Teaching Human Anatomy and Physiology Using 3d Augmented Reality and Guided Inquiry-Based Learning to College Students

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ABSTRACT

In teaching Human Anatomy, learners often experience difficulties learning the human body due to limitations and challenges, such as a lack of material, the expense of cadavers for dissection, aan nd an overwhelming amount of information. The researcher aimed to overcome the mentioned obstacles by using 3D augmented reality and an inquiry-based learning approach to support students' learning activities. The research centers on evaluating the effectiveness of 3D augmented reality and the Inquiry-Based teaching method in teaching the muscular system in a human anatomy and physiology course to college science major students. The respondents were the entire population of Bachelor of Science in Education major in science students at Sibonga Community College - Poblacion, Sibonga, Cebu. In the study, the students strongly agreed that the chosen teaching strategy and materials were effective in helping them learn human anatomy. There is also a significant difference in the treated data, leading to the rejection of the null hypothesis. Conversely, there must be aspects to focus on to ensure great results when using the application and inquiry-based learning, such as strategically constructing the questions, orienting students, and practicing using the application before using it in the instructions. Other than that, the research can provide insight into the efficacy of the materials. Thus, it is recommended that 3D augmented reality and Inquiry-Based teaching materials for the muscular system in human anatomy and physiology courses are ideal and effective.

Keywords: Human Anatomy, 3D Augmented Reality, Inquiry-Based Learning, Muscular System, College Science Students

INTRODUCTION

Recent studies highlight that teaching methods in Human Anatomy have modernized, incorporating e-learning and anatomical models (Singh et al., 2021). In developing nations, education in the 21st century is seen as a means to address teaching challenges, improve the quality of life, and achieve national goals (Aryeni, 2022). Human Anatomy, a vital prerequisite across disciplines and essential for future science teachers, remains difficult to teach due to its complexity and students' sentiments. Effective pedagogy is crucial for motivating learners and ensuring academic success (Chairueang, 2022).

Despite its importance, challenges persist: declining student performance, limited resources, costly cadaver dissections, and overwhelming information overload. At Sibonga Community College, limited access to modern tools exacerbates these issues. As future educators, students must be exposed to effective strategies and materials to model best practices in teaching.

The research aims to evaluate the efficacy of 3D learning models and Guided Inquiry-Based Learning (GIBL) in teaching Human Anatomy and Physiology, specifically the muscular system. These approaches seek to bridge the gap between theory and practice, offering accessible, cost-efficient alternatives. Prior studies reveal that even with cadaver dissection, students struggle with structural visualization and curricular design (Ngan et al., 2017; Cheung, 2021). The lack of hands-on experience, coupled with the cost of laboratory materials and limited 2D/3D resources, hinders comprehension (Campbell, 2021; Moro et al., 2021).

Recent evidence supports 3D learning as an advanced, interactive tool that enhances spatial understanding, engagement, and memory retention (Radianti et al., 2020; Moro et al., 2021; Sperl, 2020). By integrating 3D visualization with inquiry-based strategies, this study seeks to improve student performance, motivation, and accessibility in anatomy education.

METHODS

Research Design

This study employed a quasi-experimental design with a quantitative approach, utilizing a same-group pretest–posttest method to evaluate the effectiveness of the instructional paradigm. The design was chosen to measure the relationship between the independent variable—Guided Inquiry-Based Learning (GIBL) supported by 3D learning materials—and student performance in Human Anatomy and Physiology.

Data were analyzed using mean, standard deviation, and t-test to determine significant differences between pretest and posttest scores. This evaluative research design enabled a systematic appraisal of the instructional strategy and gathered meaningful feedback from respondents to identify strengths and areas for improvement (Rossi, Lipsey, & Henry, 2019).

A survey complemented the quantitative results, capturing students' perceptions of the materials and strategies. This dual approach provided both statistical evidence and experiential insights, ensuring that conclusions drawn were robust, practical, and relevant for classroom application.

