

USING STEAM TO MAKE MODELS FOR ANATOMY AND PHYSIOLOGY
CLASSROOMS

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DEDICATION

This paper is dedicated to Ryan Haahr. Thank you for your unwavering support.

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ABSTRACT

Anatomy is a course that entails a high mental load. It can be challenging for students to visualize complex structures and relate them to function. The purpose of this study was to find a better way for students to visualize complex anatomical structures in anatomy and physiology courses, especially within the nervous system. To bridge this gap, students created models demonstrating the relationship between anatomical and physiological structures in the human body. Students utilized STEAM (science, technology, engineering, art, and math) to create their models. Before implementing the model, students learned the background information on the topic, which scaffolded and guided students rather than having them teach themselves. During the implementation of the treatment, students completed a pretest and posttest about the content of the study. The entire group of students showed a statistically significant increase between the two tests. Students also maintained a journal throughout the project, indicating that they enjoyed using STEAM and creating a model while preferring nontraditional learning methods over traditional ones. Furthermore, students expressed that modeling helped them better understand how the various parts of the nervous system worked together. Overall, students not only enjoyed the creativity and hands-on learning required for modeling, but they also were able to make meaningful connections about the anatomy and physiology of the body.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Anatomy and physiology is a popular course for students in high school. Interest in anatomy courses has been growing yearly, especially in the district where I teach. Despite its popularity, students find the course difficult due to the need to visualize 3D anatomic and physiological concepts. An anatomy and physiology course is essential for students planning to pursue a career in a health-related field. However, medical schools show that students need help with visualization in anatomy and physiology courses, even at the undergraduate and graduate levels (Cheung et al., 2021; Lieu et al., 2019; Naidoo et al., 2020). Therefore, there are apparent difficulties in student comprehension of anatomy and physiology that need to be addressed to increase student success.

In my experience of taking and teaching anatomy courses, the amount of content covered is daunting. Anatomy is unlike many other courses students will take because of the extensive material and the structure in which the course is taught. Anatomy courses optimize a direct learning method where students are taught the structures and functions in the classroom and then identify these structures on different types of models in the lab. This is a challenging format for students who struggle with recalling information.

A typical anatomy assessment is called a practical. In this assessment, students must actively recall the information they have learned to identify most structures and functions from a model. Students may only be able to recall this information for short periods before unloading

their brains for the next batch of anatomical content. New teaching and learning methods need to be implemented into anatomy and physiology courses to increase students' ability to retain information.

The purpose of this study was to find better ways for students to visualize complex anatomical structures in anatomy and physiology courses, which require a significant mental load not seen in other coursework. The goal was to have students build models connecting anatomical features' structure and function to increase learning. This study focused on increasing students' exposure to content by having them design and construct models. Effective models can help students better understand the relationship of anatomical structures to the body and allow for individualized learning. Students were introduced to modeling by implementing a STEAM (science, technology, engineering, art, and math) learning protocol, where they built their models to demonstrate their understanding of the course content.

I teach anatomy courses at Devils Lake High School in Devils Lake, North Dakota. Devils Lake is a rural town of just over 7,000 people (U.S. Census Bureau, n.d.). Only one school district serves the community and enrolls 1,733 students in kindergarten through 12th grade (Devils Lake Public School District, 2024). The school district is 64% Caucasian and 30% Native American. There is only one high school, grades 9th-12th, with an enrollment of 530 students (Devils Lake Public School District, 2024). The Anatomy and Physiology course is offered to juniors and seniors as a science elective. There are 239 total juniors and seniors in the high school. Anatomy and Physiology is a yearlong course divided into two 16-week semesters. Each class period is 50 minutes and meets every day. This action research occurred during the second semester and focused on the nervous system unit, as it has been identified to be the most

challenging unit for students (Cheung et al., 2021; Lieu et al., 2019; Naidoo et al., 2020). All major body systems and a three-week dissection unit using cats are covered in the course. I had 51 students in three anatomy classes, with the class sizes ranging from 15 to 21 students. This is a higher number of anatomy students from last year showing an increased interest in the subject.

Focus Statement/Question

My focus question was, Does STEAM learning by modeling increase the understanding of the human body?

