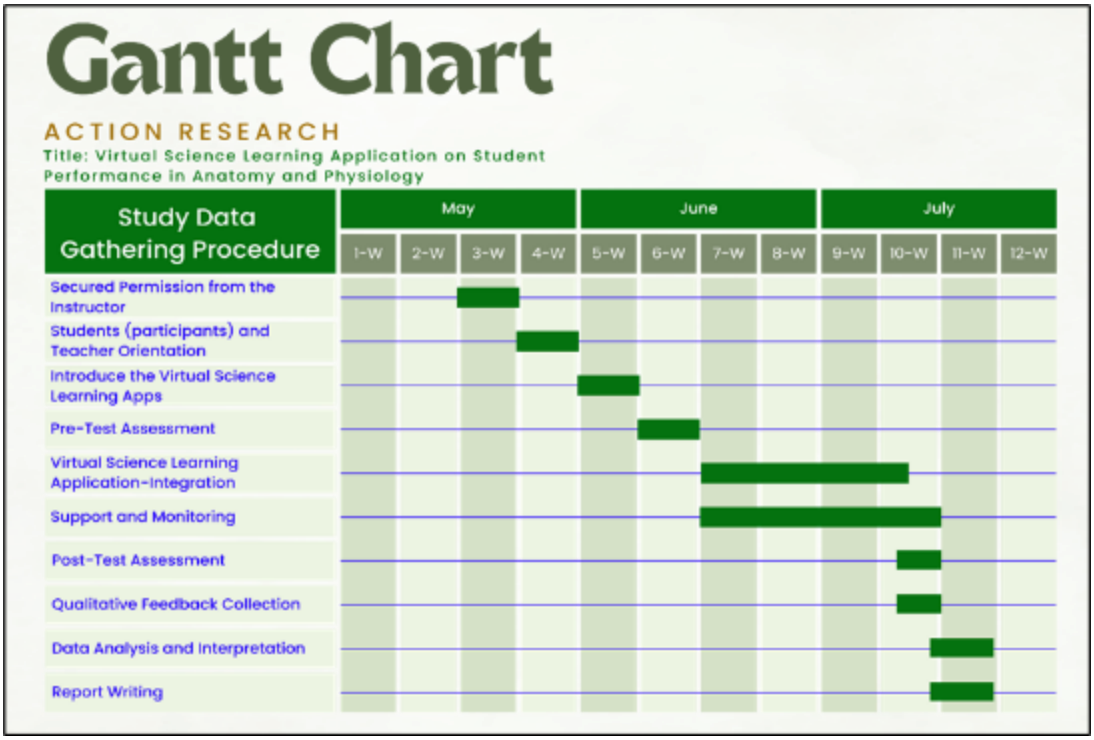

Figure 8 Gantt Chat for Data Gathering Procedure

3.6. Data Analysis

To ensure the quality and integrity of this qualitative study, several strategies were employed to establish the trustworthiness of the data. These include peer debriefing, member checking, triangulation, transferability, dependability, and confirmability—each contributing to the credibility and reliability of the findings. Peer debriefing involved presenting the research process and emerging results to colleagues uninvolved in the study. Their external insights helped identify potential biases, gaps, or overlooked perspectives, strengthening the objectivity and depth of analysis (Spillett, 2003; Figg, 2009). This collaborative critique refined both the methodology and interpretation of findings.Member checking, or respondent validation, allowed participants to review interview transcripts and observation notes to confirm the accuracy of their contributions. By validating their own experiences, participants ensured the authenticity of the data and contributed to the study's credibility (Birt, 2016; Hallett, 2012). Triangulation was achieved through the use of multiple data collection methods, including questionnaires, interviews, performance assessments, and observation checklists. This multi-method approach enriched the data, allowing for cross-verification and reducing potential bias (Noble, 2019; Carter, 2014). Transferability was addressed by providing a detailed description of the study context, participants, and procedures. This "thick description" enables readers to assess how the findings may apply to similar educational settings, particularly within the context of Abuyog Community College and its third-year BSEd science students (Younas, 2023). Dependability was ensured through a transparent audit trail documenting every phase of the research—from data collection to analysis and decision-making. This traceable process allows future researchers to replicate the study or evaluate its methodological soundness (Bowen, 2009). Confirmability was supported by reflexivity, where the researcher acknowledged their own biases and their influence on the research process. Member checking further validated that findings genuinely reflected participants' perspectives. While audit trails also support confirmability, care was taken not to let process override the importance of interpretive credibility (Cutcliffe, 2004). Altogether, these strategies strengthen the trustworthiness of the study by ensuring that the findings are credible, reliable, transferable, and grounded in participants' real experiences. This framework supports a robust evaluation of how virtual science learning applications influence student performance.