Participants

The respondents were the entire 3rd year B.S.Ed. Science major students in Sibonga Community College. Most of them are 20-21 years old and residents of the Municipality of Sibonga and Carcar City. The cohorts belong to the batch that has been greatly affected by the pandemic and had been students of modular and online learning. Since the population of the respondents is small in number the researcher decided to choose population type. Population is the entire set of individuals in a particular group that composes the data pool for a study to observe in order to come up with a conclusion (Bhandari, 2022).

Table 1 Frequency Distribution of Respondents

Respondents	Total Population		Total
	Male	Female	
BSED Science 3	6	15	15
Total			15

Research Setting

This study was conducted in Sibonga Community College, which was established in 2008, a public non-sectarian higher education institution located in Poblacion, Sibonga, Cebu. Recognized by the Commission on Higher Education (CHED), the College serves approximately 3,000 students. It offers baccalaureate programs in Information Technology, Business Administration, BSED English, BSED Mathematics, BSED Science, and BEEd Teacher Education.

Its mission is to provide quality and holistic education across diverse fields, fostering graduates who act as catalysts for community and national development. The institution upholds the core values of self-discipline, commitment, and compassion.

Research Instrument

The researcher adopted Likert-scale statements on the application of 3D learning materials from recent studies on the use of interactive and 3D visualization tools in anatomy education (Moro et al., 2021). The researcher

created a 30-item test questionnaire, which was used for both the pretest and post-test as the primary data-gathering procedure. The 30-item test was created based on the competencies. The statements were crafted to assess how good the articulation was, how relevant the questions were to the topic, and whether the scale was on point and not too vague, and were based on and guided by Beagle Learning's Question Productivity Index (QPI) Rubric.

Data Gathering

Before data collection, a transmittal letter was submitted to the College President for approval to conduct the study. Once approved, a letter was sent to the respondents, followed by a semi-formal orientation to explain the nature of the research and emphasize the importance of their participation. A **pretest** was then administered to establish baseline scores and averages before the intervention. During data gathering, the respondents attended a class where **3D learning materials** and **Guided Inquiry-Based Learning (GIBL)** strategies were applied to teach competencies from the Human Anatomy and Physiology syllabus. Students engaged in guided activities, answered structured questions, collaborated with peers, and consulted educational resources to deepen their understanding of the subject. After the intervention, a **post-test** was conducted to measure learning outcomes. The pretest and post-test scores were then analysed using **a t-test**, along with the mean and standard deviation, to determine significant differences. Results were assessed to draw valid conclusions and provide strong recommendations regarding the effectiveness of the 3D model and GIBL approach in teaching Human Anatomy and Physiology.

Data Analysis

The study employed a dependent t-test to compare pretest and post-test results from the same group of respondents. This statistical method was appropriate since the population was tested twice under different conditions, allowing the researcher to determine whether the intervention using 3D learning materials and Guided Inquiry-Based Learning (GIBL) produced significant improvements. The assumptions for the t-test included: (1) participants drawn from the same sample group, (2) absence of significant outliers between datasets, and (3) approximate normal distribution of differences in scores.

To complement the quantitative analysis, a Likert scale survey was administered to capture students' perceptions of the instructional strategies and materials. It provided qualitative insights into the acceptability and effectiveness of the intervention.

For scoring, both pretest and post-test results were evaluated using a performance matrix. Scores were categorized as follows: 1–3 (Not Meeting Expectations), 4–6 (Poor Performance), 7–8 (Satisfactory, aligned with the 50% passing rate), 9–11 (Very Satisfactory), 12–13 (Excellent), and 14–15 (Outstanding). This matrix served as the basis for comparing academic performance before and after the intervention.

The combination of t-test analysis and Likert-scale evaluation enabled the researcher to assess both statistical significance and student perceptions. This dual approach ensured that conclusions were supported not only by quantitative evidence but also enriched by experiential feedback, thereby strengthening the validity of recommendations for classroom application.

Ethical Considerations

The researcher ensured that the study adhered to ethical standards throughout by involving the respondents, who were the entire 3rd-year B.S.Ed. class. Science major students at Sibonga Community College volunteered. They were informed of the study's purpose and assured that their responses would be kept strictly confidential. No personal identifiers were included in the data presentation to protect their privacy.