My sub-questions included the following:

1. Does STEAM learning increase the understanding of the human anatomy among different groups of students (i.e., males, females, 504 plans, ELLs)?
2. Do students enjoy STEAM learning and modeling?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Introduction

Anatomy and physiology courses have been deemed difficult for students of all ages and abilities. Many reasons make anatomy difficult, including the mental load of content, lack of sufficient models, and poor student visualization skills (Cheung et al., 2021; Lieu et al., 2019; Naidoo et al., 2020). The difficulties in these courses are due to the lack of models and visualizations, which makes the connections between student understanding more challenging. Constructivism is an education theory that posits that learning should be constructed authentically from tasks relating to the real world (Llewellyn, 2013; McLeod, 2019; Shah, 2019). One method of constructivism supported by this theory is the use of modeling. Models are used as representation tools to show complex or abstract concepts (Belzen et al., 2019). There are a variety of models that students can use, both physical and mental, to visualize complex concepts. Modeling in 3D can effectively demonstrate the relationship between structure and function in anatomy and physiology (Yammine & Violato, 2016). STEAM supports modeling by imploring students to use scientific principles and humanities to support a well-rounded education (Taylor, 2016). STEAM also encourages student engagement and motivation (Quigley et al., 2017; Taylor, 2016). Therefore, student engagement and success could be increased in anatomy courses by implementing STEAM to build models of complex concepts.

Constructivism

Constructivism is an educational theory that encourages collaboration and knowledge-building. The constructivism theory supports students actively engaging in their education by constructing their knowledge through a student-centered collaborative approach (Llewellyn, 2013; Shah, 2019). Through collaboration, students and their peers use the process of trial and error to construct knowledge. Applying a constructivist approach helps students better understand complicated information by encouraging authentic tasks and multiple modes of representation, including models, presentations, or demonstrations (McLeod, 2019). Models are used in authentic learning tasks such as projects or group learning to support constructivism and collaboration. Constructivism is a powerful framework in science education that supports the consolidation of student learning through the utilization of peer collaboration on authentic tasks.

Despite the benefits of constructivism, there can be some difficulties in implementing this learning style. Criticisms of constructivism come from the history of poor implementation of the theory. Criticism of constructivism is that students teach themselves rather than be guided through the subject matter (McLeod, 2019; Shah, 2019). This comes from the misconception that a constructivist classroom does not need the teacher to be an expert on the subject material (Shah, 2019). In constructivist classrooms, teachers need to be content experts who can effectively guide and enhance student learning. Educators should initially focus on scaffolding information to prevent students from being entirely self-taught. This involves gradually increasing the difficulty of the content, ultimately leading to student modeling. By doing so, teachers can better support students' understanding and mastery of the material. The difficulties

of constructivism can be eliminated with proper implementation of the theory by scaffolding content.

Modeling in Constructivism

Constructivism relies on multiple modes of representation to help students construct their understanding of a topic. Models are tools used by constructivists to gain insights into complex principles. There are four different types of models used to represent complex concepts: (1) consensus models, (2) teaching models, (3) expressed models, and (4) mental models (Chittleborough & Treagust, 2009). *Consensus models* are those used and accepted by scientists; *teaching models* are used in classrooms and other educational settings; *expressed models* are a student's construction of understanding of a topic; and a *mental model* is the internal understanding of a concept (Chittleborough & Treagust, 2009). Each of these models is responsible for teaching and building students' understanding of complex material in different ways. The use of modeling has shown an increase in comprehension and problem-solving abilities (Meli et al., 2022). The models students use and make should accurately represent the original content while also creating predictions and explaining phenomena (Meli et al., 2022). Modeling is a fundamental tool of constructivism because students can use many modes of representation for complex concepts. Therefore, constructivists value models because they can be used to represent abstract ideas while encouraging a variety of connections, both physically and mentally, to the content.

Anatomy Education

Anatomy and physiology education typically relies on the use of traditional teaching methods. Courses that teach anatomy focus on the structures found within the body, while physiology courses focus on how those structures work together to make the body function (Tortora & Derrickson, 2018). Anatomy education can use a variety of teaching methods but most often involves a combination of direct teaching and cadaver dissection (Cheung et al., 2021). These direct teaching methods include content lectures, memorization, and workbook laboratory sessions (Cheung et al., 2021; Joseph et al., 2021; Lieu et al., 2018). These traditional methods are often used at all levels of anatomy courses, including secondary and undergraduate education.