3.7. Ethical Considerations

This study upholds strict ethical standards to ensure the validity of data and protect all participants from harm. Key ethical principles guided the research process, as outlined below. Participants were first provided with informed consent, clearly detailing the study's purpose, methods, potential risks and benefits, and their right to withdraw at any point without consequences. Both students and instructors signed written consent forms. While informed consent is universally recognized in ethical research, challenges such as literacy levels and comprehension often complicate its implementation (Lipman, 2007; Kadam, 2017; Xu, 2020). Despite debates over how much information to disclose or the

best method to secure consent, its necessity is widely accepted. Researchers must continue developing accessible and meaningful ways to inform participants. Confidentiality and anonymity were strictly maintained. Participants' names were replaced with codes, and identifying information was accessible only to researchers. Results were reported anonymously to uphold participant privacy. Although masking identities through aliases or altered attributes is common, researchers must remain sensitive to individual preferences and the ethical complexities involved (Crow, 2008). To minimize harm, the study was carefully designed to avoid negative impacts. The features of the virtual science learning tools were scrutinized, and participants were supported throughout the process to address any concerns or challenges. The principle of non-maleficence remains central to ethical research, requiring that any risks be minimized and potential benefits maximized (Bell, 2008). Participants were also assured of their right to withdraw at any point without penalty. This freedom was emphasized in the consent process, reinforcing respect for autonomy. Ethical research extends beyond procedures—it involves handling withdrawn data and storing sensitive information with care, especially in qualitative contexts (Dahal, 2024). Finally, ethical approval was secured from Abuyog Community College's institutional ethics review board. This approval confirmed adherence to ethical standards, including respect, beneficence, and justice. The role of ethics committees is crucial in evaluating risk, safeguarding participants, and promoting transparency, such as through the pre-registration of research protocols (Gelling, 2016; Tajir, 2018; Gelling, 2021).

4. Results and discussion

4.1. Demographics Information of the Participants

The characteristics of the studied population offer a better understanding of the findings drawn from this action research. The information on students' age, gender, and prior exposure to the applications of virtual learning assists in evaluating the extensiveness of the results. Age also presents itself as a factor that can determine not only learning but also perceptions of technology-enhanced learning.

The following is the profile of the respondents used in this study: Participants of this study are thirty (30) 3rd year BSEd Science students from Abuyog Community College grouped into experimental and control groups with fifteen-person capacity each. The evaluation group was assigned to sections utilizing virtual learning applications, while the compare group was allowed to browse conventional teaching techniques. This information is summarized below by means of the following table elaborated in more detail below

Table 1 Demographics Information

Respondents	Age Group	Gender	Previous use of virtual learning application
P1	20-24	Female	Yes
P2	20-24	Female	Yes
P3	20-24	Female	Yes
P4	20-24	Female	Yes
P5	20-24	Prefer not to say	Yes
P6	20-24	Female	Yes
P7	20-24	Female	Yes
P8	20-24	Female	No
P9	20-24	Male	Yes
P10	20-24	Prefer not to say	Yes
P11	20-24	Female	Yes
P12	20-24	Female	Yes
P13	20-24	Female	Yes
P14	20-24	Female	Yes
P15	20-24	Female	No

4.2. Age Distribution

All the participants were between the ages of 20-24 years. This age range is characteristic of college students, which means that the results can be applied to the target group of young people aiming at further education. The variation in parameters such as age and experience are slightly minimal in the case of these groups, thus providing the researcher with a means of comparing the effects of the virtual learning applications on students with fewer or limited differences in learning and technological preferences (Figure 9).

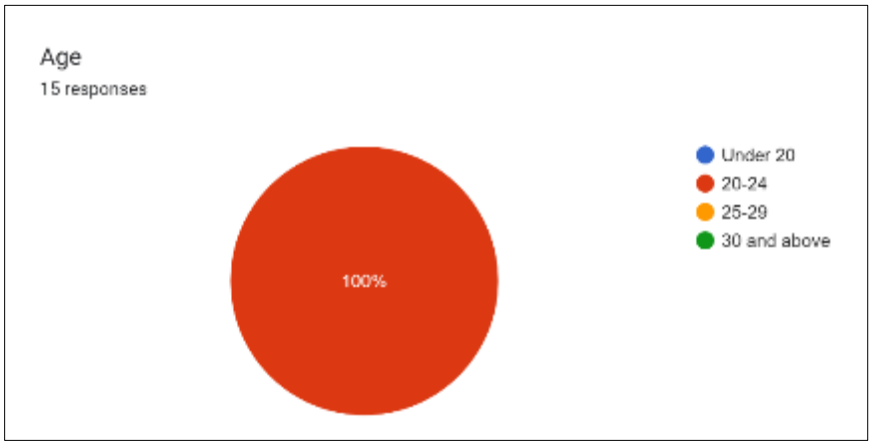

Figure 9 Age Distribution

4.3. Gender Distribution

Most of the participants were female; some participants marked male while others chose 'Prefer not to say.' The gender distribution is beneficial in understanding the possibly different perceptions and interactions of male and female students to virtual learning technologies. Prior studies reveal that gender plays an important role in attitude toward technology, and gender differences in technology anxiety are well documented; females tend to be more anxious and less self-confident in using technological tools than males. However, what has grown is the involvement of technology in the classroom, putting a stop to this disparity (Figure 10).