Given that the respondents are young adults (20–21 years old) and part of a cohort significantly affected by the pandemic, sensitivity was exercised in framing questions to avoid psychological discomfort. The researcher

guaranteed that the data collected would be used solely for academic purposes and that the findings would be reported honestly, without manipulation.

Before data collection, permission was sought from the appropriate academic authorities, and informed consent was obtained from the participants. The study complied with institutional and community ethical guidelines, ensuring respect, fairness, and integrity throughout the research process.

RESULTS AND DISCUSSION

The chapter covers the organized presentation of data; analysis provision; and narrowing down perplexities in this research through exquisite interpretation of the statistically significant information.

TABLE 2. Pretest Scores of the students in Human anatomy in terms of identifying the different parts of the muscles.

Score Range	**f**	**%**	**Category**
1–3	0	0%	Did Not Meet Expectations
4–6	1	6.67%	Poor
7–9	0	0%	Fair
10–12	5	33.33%	Satisfactory
13–15	9	60%	Excellent
Mean		**12.4**	**Satisfactory**
Std. Dev.		**2.293**	

Legend: 13-15 - excellent, 10-12 - satisfactory, 7-9 – fair,

4-6 – poor, 1-3 – did not meet expectations.

The pretest served as a diagnostic test of students' prior learning. The students' pretest scores, as presented in Table 2, showed that 6.67% fell under the poor category, 33.33% had satisfactory performance, and 60% fell under the excellent category. The grand mean fell under a satisfactory performance. Campbell (2021) mentioned that students typically find it challenging to fully visualize and understand the varied aspects of the human body due to its complexity. However, it's a different case in this type of learning outcome, which is less complex. The results indicate that the students have varying levels of anatomical knowledge, as only 60% received excellent scores. The scores also indicate that most students have a good background in human anatomy, as only a very small percentage fell below the passing rate set during the planning stage of this lesson. The students' scores also indicate that this learning outcome is not that difficult at all, as 33.33% of the scores fall in the satisfactory range and 60% fall in the excellent level of academic performance. The researcher then focused on determining if the scores would be higher than this pretest result.

TABLE 3. Post-test Scores of the students in Human anatomy in terms of identifying the different parts of the muscles

Score Range	f	%	Category
1-3			did not meet expectations
4-6			Poor
7-9			Fair
10-12			Satisfactory
13-15	15	100%	Excellent
Mean	**14.53**		
Std. Dev.	**0.516**		

Legend: 13-15 - excellent, 10-12 - satisfactory, 7-9 – fair,

4-6 – poor, 1-3 – did not meet expectations.

The post-test was conducted to examine whether students' scores increased after the intervention. The table shows that, after the intervention, the students garnered a grand mean of 14.53, equating to an excellent performance level. Comparing this to the pretest performance, which yielded a mean of 12.4, only showed that the scores were higher after the intervention. O'Donnell (2017) noted that 3D experiences promote a multisensory experience, leading to increased students' academic performance. Table 3 shows a significant change in scores from table one, where students from the lower category have achieved excellent performance. The learning material was effective in improving students' performance on this specific learning outcome: identifying the different parts of the muscles. Identifying the parts is rote learning that falls under remembering; therefore, the results suggest that application and 3D learning are effective in attaining a good score in this outcome.

TABLE 4. Pretest Scores of the students in Human anatomy in terms of locating the different parts of the muscles

Score Range	f	%	Category
1-3	1	6.67%	did not meet expectations
4-6			Poor
7-9	7	46.67%	Fair
10-12	6	40%	Satisfactory
13-15	1	6.67%	Excellent
Mean	**9**		
Std. Dev.	**2.98**		

Legend: 13-15 - excellent, 10-12 - satisfactory, 7-9 – fair,

4-6 – poor, 1-3 – did not meet expectations.

The entire population had a grand mean of 9 on the pretest, indicating fair performance and falling short of expectations for students majoring in science. Only 6.67% got an excellent performance; 40% fell in the satisfactory range; 46.67% got fair scores; and 6.67 did not meet expectations. The second learning outcome is to locate the different parts of the muscles. Table 4 shows that the performance wasn't as promising as the previous pretest scores, indicating that this learning outcome is more difficult than the previous one. As discussed in Campbell (2021), the lack of a concrete basis for learning makes it hard for students to fully understand and visualize varied aspects due to the high complexity and bombardment of information. One challenge for non-medical students is that dissection of the real human body is not required, making it more difficult to accurately locate internal organs and observe their physiological processes, as noted by Ngan, Tang, Chen, and Chan (2017). The study by Cheung (2021) also found that students had difficulty acquiring knowledge in human anatomy.