Students at all levels of study have identified anatomy as a complex subject because of the amount of content covered in the course, the lack of models, and the difficulties with the visualization of structures (Cheung et al., 2021; Lieu et al., 2019; Naidoo et al., 2020). The traditional teaching methods used in anatomy and physiology courses may contribute to students' difficulties in these courses. Without sufficient tools to help visualize anatomical structures, anatomy educators need to find new ways to help students better engage and visualize the human body. The difficulties in anatomy education are exacerbated by traditional teaching methods, which lack sufficient models for student learning.

Difficulties in Anatomy Education

Difficulties in the overall content of anatomy courses come from both the amount of content and the standard methods of learning. Professors of anatomy and physiology courses attribute the material itself to being inherently difficult (Slominski, 2019). The difficulty level in these

courses has increased dropout rates among undergraduate students (Slominski, 2019). However, many undergraduate students attempt to learn anatomy by memorization (Lieu et al., 2018; Slominski et al., 2019). Students from these studies equate memorization of the material with learning. However, memorization does not allow students to comprehend knowledge or store it properly in long-term memory (Khamees, 2016). Students must be engaged in meaningful study practices to recall information accurately and demonstrate retention. The poor educational tactic of memorization highlights the need for a new way to teach anatomy and physiological concepts to students.

One tool for mental reduction is modeling. The models students have used to learn anatomy in previous years are becoming increasingly scarce. The most common model in anatomy education has traditionally been the human cadaver, which students use to learn anatomical content (Harmon et al., 2020; Lieu et al., 2018; Naidoo et al., 2020). However, there has been a nationwide decline in cadaver availability at all academic levels, forcing anatomy educators to seek alternative models (Gholipour, 2019). Due to the challenges in obtaining and using human cadavers, educators now need models that can accurately represent anatomical relationships and even the colors of human tissue.

In a study of 842 doctors, 64% believed their practice of medicine would be unaffected if they had never taken an anatomy course involving cadaver dissection (Ghazanfar et al., 2018). With the decreasing reliance on cadaver dissection in anatomy courses, it is essential to identify other effective methods for visualizing and modeling anatomy and physiology material. The lack of adequate models has made anatomy education more difficult for students than in previous years, prompting educators to explore new teaching options.

The shortage of models has impaired the visualization of the human body. One of the biggest challenges in anatomy and physiology courses is that students struggle to visualize structures, including organs (Cheung et al., 2021). Students find it difficult to comprehend the shape and size of organs relative to their locations in the body. Moreover, embalmed cadavers can have compressed organs, which can shift anatomical orientations (Gholipour, 2019), further demonstrating the inadequacy of available models.

Students need to be able to see information learned in the textbook and apply it to practical knowledge. However, this can be difficult if students cannot identify structures and make sense of them (Silen et al., 2022). For anatomy and physiology students to be successful, pedagogy should focus on introducing new theories and practices that allow students to construct their understanding and visualization of the human body using creativity and problem-solving skills.

Models in Anatomy Education

Models have become a vital tool in science education. The process of making models has been known to support inquiry by encouraging students to observe, compare, and classify models (Belzen et al., 2019). Modeling can be used to help students and scientists visualize abstract concepts (Jeon et al., 2022). Educators can guide students to understand complex processes by encouraging them to create a model representing the phenomena (Woolcott & Whannell, 2018). To make modeling an effective educational tool, students must be exposed to viewing and making models in the classroom. The making and viewing of models can be beneficial in various sciences, including anatomy courses.

The general positioning and physiology of anatomical structures need to be understood to understand the human body's interconnectedness. To show how body systems work together,

anatomy classrooms are using 3D models to help (Öktem et al., 2019). These 3D models are typically digital in the form of online applications. Models are necessary for a discipline like anatomy because of the mental load required to understand the relationships between the body systems (Yammine & Violato, 2016). Yammine and Violato (2014) have summarized several articles that indicate 3D models are more effective in teaching students than 2D models. A significant advantage of 3D models is that they better demonstrate spatial relationships within the body. Visualizing the physiology and structure of human organs was among the highest difficulty levels identified in anatomy education (Yammine & Violato, 2016). Therefore, the construction of 3D models would benefit students by increasing their understanding of the interconnectedness of body systems while also constructing their understanding of the content. This authentic construction of knowledge could decrease the difficulty of anatomy by supporting the students' needs for visualization of the body using models.