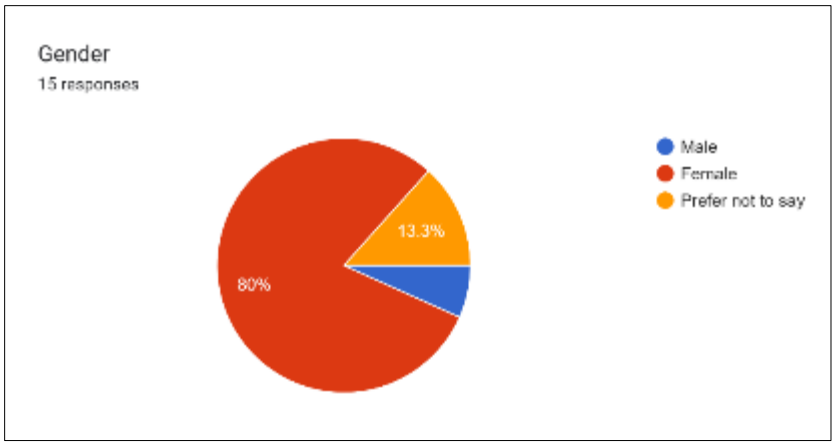

Figure 10 Gender Distribution

4.4. Prior Use of Virtual Learning Application

Most of the participants had prior usage of applications associated with virtual learning, and this is important for several reasons. First, familiarization or lack of familiarity with the technology can influence the rate and extent of student's learning with the new media resources. Second, in their pre-learning and historical encounter with virtual solutions applied in this study, their perceptions and satisfaction levels would be affected. The policymakers' positive prior experience in the experimental group might result in a more favorable attitude toward respecting the new applications. Meanwhile, the policymakers in the control group with less or no prior exposure might find traditional methods relatively easier or more effective (Figure 11).

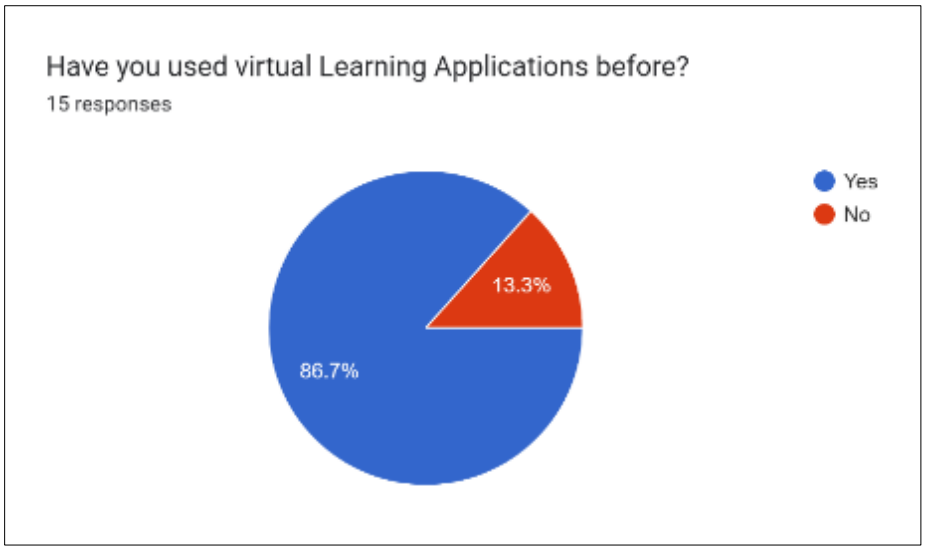

Figure 11 Prior Use of Virtual Learning Application

4.5. Data Collection and Analysis

This study used both quantitative and qualitative data to analyze the application of virtual science learning applications, hence meeting the mixed-method research design. The measures that were taken for quantitative data were descriptive statistics, paired t-tests, and correlation analysis to compare the experimental and control groups' pre-test and post-test scores (using SPSS).

4.5.1. Qualitative Results for Post-test and Pre-test scores Respondents Assessment Scores (pre-test and post-test) Experimental Group

Table 2 Experimental Group (pre-test and post-test scores)

Experimental Group		
Respondent	Assessment Scores	
	Pre-test	Post-test
P1	46	59
P2	28	45
P3	48	53
P4	39	48
P5	42	50
P6	33	39
P7	40	47
P8	25	32
P9	39	48
P10	40	47
P11	35	46
P12	39	43
P13	31	38
P14	35	46
P15	43	47

Table 3 Control Group (pre-test and post-test scores)

Control Group		
Respondent	Assessment Scores	
	Pre-test	Post-test
P1	54	66
P2	40	48
P3	59	69
P4	44	56
P5	47	58
P6	55	65
P7	55	59
P8	47	58
P9	43	60
P10	49	55
P11	44	49
P12	40	60
P13	43	53
P14	49	62
P15	50	60

Descriptive Statistics Descriptive statistics gives the researchers a central point for the distribution of the data. (Table 4.4 and Table 4.5) display the test result, Mean, and Standard Deviation of the experimental group as well as the control group on pre-test and post-test.