TABLE 5. Post-test Scores of the students in Human anatomy in terms of locating the different parts of the muscles

Score Range	f	%	Category
1-3	0	0	did not meet expectations
4-6	2	13.33%	Poor
7-9	1	6.67%	Fair
10-12	3	20.00%	Satisfactory
13-15	9	60%	Excellent
Mean	**11.67**		
Std. Dev.	**3.27**		

Legend: 13-15 - excellent, 10-12 - satisfactory, 7-9 – fair,

4-6 – poor, 1-3 – did not meet expectations.

The grand mean across all respondents is 11.67, which can be interpreted as satisfactory performance. 60% of the population has now achieved excellent performance, compared to the pretest, when 6% (one student) got 13-15 scores. Table 5 shows that most respondents increased their scores after undergoing the intervention. According to Dimitriadis (2019), 3D learning paired with guided inquiry-based learning is an excellent instructional material and method for contextualizing learning and increasing students' performance. An overwhelming increase in the number of people getting an excellent performance rate is a positive sign of the efficacy of the learning materials. A study on the increased number of times or other aspects would be ideal to ensure higher results than those projected in the table. The improvement in students' scores indicates that 3D learning, paired with guided inquiry-based learning, is helpful to students. However, further studies should focus on a small number of students who were unable to increase their scores or had a decrease in their scores to determine the efficacy of the material and strategy.

TABLE 6. Paired T-test Result for the first Learning Outcome

Paired Samples T-Test									
			statistic	df	p	Mean difference	SE difference		Effect Size
A	B	Student's t	-3.7	14	0.001	-2.13	0.576	Cohen's d	-0.956
Note. H_a μ Measure 1 - Measure 2 < 0									

Paired Samples T-test

This study aims to determine whether there is a significant difference between the pretest and posttest scores after teaching using three-dimensional augmented reality and inquiry-based learning materials. A paired t-test was used because the researcher opted for a within-subjects design. As supported by recent studies, 3D and digital learning materials are effective tools for improving students' academic performance and learning outcomes (Radianti et al., 2020). In the first learning objective, the comparison of data revealed that the posttest scores ($m = 14.5$, $s = 0.516$) were significantly higher than the pretest scores ($m = 12.4$, $s = 2.293$), $t(14) = 4.12$, $p < 0.002$, $d = -0.956$. In Cohen's d, 0.2 represents a small effect size; 0.5, a medium effect size; and 0.8 and above, a large effect size (Zach, 2021). The effect size indicates a large increase in students' scores. Based on the accumulated results, the learning materials have a significant effect on students' academic performance in identifying the different muscles of the human body. The significant increase in students' scores is a great indicator that the instructional materials used were effective.

TABLE 7. Paired T-test Result for the 2nd Learning Outcome

Paired Samples T-Test									
			statistic	df	p	Mean difference	SE difference		Effect Size
A	B	Student's t	-4.78	14	< .001	-2.67	0.558	Cohen's d	-1.23
Note. H_a μ Measure 1 - Measure 2 < 0									

In the second learning objective, the comparison of data revealed that the post-test scores ($m= 11.67$, $s= 3.27$) were significantly higher than the pre-test scores ($m= 9.00$, $s= 2.96$), $t(14) = 4.12$, $p < .001$, $d = -1.23$. The effect size in this comparison also indicates a quite large effect on students' scores. Based on the accumulated results, it can be argued that the learning materials have a significant effect on students' academic performance in locating the different muscles of the human body. A p-value less than 0.001 is an ideal indicator that the null hypothesis should be rejected.