STEAM Learning

New educational tools should be utilized to help anatomy students create authentic and appropriate models. A new trend in education is the inclusion of art and humanities into science practices. STEAM stands for science, technology, engineering, art, and mathematics (Quigley, 2017). Including art in the acronym is the separating factor from its predecessor, STEM. The inclusion of art in science education is intended to create more well-rounded students by including liberal arts (Khine & Areepattamannil, 2019). Adding art and humanities to science encourages students to seek multiple perspectives and creative solutions to problems (Taylor, 2016). Art in science principles has been shown to increase the motivation and engagement of students participating in STEAM activities (Quigley et al., 2017; Taylor, 2016). Adding art into

science practices should empower students and educators to seek innovation in their classrooms to support the learning of science practices and liberal arts. The use of STEAM in an anatomy classroom can increase the students' exposure to models while also allowing students to construct their personal understanding of the human body.

STEAM Modeling

STEAM promotes hands-on learning that challenges students to assess and implement new technology to solve problems that may occur in life (Bautista, 2021). The principles of STEAM bring convergent and divergent thinkers together to identify new perspectives on these problems (Bautista, 2021). STEAM and STEM both support interdisciplinary frameworks and student-centered classrooms, ideas that are foundational to constructivism (Falloon et al., 2021; Li et al., 2022). STEAM educators believe students should be active in the construction of their learning, which supports the principles of STEM. Therefore, the building of models using both STEAM and STEM practices would promote constructivism theorems and highlight different thinkers in the classroom. A united approach of STEM and STEAM can be used effectively in a classroom to encourage student collaboration and creativity.

STEAM can be used to create authentic models for the classroom. The construction of models is an authentic STEM practice (Hallström & Schönborn, 2019). STEAM is still a new concept in education and has less of an official framework than STEM. This means that many STEAM projects are based on the principles of STEM but continue with the incorporation of humanities and art. For example, in STEM, modeling allows teachers and students to explain phenomena realistically (Stillman et al., 2015). Modeling can be descriptive or prescriptive. Descriptive modeling is used "to design, prescribe, organize, or structure certain aspects of it [the

model],” while prescriptive modeling is used to act and make decisions (Stillman et al., 2015, pp. 4). Therefore, a modeling activity would follow similar guidelines to a STEM project but include art in the form of collaboration or other liberal arts. Overall, STEAM is a promising tool for producing authentic models because it includes multiple perspectives, creativity, and reliance on fundamental STEM processes. Making comprehensive models in anatomy and physiology courses can help students better visualize complex content, leading to increased comprehension in the course.

Conclusion

Anatomy courses are difficult for students at all levels of education. Making comprehensive models in anatomy and physiology courses can help students better visualize complex content. The building and use of models are embedded in the philosophy of constructivism. Constructivists support students’ building models since they promote the construction of their unique knowledge through tasks and authentic learning opportunities. The typical models used in anatomy courses are becoming obsolete; therefore, there needs to be a shift in how anatomy is taught. This shift can be accomplished through the guidance of STEAM to support students in having a well-rounded understanding of complex science concepts while also incorporating new perspectives and humanities into their understanding. Therefore, students in anatomy courses would benefit from implementing STEAM learning so they can build models that represent their understanding of anatomical content in a way that suits their individualized learning style.

CHAPTER THREE

METHODOLOGY

Demographics

There is an increasingly high volume of content in an anatomy course. This content can be overwhelming for students without proper visualization tools and models. The purpose of the study was to determine if STEAM learning via modeling is an effective tool to teach students about the anatomical and physiological relationship of the nervous system. Due to the difficulty of anatomy courses and the lack of models, the students define their understanding of the human body by creating their models. The use of STEAM has shown to be an authentic constructivist tool for students to demonstrate learning on a topic (Falloon et al., 2021; Li et al., 2022). This demonstration of learning via modeling allowed students to construct their own knowledge about the nervous system.