4.5.2. T-Test Statistic

Table 4 Paired Sample Statistic of Experimental Group

Pair 1	**N**	**Mean**	**Std. Deviation**
Pre-test	15	37.53	6.402
Post-test	15	45.87	6.346

Table 5 Paired Sample Statistic of Control Group

Pair 1	**N**	**Mean**	**Std. Deviation**
Pre-test	15	47.93	5.812
Post-test	15	58.53	5.842

The paired sample statistics show that the mean pre-test score of the experimental group was 37.53 (SD = 6.402), while the mean post-test score was 45.87 (SD = 6.346). In the other group, which is the control group, the mean pre-test score was 47.93 (SD = 5.812), and the mean post-test score was 58.53 (SD = 5.842). This result conveys that both groups showcase a development in scores from pre-test to post-test.

Paired Samples Statistics: The paired samples statistics contain precise information on the mean differences between the scores of the pre-test and the post-test with each group.

Table 6 Paired Samples Statistics for Experimental Group

Pair 1	Mean	N	Std. Deviation	Std. Error Mean
pre-test – post-test	37.53	15	6.402	1.653
	45.87	15	6.346	1.638

Table 7 Paired Samples Statistics for Control Group

Pair 1	Mean	N	Std. Deviation	Std. Error Mean
pre-test	47.93	15	5.812	1.501
post-test	58.53	15	5.842	1.508

The paired sample statistics highlight the refinement within each group. The mean difference for the experimental group was -8.333, with a standard deviation of 3.519, conveying a significant improvement. Likewise, the control group showed a mean difference of -10.600, with a standard deviation of 4.171, resulting in an even significant improvement.

Paired Sample Correlations: The paired sample correlations show the degree of relationship between the pre-test and the post-test scores in each group.

Table 8 Paired Samples Correlations for Experimental Group

Pair	N	Correlation	Sig. (2-tailed)
Pre-test & Post-test	15	0.848	0.000

Table 9 Paired Samples Correlations for Control Group

Pair	N	Correlation	Sig. (2-tailed)
Pre-test & Post-test	15	0.744	0.001

The result showed a high correlation for both groups *(experimental: 0.848, control: 0.744)*, resulting in a strong connection between the pre-test and post-test scores. This result suggests that the student's performance in the pre-test is a good predictor of students' performance in the post-test.

A paired sample test is used in this study to compare the pre-test and post-test scores conducted in each group.

Table 10 Paired Samples Test of Experimental and Control Group

Group	Paired Differences	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	95% Confidence Interval of the Difference
E. Group	Pre-test & post-test	-8.333	3.519	0.909	-9.842	14	0.000	Lower-10.282 Upper-6.385
C. Group	Pre-test & post-test	-10.600	4.171	1.077	-9.172	14	0.000	Lower-12.910 Upper-8.290

The paired samples test results showed that the increase in scores for both groups is statistically significant ($p < 0.001$). The 95% confidence intervals for the differences in means do not include zero, further confirming the significance of the results. The experimental group's confidence interval is (Lower-10.282, Upper-6.385), and the control group's confidence interval is – (Lower-12.910, Upper-8.290).

It was equally observed that both groups improved. However, the level of improvement shown by the experimental group was higher than the control group, where the mean improvement was (-8.333) to (-10.600). From this, it can be inferred that the traditional teaching method might have been slightly more appropriate. Nonetheless, in the experimental group, there was also high enhancement, which proves that the new method of teaching is possible.

In conclusion, this study implies that while shifting teaching is efficient in enhancing students' performance, traditional and new teaching approaches are efficient. While the mean improvement for the groups that underwent the traditional method was slightly higher, the mean improvement with the new method also ranked positive. Thus, the findings of this study are useful for understanding the possibilities of various teaching approaches and indicate that both types of interventions are potentially helpful in improving students' learning achievements. Hence, the results describe and explain the analysis of the collected data under T-test descriptive statistics, paired samples statistics, paired samples correlations, and paired samples tests. These results have been discussed in the study, concluding the evaluation of the practical applicability of the teaching approaches under consideration, especially in using technology tools like virtual science learning applications.

4.6. Descriptive Statistics for Likert Scale Items

In this study, Virtual Learning Applications means researchers seek to determine how the use of virtual learning applications in anatomy and physiology courses affects students' engagement and their performances in such courses. The use of Virtual Learning Applications means a change from the normal traditional teaching and learning practices that involve the use of highly interacted graphics and animated materials that may have the potential to expand students' knowledge base in difficult concepts. The Likert scale questionnaires were also used in this study to categorically quantify the students' responses regarding this new approach to teaching.

The Likert scale that is used in this study is a set of statements that are concerned with the use of virtual learning applications. The student's perceptions of the learning environment were measured based on the self-rating of their level of agreement with each state which was responded in a Likert scale of Strongly Disagree-(SD), Disagree-(D), Neutral-(N), Agree-(A), and Strongly Agree-(SA). It is a more objective quantitative approach that gives a highly detailed view of the student's perceptions and experiences; consequently, it allows them to quantify their attitudes to the new instructional method.