A large effect on the sample size also indicates that the materials supported respondents' learning and tended to increase their scores. 3D learning material, as concluded in the study of Balzli, Rehberg, Ebert, Enders, and Sieberth (2022), is a good alternative to expensive learning materials in learning Human Anatomy while increasing academic performance in learners, and Aulia (2018) mentioned that inquiry-based learning is effective in enhancing students' scientific literacy skills, attitude, and academic achievement. The statistical results proved that the material is also effective in. As indicated by Cohen's test results, the increase in scores can be replicated using the same method and instructional material.

TABLE 8. Evaluation results of 3D Augmented Reality as a Learning Material

Q	Learning Material	Mean	Interpretation
1.	I found that studying human anatomy using 3D augmented reality was very interesting.	3.73	Strongly Agree
2.	I found that studying human anatomy using 3D augmented reality was very helpful for learning human anatomy.	3.73	Strongly Agree
3.	I found that the 3D augmented reality application was easy to use.	3.00	Agree
4.	I found that the 3D augmented reality application was very informative.	3.27	Strongly Agree
5.	I found that studying human anatomy with 3D augmented reality made it easier for me to learn and remember complex anatomical terms.	3.27	Strongly Agree
	Average	**3.40**	Strongly Agree

The perception of 3D as a learning material falls at 3.40, which equates to "strongly agree," as presented in Table 8. Undeniably, 3D as a teaching material from the students' point of view is well accepted. In the study by Hadžiomerović et al. (2022), it was emphasized that 3D learning in human anatomy is more effective than any instructional material used in teaching human anatomy. 3D as a teaching material garnered quite satisfactory survey results. Respondents agreed that 3D material is interesting, helpful, slightly easy to use, very informative, and aids them in remembering complicated anatomical terms. However, it needs to be made more user-friendly, as some still find it difficult to use the application.

TABLE 9. Evaluation results of 3D Augmented Reality's User Interface

Q	3D Augmented Reality User Interface	Mean	Interpretation
6.	I find the design of 3D augmented reality very interesting.	3.27	Strongly Agree
7.	I find that anatomical learning applications using 3D AR with markers are more engaging than static images.	3.50	Strongly Agree
8.	I think the application is user-friendly.	3.13	Agree
9.	I believe that anatomical learning applications using 3D AR can provide an accurate and detailed human anatomy model.	3.60	Strongly Agree
10.	I believe that anatomical learning applications using 3D AR can help me accurately identify the location of muscles, including their origin and surrounding structures.	3.33	Strongly Agree
	Average	**3.36**	Strongly Agree

The students' perception of the user interface when using the 3D application resulted in an average of 3.36 on a 4-point Likert scale, corresponding to a strongly agree response regarding their experience with the application. The app received only an agreed-upon average score because few students find it challenging to use, yet the majority find it user-friendly. The study by Bogusevschi (2020) showed that 3D had high usability and user experience scores, where students found it more enjoyable and were more interested in the lesson. Same results in the survey conducted in this research, where students strongly agreed that the design is interesting and user-friendly, provides a perfect model for learning anatomy, and helps locate the position of the muscle.

TABLE 10. Evaluation results of 3D Augmented Reality's Multimedia feature

Q	3D Augmented Reality Multimedia feature	Mean	Interpretation
11.	I believe that anatomical learning applications using 3D AR with markers are more helpful for visualizing the human body's anatomy.	3.40	Strongly Agree
12.	I believe that anatomical learning applications using 3D AR with markers support a deeper understanding of human anatomy.	3.20	Agree
13.	I believe that anatomical learning applications with 3D AR and markers make it faster to understand the human body's anatomy.	3.33	Strongly Agree

14	I believe that markers or highlighters help us clearly see the full form and position of muscles.	3.53	Strongly Agree
15	I believe that the visual components are advanced and accurately represent the actual human muscular system.	3.13	Agree
	Average	**3.32**	Strongly Agree

The students were very satisfied with the 3D multimedia feature. The average response was 3.32, indicating strong agreement in this category. Recent studies indicate that 3D visualization tools significantly enhance students' understanding of spatial anatomical structures and improve learning satisfaction in anatomy education (Jensen & Konradsen, 2021). The respondents agreed that the images were good in the application, enabling them to see the exact form and position of the muscles. The students scored the 3D app markers at 3.20, suggesting that the feature's use should be emphasized for students or that the marker itself should be improved to highlight the muscles better.