Table 11 Summarized Likert Scale Survey Responses

Survey Statement	**SD**	**A**	**N**	**D**	**SA**
A: Engagement and Interest					
S1: Using the virtual learning applications increased my interest in studying anatomy and physiology.	11	3	1	0	0
S2: I felt more engaged in my anatomy and physiology classes when using the virtual learning applications.	10	3	1	1	0
S3: The virtual learning applications made learning anatomy and physiology more enjoyable.	11	3	1	0	0
B: Understanding and Comprehension					
S4: The virtual learning applications helped me understand difficult concepts in anatomy and physiology.	8	6	1	0	0
S5: I found it easier to retain information when using the virtual learning applications.	10	4	2	0	0
S6: The visual and interactive elements of the virtual learning applications enhanced my learning experience.	7	7	1	0	0
C: Usability and Accessibility					
S7: The virtual learning applications were easy to use and navigate.	8	5	2	0	0

S8: I had sufficient access to the necessary technology to use the virtual learning applications effectively.	8	5	2	0	0
S9: Technical issues with the virtual learning applications were minimal and did not interfere with my learning.	7	6	2	0	0
D: Overall Satisfaction					
S10: Overall, I am satisfied with my experience using the virtual learning applications in anatomy and physiology.	9	5	1	0	0
S11: I would recommend the use of virtual learning applications to other students studying anatomy and physiology.	11	3	1	0	0
S12: The virtual learning applications should be integrated into more courses beyond anatomy and physiology.	11	3	1	0	0

Descriptive Statistics for Likert Scale: The table below presents the mean and standard deviation for each item on the Likert scale, indicating the general trends in students' perceptions.

Table 12 Descriptive Statistics for Likert

Question	Mean	Std. Deviation	Minimum	Maximum
Q1	4.60	0.632	3.00	5.00
Q2	4.47	0.743	2.00	5.00
Q3	4.53	0.629	3.00	5.00
Q4	4.33	0.617	2.00	5.00
Q5	4.53	0.629	3.00	5.00
Q6	4.47	0.743	2.00	5.00
Q7	4.40	0.621	2.00	5.00
Q8	4.27	0.593	2.00	5.00
Q9	3.80	0.961	1.00	5.00
Q10	4.33	0.724	2.00	5.00
Q11	4.33	0.724	2.00	5.00
Q12	4.27	0.679	2.00	5.00

The findings show that there is a general acceptance of virtual learning applications among students due to the high mean values observed in most of the items. Especially the questions associated with engagement (Q2), enjoyment (Q3), and the easiness of information retention (Q5) elicited high scores, indicating that the students benefitted from the virtual learning tools in enhancing engagement, enjoyment, and information retention ease.

Reliability Analysis (Collins, 2007), is a way of assessing reliability by comparing the amount of shared variance, or covariance, among the items making up an instrument to the amount of overall variance.

Table 13 Reliability Statistics

Cronbach's Alpha	N
0.956	12

The reliability index in the form of Cronbach's Alpha value was (0.956), which shows evidence of excellent internal reliability as the items on the scale are very related and suggest the same concept. This high reliability justifies the use of the Likert scale assumption in arriving at the conclusions made.

Exploratory factor analysis (EFA) is used to determine the underlying structure of the Likert scale items.

Table 14 KMO and Bartlett's Test

Measure	Value
Kaiser-Meyer-Olkin (KMO)	0.837
Bartlett's Test of Sphericity	Chi-Square Approx. 455.626
df	66
Sig.	0.000

The obtained value of KMO was 0.837, which is quite decent, which means that the number of cases is sufficient for factor analysis. Where Bartlett's Test Sphericity is significant ($p < 0.000$), this is enough evidence to proceed with EFA as the current correlations between the items are adequate.

Table 15 Total Variance Explained

Component	Initial EIGENVALUES % OF Variance	Cumulative
1	7.59	63.20
2	1.07	71.13
3	0.73	77.15

The values of the total data variance, as reflected by the initial eigenvalues, indicate that the first factor accounts for 63.20%. It identified that variance is accounted for and this according to its significance. This suggests that most of the movement in the data can be accounted for by one latent factor supporting the notion that the Likert scale items reflect a single construct concerning virtual learning applications' effectiveness.

Thus, the results of descriptive statistics, reliability analysis, and exploratory factor analysis illustrate the overall picture of the perceptions that students have about virtual learning applications. The scale analysis reveals a positive attitude with the Likert scale mean scores in all the items approving and supporting students' view that Virtual learning tools positively impact students' engagement, comprehension, and learning experiences in anatomy and physiology.

The Cronbach's Alpha coefficient is very high at (0.956), meaning that the Likert scale items used to gauge the students' perception have reliable internal consistency. The EFA results also confirm this as one component reveals a considerable amount of variation, which suggests that the items are used to pinpoint the usefulness of the virtual learning applications.

Based on the findings, incorporating virtual learning applications in students' anatomy and physiology classes can have a positive impact on the extent of students' learning. The feedback received refers to some aspects of the developed applications, where several features that enhance the feasibility of the Integration of these tools into the curriculum can be noted. This corresponds with the general objectives of the study, which sought to address the use of innovative methods in enhancing students' achievement.