TABLE 11. Evaluation results of 3D Augmented Reality's Interactive function

Q	Interactive function- 3D Augmented Reality	Mean	Interpretation
16.	I believe that the function of anatomy learning applications with AR, which allows users to view descriptions of each organ, is very helpful and interesting.	3.40	Strongly Agree
17.	I believe that the function of anatomy learning applications with AR, which allows users to rotate a 3D model, is useful for anatomical observation.	3.53	Strongly Agree
18	I believe that the function of anatomy learning applications with AR, which allows users to enlarge 3D models, is very helpful for examining anatomical details.	3.47	Strongly Agree
19	I believe that the function of anatomy learning applications with 3D AR is very helpful for adjusting the body's position to clearly view the specific part being studied.	3.47	Strongly Agree
20	I believe that the function of anatomy learning applications with 3D AR is very helpful for clearly identifying the different parts of the muscular system from each distinct region.	3.4	Strongly Agree
	Average	**3.44**	Strongly Agree

The scores accumulated an average of 3.44, indicating strong agreement with the interactive function of the 3D application during the use of the material. The interactive 3D animation and multimedia application increases learners' interest; completes learners' incomplete cognitive model with a concrete mental model; and increases the appeal of the materials, according to the study by Korakakis (2008).

The respondents strongly agreed that the description and presentation of each organ were very helpful and interesting; being able to rotate, enlarge, adjust, and remove parts helped locate deeper muscle parts.

TABLE 12. Evaluation results of 3D Augmented Reality's Interactive function

Q	3D Augmented Reality Practicability	Mean	Interpretation
21	I believe that learning through an anatomy learning application with 3D AR is highly suitable for anatomy classes.	3.7	Strongly Agree
22	I am very interested in using anatomy learning applications with AR at any time.	3.4	Strongly Agree
23	I believe that the application contains the necessary information and features needed to effectively learn the muscular system.	3.27	Strongly Agree
24.	I believe that the sound effects and information included in the app are helpful for learning human anatomy, particularly the muscular system.	3.20	Agree

25.	Overall, I believe that anatomy learning applications with 3D AR greatly enhance the learning process.	3.47	Strongly Agree
	Average	**3.40**	Strongly Agree

In this study, 3.40 respondents reported that the application was very useful in helping them learn. The study by Rabattu, Debarnot, and Hoyek (2022) noted that advances in technology, such as 3D digital tools, help learners overcome challenges in learning human anatomy, especially when there is high interactivity. The respondents gave a satisfactory rating to the application as quite useful, though a few were confused while using it at first. Can they be trained to utilize the platform well? The application's sound (voice feature) only got a rate of 3.20, which is equivalent to agree ", and must also be improved in order to improve the learning experience of the students.

TABLE 13. Evaluation results of Guided inquiry-based learning scale of questions

Q	Scale- Questions- Guided inquiry-based learning	Mean	Interpretation
26	I think that the questions guide the learner through a reasonable progression from their current knowledge.	3.13	Agree
27	I think that the questions are already appropriately structured and do not need further breakdown.	2.87	Agree
28	I think that the thinking questions are clear and not misleading.	3.27	Strongly Agree
29	I think that the questions address important topics related to the competency being assessed.	3.47	Strongly Agree
30	I think that the questions are concise and specific enough to elicit the required answers.	3.33	Strongly Agree
	Average	**3.21**	Agree

The average score of 3.21 indicates that students were satisfied with the questionnaire's function in the materials used to aid their learning in human anatomy and physiology. According to Beagle Learning's Question Productivity Index (QPI) Rubric, appropriately sized questions can create more productive discussions, as there is no need to break them down or impose limitations. Since the students had a mean score of 3.21, the researcher met the expected standard for the material's questions. The questions must be improved by connecting them to students' prior knowledge, as they received a 3.13 rating from students, indicating a need for improvement. The score of 2.87, which equates to agree, is not excellent enough and must be improved by simplifying it and using a smaller, narrower scale.

TABLE 14. Evaluation results of Guided inquiry-based learning articulation of questions

Q	Articulation Questions- Guided inquiry-based learning	Mean	Interpretation
31	I think the questions were well-constructed and used proper grammar.	3.27	Strongly Agree
32	I think the questions would be interpreted consistently by a wide range of readers.	3.07	Agree
33.	I think the word choices in the questions are appropriate and not overly difficult.	3.20	Agree
34	I think the sentences are simple enough for students to answer without requiring an excessive amount of time.	3.20	Agree
35	I think the questions are not too incremental or overly simplistic such that they could be easily answered through a quick internet search.	3.13	Agree
	Average	**3.17**	Agree

Teachers must know how to ask questions that guide students to attain lesson objectives, as emphasized in recent studies on guided inquiry and effective questioning strategies in classroom instruction (Pedaste et al., 2022). Questions must be articulated well; they must be well-presented and must not include any grammatical errors or subjective terms. The 3.17 mean of this category indicates that students are satisfied with the grammar and presentation of the questions. It must not be too complicated for them, cannot be easily googled, and can be

understood in the same way by a large group of readers without having different interpretations. In terms of having the questions interpreted by students as something that can be perceived by the larger population, only an average of 3.20 was achieved, which means the questions must not be that easy to guide them to find the correct answer. The choice of words must also be changed, as it only garnered a mean score of 3.20, which requires revision to make it easier and more relatable. The sentence must be more specific to fit within the learning time frame, making the objectives more attainable.

TABLE 15. Evaluation results on the relevance of the questions for Guided inquiry-based

Q	Relevance	Mean	Interpretation
36	I think the questions were relevant to the topic.	3.53	Strongly Agree
37	I think the answers to the questions would attend to the issues or goal of the course topic.	3.20	Agree
38	I think the questions were helpful to remember terms as I try to answer them.	3.20	Agree
39	I think the questions increased our curiosity to learn more things.	3.33	Strongly Agree
40	I think the questions were thought provoking and guided our learning process.	3.27	Strongly Agree
	Average	**3.31**	Strongly Agree

The respondents gave a mean score of 3.31, indicating strong agreement and suggesting that the questions were highly relevant and helpful in the learning process. The questions, in terms of addressing the study's issue or goal, must also be improved, as they only received an average of 3.20, indicating that they can be improved further. Teachers must ask the right questions relevant to the topic, as recent research emphasizes that effective questioning strategies enhance student understanding, critical thinking, and engagement in learning (Chin & Osborne, 2021).

The researcher based the questions on Beagle Learning's Question Productivity Index Rubric, which emphasized that questions must help students see that the answers lead to the network of information needed to deeply understand and remember the key points of the topic and the concept. The researcher suggests that questions must be more specific and aligned with the topic, or help guide students effectively toward the aspired outcomes. Questions must also help students to remember prior knowledge and connect it to understanding more complex lessons in Human anatomy.

TABLE 16. Summary of results for the survey questions

Q	Relevance	Mean	Interpretation
Q 1-25	Average for 3D augmented reality as learning material	3.38	Strongly Agree
Q 26-40	Average for Inquiry-based learning as learning strategy used in the material	3.23	Agree
.	Overall average:	3.33	Strongly Agree

Overall, both materials used for learning human anatomy garnered a 3.33 average across all aspects considered, which equates to strongly agree. Almost identical results were also acquired in this study, where students strongly agreed that the application was effective in helping them learn. The study by Mutlu (2020) found that students had more positive opinions about learning science when IBL was used as part of their learning materials. It was also mentioned that they have improved the use of scientific terms and the scientific process.

The study also acquired the same sentiments and reactions in the guided inquiry-based learning aspect of the material used in the learning process. Positive student feedback on the material is associated with increased academic performance, providing evidence of its efficacy. The results showed that the students had generalized that most respondents chose agree and strongly agree, indicating that the learning material had satisfied learners' needs and requirements, aided their learning of human anatomy, and helped them overcome the difficulties associated with the learning process.