Therefore, the structure and results of the Likert scale analysis give useful and detailed information about the student's views on virtual learning applications. All the positive responses to the items suggested that using these tools is an advantage if used in anatomy and physiology lessons. These characteristics enhance the validity of the findings since the scale was highly reliable and consisted of a single dimension. These findings help advance the knowledge of the effects that new forms of learning technologies can have on learning effectiveness in tertiary education.

5. Thematic Discussion of Findings

5.1. (SOP 1) Theme 1: Influence of Virtual Learning Applications on Student Engagement

The use of technologies in virtual learning environments and their impact on the engagement of students focuses on the effects of learning tools, which are interactive and visually appealing regarding students' motivation, attendance, and level of engagement in class. This is an essential theme that determines the benefit of digital learning tools in developing educational experiences, mainly in difficult courses like Anatomy and physiology.

Since the emergence of applications of virtual learning, a new dimension or overall change in learning styles has opened. Researchers are intended to capture the learner's active participation, hence making learning more fun and efficient. From the perspective of Anatomy and Physiology, applications can refer to 3D view models, simulation models, and quizzes that can be in line with the virtual models, as this allows for the students to be able to comprehend the concepts shown and manipulated in a physical way rather than just being taught and thus only understanding in a theoretical manner.

The results obtained for questions directly concerning student motivation (Q1, Q2, Q4, Q6) express high mean values (table 4.12), which points to the fact that the applications of virtual learning contributed considerably to the motivation of students. In this regard, students expressed higher levels of motivation and interest in the course contents when using the virtual tools. This conforms with knowledge from past research, which posits that through gamification and place-based learning methods, the learners' engagement would rise (Jingyuan Chen, 2023).

As stated by (Putu Wuri Handayani, 2021), the learning management system offers prospects for active learning, hence increasing the students' involvement and participation. Such work contributes to such findings by presenting students' engagement as higher among those who used virtual learning applications as opposed to those who relied on traditional means.

5.2. Sub-theme 1. 1: Increased Motivation

The P2, P7, P13, and P14 were motivated to learn Anatomy and Physiology with the help of virtual learning applications. This discovery is in harmony with previous research that seeks to unravel the factors that influence students' performance in their studies. Incentives can also be a virtue since when students are intrinsically motivated, they will be able to study hard, play active roles during classroom sessions, and certainly get better grades.

- P2: "Virtual learning applications made me more interested in studying anatomy and physiology as I am both enjoying while learning."
- P7: "It increases my motivation to study more."
- P13:" Using virtual learning applications, I would say that my interest in anatomy and physiology class has increased, and I am more engaged and cooperative in the class."
- P14: "The virtual learning applications greatly increased my engagement during anatomy and physiology classes. The interactive nature of the tools kept me actively involved in the learning process."

Thus, P2, P7, P13, and P14 answer stresses the concepts of pleasure and fun while also implying that the applications for virtual learning are enjoyable. In line with the (Self-Determination Theory), enjoyment has a positive interaction with intrinsic motivation; P2, those who derive pleasure in their studies are more intrinsically motivated.

In its simplicity, the statement above puts much focus on how applications of virtual learning affect the motivation of the participants. This can be explained by the fact that through such tools, learning becomes more attractive, and this could have resulted in increased motivation. A study conducted by (B. Neeraja, 2020) were indicated that through motivation, students will tend to embrace self-regulating mechanisms for learning, hence improving academic performance. Utilizing virtual learning applications has allowed me to confess that my interest in anatomy and physiology class has grown, and students have become active and willing to cooperate in the class.

5.3. Sub-theme 1. 2: Active Participation

Some of the findings based on the data obtained are that virtual learning applications contribute to the increase in students' activity levels during the learning process. In as much as the interactivity of these applications has been found to contribute to the increased engagement of P2, P4, P13, and P15, stated felt more involvement and cooperation during classes.

- P2: "It made me more engaged as I could actively recall the concepts I have encountered in the apps when our teacher has a recitation."
- P4: "Through its interactive features, I find it enjoyable and interesting as it is very helpful and beneficial towards us/students. It makes us more engaged during class hours."
- P13: "Using virtual learning applications, I would say that my interest in anatomy and physiology class has increased, and I am more engaged and cooperative in the class."
- P15: "Through a virtual learning app, I can participate during the discussion because I have prior knowledge of the topic."

P2, P4, P13, and P15 responses indicate the effectiveness of application in active participation. Hence, literature evidence is in line with the idea that virtual learning environments foster active learning and consequently increase students' engagement and participation. According to (B. Neeraja, 2020), the paper affirms that the versatility of virtual learning environments can spur the aspect of active participation, thus making the learning process more participative. This research work, therefore, affirms these findings, identifying that students using the virtual learning applications were more engaged with their learning process than those who adopted the conventional approaches.

In another study involving learners' engagement and participation, (Jingyuan Chen, 2023) noted that the use of gadgets for virtual learning boosts engagement and learners' participation immensely. These tools ensure that learners engage with the content and make changes from time to time, ensuring better performance.

5.4. (SOP 2) Theme 2: Impact on Performance and Understanding

The comparison of the results obtained in pre-tests between the control and the experiment group shows that the knowledge gained in the experiment group was much higher, which proves that the virtual learning applications influenced the students' performance and comprehension positively.

As to the statistical results in the Control Group, they had an average score of 47.93 in pre-test, and the mean post-test score was 58.53, showing an improvement of -10.06 points. In the experimental group, the mean pre-test score was 37.53, and the mean post-test score was 45.87, showing an improvement of -8.34 points. The mean difference denotes that both groups gained something; however, overall enhancing learning, the experimental group gained more, thus highlighting the importance of Virtual learning applications in the improvement of the Retention and understanding of knowledge.

The researchers have had a key observation during the implementation of the virtual science learning application. First, Improved Scores: The experimental group's significant improvement in post-test scores highlights the effectiveness of virtual learning tools in helping students retain and comprehend complex information in Anatomy and Physiology. This aligns with the principles of active learning, where interactive elements can make abstract concepts more concrete and understandable. Second, Engagement and Interaction, the interactive nature of virtual learning applications, likely contributed to these improved scores. Interactive tools can engage students more effectively than traditional methods, providing immediate feedback and allowing for a more personalized learning experience. This engagement is crucial for deeper understanding and Retention of information.

- Several studies support the findings of this study, highlighting the benefits of virtual learning applications in improving student performance, based on the testimony of P4, P6, P8, P1, and P3:
- P4: "The thing is, virtual learning applications were a great factor in my interest, which made it easier to cope with and understand certain topics in studying anatomy and physiology."
- P6:" It helps me to learn more, easily understand, and have an experience in the Laboratory and experimenting."
- P8:" It was not hard to retain the concept."
- P3: "Virtual learning application is interesting, especially the 3D visualization because it has a model wherein you can easily understand, but it is somewhat difficult."

Interactive and Personalized Learning pointed out that virtual learning tools help to improve the performance of students as learning activities are fun-filled and can, in a way, be customized for individual students. It enables the learners to work at their abilities and speed, making it enjoyable, and the learners can easily understand more ideas and concepts.

Active Learning and Knowledge Retention Theory of Multimedia Learning provides empirical evidence to suggest that interactive multimedia can play a vital role in learning by increasing classroom interest and course material interest, as well as making use of multiple senses to increase the comprehensiveness of learning. This theory is supported by the

conclusions made in this study, where one identified that the students who used virtual applications were performing and comprehending better.

Enhanced Learning Outcomes, in the participants' review, suggested that students are actively learning in virtual learning environments, hence enhancing learning achievement. These findings correspond to the enhanced post-test alterations in the experimental group, proving that virtual learning applications indeed improve educational achievements.

Therefore, it proved clear through the enhanced post-test results of the experimental group, hence validating the effectiveness of virtual learning applications to enhance students' performance. These tools not only help in the acquisition and understanding of information but also in the way the content is more interesting and efficient in delivering specific knowledge. The sync with the literature review on the principles of interaction and personalization of learning strengthens the applicability of virtual learning applications in learning environments. When implemented in conventional academic programs, achievement and comprehension of concepts such as Anatomy and Physiology can be enhanced, as exemplified by the Integration of these tools into traditional curricula.

5.5. (SOP 3) Theme 3: Student Perception of Virtual Learning Applications

Consequently, understanding the perceptions the students hold about these applications of virtual learning is crucial for the evaluation of such applications and students' suitability for increased deployment. The few comments received further support the function delivered by such applications in increasing learners' satisfaction regarding learning because of fun when learning difficult subjects such as Anatomy and Physiology.

Exploring the Likert scale responses, students had positive attitudes toward the virtual learning applications regarding the construct of enjoyment and satisfaction. The questionnaire results indicated that the mean values for questions (Q3, Q5, Q7, and Q9), which focused on the student's enjoyment and satisfaction with the virtual tools, were particularly high, showing that students were not only served or helped by the tools but also enjoyed using them. This is important as a positive reception means that the students will be encouraged to use these tools optimally.

- P3: "The virtual learning applications made learning anatomy and physiology more enjoyable."
- P7: "I found it easier to retain information when using the virtual learning applications."
- P9: "The virtual learning applications were easy to use and navigate."
- P11: "Technical issues with the virtual learning applications were minimal and did not interfere with my learning."

These positive student perceptions of participants (3,7,9 and 11) also join some of the theoretical frameworks and empirical studies.

First, the Technology Acceptance Model (TAM) posits that perceived usefulness and perceived ease of use are two of the major factors leading to the acceptance of new technologies. The results of this study support TAM, as students found the virtual learning applications useful and easy to use. If they believe a tool is conducive to better learning and is user-friendly, then they will adopt and integrate the same into their study routines. Second is the engagement theory, which states that engagement is at the very heart of learning. This condition thus fills the heightened student engagement in virtual learning applications with prospects for improved understanding. Only those who are more engaging take part actively in learning, hence understanding things better. Third, in the Cognitive Theory of Multimedia Learning, well-designed multimedia learning environments can enhance complex information understanding and Retention. The elements that will fit this theory within virtual learning applications are interactive and visual, making subjects like Anatomy and Physiology more approachable and digestible for students. Fourth, student-centered learning, such as virtual learning environments, can help with student-centered approaches where students take an active interest in the learning process. This paper supports such contention by showing that virtual learning applications have the power to let students further engage with the material and create a far more personalized and effective experience for each learner.