Implications

The results of the study suggest that integrating three-dimensional augmented reality with inquiry-based teaching materials can significantly enhance students' understanding of complex topics, such as human anatomy. The outstanding post-test performance demonstrates that immersive and interactive tools are effective in improving academic achievement, suggesting that educators should consider adopting such technologies in science instruction. However, the findings also highlight the importance of adequate teacher preparation, as the application requires familiarity with its multiple features before it can be maximized in the classroom. It underscores the need for professional development programs that train teachers to use augmented reality tools effectively. Moreover, while students strongly agreed on the efficiency of the multimedia and interactive functions, their feedback regarding the complexity of certain features and the articulation of inquiry-based questions indicates that refinement is necessary. Curriculum developers should ensure that inquiry prompts are clearly structured and aligned with learning outcomes. At the same time, technology designers must prioritize user-friendly interfaces and improved visual presentation to make applications more accessible. Overall, the study underscores the potential of augmented reality and inquiry-based methods to transform science education. However, it also emphasizes the need for continuous improvement in usability, teacher training, and instructional design to maximize their impact.

LIMITATIONS AND RECOMMENDATIONS

Although the study demonstrated the effectiveness of three-dimensional augmented reality and inquiry-based teaching materials in enhancing students' learning of human anatomy, certain limitations must be acknowledged. First, the research was conducted with a relatively small population, limited to the third-year B.S.Ed. Science major students of Sibonga Community College, which restricts the generalizability of the findings to broader student groups or other institutions. Second, the study focused only on specific learning outcomes related to the muscular system, so the results may not fully represent the application's effectiveness across other areas of anatomy or different science subjects. Third, the novelty of the augmented reality tool posed challenges, as students required additional time to familiarize themselves with its features, which may have influenced their initial performance and perceptions. Fourth, the evaluation relied heavily on self-reported measures of agreement, which are subject to bias and may not fully capture the depth of students' experiences. Lastly, external factors such as prior exposure to modular and online learning during the pandemic may have affected students' adaptability and engagement with the new materials. These limitations suggest that while the findings are promising, further studies with larger samples, diverse contexts, and extended timeframes are necessary to validate and strengthen the conclusions.

This new era, the 21st century, brought a massive, rapidly evolving technological revolution. Along with this, there is the evolution of people's needs in different aspects, including education, to keep up and maintain dynamism amidst the changes around us and persist. One of them is learning science, especially human anatomy, in which the learning process and the materials used have changed significantly over the years. 3D augmented reality is one product that has become a trend. This research has been keen to assess its efficacy and to identify ways to ensure improved academic performance in human anatomy and physiology.

First in hand, teachers must consider the technical aspects of the application, as it would require skills in using it and more time to practice to ensure the best outcomes. There are instances when the application hangs; thus, the teacher must be obliged to motivate their students to remain patient and to always be available for basic troubleshooting assistance to ensure a productive experience for the learners. Some of the students find it challenging to use the app. Not every student would find the application easy to use and would require demonstration and thorough guidance. Thus, teachers must be technologically savvy.

Secondly, to ensure that both materials used yield the best results, the guided-inquiry-based method serves as a guide to the vast amount of information in the application. It must be carefully planned, well-constructed, and highly relevant to the lesson objectives to serve as an excellent guide that facilitates students' learning. The students must immediately identify and extract the important details, then connect them to the topic they are learning. The questions must be appropriately sized to ensure they lead to a fruitful discussion and be time-

bounded. Additionally, questions must appear equally to students at different levels to eradicate misconceptions and skepticism. Furthermore, the questions must be well-posed, clear, and free of grammatical errors.

Lastly, it is highly recommended to conduct thorough observation and research to refine the suggested strategy further. There must also be research to determine why the few students did not increase their scores, and why those who actually got lower scores on the quiz.

CONCLUSION

It was assumed in this study that learning materials used with inquiry-based learning could provide excellent instructional materials and methods for contextualizing learning and improving students' academic performance. The same results were obtained in this study. The overall summation of students' feedback, considering their perceptions of the experience, suggests that 3D learning materials paired with inquiry-based learning are effective and appropriate tools for learning human anatomy, especially the muscular system. The rejection of the null hypothesis with a large effect size is strong evidence of the efficacy of the previously mentioned materials.

Inferred from the study, the results strongly suggest that both strategies used in the material were highly effective.

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