Thus, this indicates that students generally really enjoy using virtual learning applications, not only in terms of enjoyment and satisfaction but also because the user-friendly and reliable nature of these tools enhances the enjoyment and overall satisfaction with the learning experience. The potential of virtual learning applications to change traditional ways of teaching further glutamates with their alignment to theoretical frameworks on TAM, Engagement Theory, and Cognitive Theory of Multimedia Learning. Integrating these applications into the curriculum will ensure improved educational output and a more engaging, satisfying experience for students in their learning that is effective.

5.6. (SOP 4) Theme 4: Components of Virtual Learning Applications and Learning Outcomes

The participants identified the interactive simulation and 3D models of structures as the most valuable components that helped in a better understanding of the complex anatomy and physiological processes, which are usually difficult to clean with traditional methods of teaching.

The researcher was able to observe the participant's engagement through the learning applications, and it enables manipulation and the exploration of 3D models, thereby letting students appreciate complex anatomical structures and their spatial relationships more clearly. This hands-on interaction makes the learning process more engaging; therefore, such abstract concepts become more concrete and easier to learn. Higher levels of engagement, Active simulations engage learners by letting them get hands-on in the learning process. Such interactivity, apart from allowing more enjoyable learning, also helped improve Retention and grasp of the subject matter. Students could experiment, test out hypotheses, and find answers immediately, which reinforced their learning and, hence, Better Outcomes in Learning; as the use of interactive simulations and 3D models is positively correlated with better learning outcomes, these components could have contributed to an increase in student performance. The content visualization and interaction abilities developed could have led to higher post-test scores and better comprehension of complex concepts. Participants (1, 6, and 9) highlighted the positive impact during the Integration.

- P1: "The 3D anatomy models helped me envision the structures in anatomy that I could not quite get from textbooks. It is easier to learn when you have an idea and can visualize and manipulate it."
- P6: "Interactive simulations have let me in on the dynamics of physiological processes. I could see how various systems interacted and influenced one another, which has been very helpful."
- P9: "Through the visual and interactivity aspects, the virtual learning applications packaged complex learnings into stuff that was easier to learn. I could fiddle and learn at my own pace, which improved my comprehension and Retention."

Specifically, this study's findings fall in with multimedia learning principles (Mayer, 2021), focusing on interactive and visually rich content for enhancements in understanding and Retention. (Mayer, 2021) Cognitive Theory for Multimedia Learning, Interactivity, and Multimodal Content will challenge students to learn better. In an interactive simulation, 3D models work in accordance with this theory since they provide a visual and kinesthetic experience for the learner, resulting in better comprehension and Retention of information.

Moreover, Visual and interactive content effectiveness study shows that the learning outcome was greatly improved when visual aids, in the form of 3-D models, were employed since these would provide an easier view and thus a more intuitive one of complex concepts. Engagement and Retention: interactive, very visual educational tools engage students better and enhance Retention. Involvement in the material through simulations and models could promote stronger learning and make the educational experience more enjoyable.

Therefore, it would be the effect of interactive simulations and 3D models on student learning outcomes that would show students' worth as constituents of virtual learning applications. These tools make the learning environment more engaging and interactive, allowing learners to project 3-D images that help in understanding abstract concepts, hence leading to better performance and comprehension. Alignment with (Mayer, 2021) multimedia learning principles and supporting literature serves to further validate their effectiveness as interactive and visually rich educational tools. This will increase the level of student engagement, understanding, and Retention in complex subjects like Anatomy and Physiology through such component additions in traditional and virtual learning environments.

6. Conclusion

Anatomy and Physiology education has significantly benefited from the integration of virtual learning applications, which have proven to enhance student engagement, performance, and conceptual understanding. This action research revealed that learners using virtual tools outperformed those taught with traditional methods, both in terms of knowledge retention and test results. Interactive simulations and 3D models emerged as particularly effective components, helping students visualize complex anatomical structures and physiological processes more clearly. The findings confirm that virtual learning applications not only increase academic performance but also foster positive student attitudes and motivation toward learning. These results support the adoption of virtual tools alongside traditional teaching practices to create a more interactive and immersive learning environment that accommodates diverse learning styles. Overall, the study establishes that virtual learning applications are valuable in advancing educational practices and should be considered an essential addition to science education curricula.

Recommendations

Based on the findings, it is recommended that educational institutions integrate virtual learning applications, especially in complex subjects like Anatomy and Physiology, to boost student engagement and achievement. Educators should receive proper training to maximize the effectiveness of these tools and ensure meaningful classroom integration. Schools and universities are encouraged to invest in educational technologies featuring interactive content and rich visual media, such as 3D models and simulations, to support deeper learning. Further research should explore the long-term impact of virtual learning applications across various disciplines and educational levels. Additionally, developers of virtual tools should continuously gather feedback from users to improve usability and effectiveness. Combining traditional methods with virtual applications can transform the learning experience, increase student success, and support the modernization of science education.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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