This study was conducted on three sections of a high school anatomy and physiology course, an elective course for juniors and seniors. The treatment was implemented in the same way across all three sections of the course, which totaled 51 students, and 49 of them participated in the research. A consistent treatment across all sections was used, which is characteristic of a quasi-experimental design. A quasi-experimental design compares scores from pre- and post-intervention without using randomization (Harris et al., 2006). The pre- and post-scores were compared to determine how the treatment affected student learning. This is an appropriate design because in studies comparing groups of students, randomizing data collection methods is not possible.

Since there were various groups within the three sections, comparison data was done against the whole group and smaller subgroups: 504 plans, English Language Learners (ELL), males, and females. These groups provided an appropriate comparison between the norm because they established whether STEAM and modeling supported the learning of various groups of students. All sections participated in the treatment so there is no formal control within the project. The control for the project was the comparison to the norm. This methodology supported quasi-experimental research by potentially demonstrating an increase in the learning of students of various groups. Of the possible groups of students, 10% of students participating are on a 504 plan, 8% are ELL students, 63% of students are female, and 37% are male. Although 74% of the students are Caucasian, there are a variety of other races represented in the student population (Figure 1).

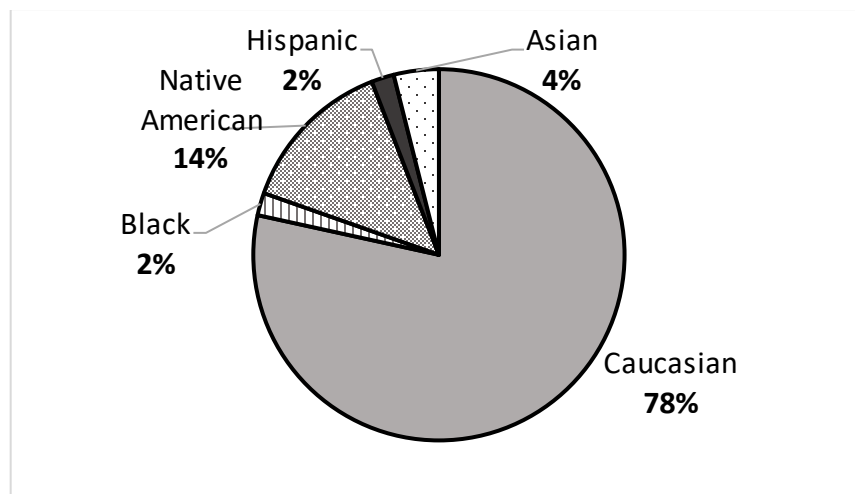


Figure 1. Breakdown of ethnicities of students in three sections of a high school Anatomy course, (N=51).

The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

Treatment

The methodology for this design follows the principles of constructivism. The purpose of this treatment was for students to construct their knowledge about the nervous system through modeling. Students were given foundational knowledge about the nervous system to help guide them in their construction. This was done throughout several class periods by using traditional learning methods (i.e., notes, direct teaching, worksheets) to learn the components of the nervous system. From these methods, students learned the anatomical structure of neurons and the central and peripheral nervous system divisions. Didactic teaching helps appropriately scaffold student learning so students are not being self-taught (McLeod, 2019; Shah, 2019). Students were also most familiar with this type of teaching style, so this served as a control to the experiment. This control ensured that the pretest result was not influenced by the treatment, ensuring an authentic comparison for the quasi-experiment. The pretest of the Pretest/Posttest Design was used to get a baseline of what students knew about the nervous system and its relationship to action potentials. After finishing the pretest, students implemented the treatment by creating a model (Figure 2).

Pre Treatment	Treatment	Post Treatment
• Didactic Teaching Methods • Pretest	• Students make models • Student Interview Part 1 • Student Journals	• Student Survey • Posttest • Student Interview Part 2

Figure 2. Methodology and treatment progression of student modeling project and data collection tools.

The treatment began with the implementation of creating student models. Students chose their own materials to construct a model over seven 50-minute class periods. Students needed to use all parts of STEAM (Science, Technology, Engineering, Art, and Math) when creating their model. The model represented a nerve impulse conducting from the peripheral nervous system to the central nervous system and back. Students worked individually to create their models while reflecting on their daily learning. Every day, students answered questions in their online Student Journal and reflected upon the model and how it influenced their learning of the nervous system. In addition to keeping journals, during the treatment, students were interviewed using the initial Student Interview questions. These questions determined if students enjoyed using models and STEAM learning to understand anatomical structures and processes.

Once the treatment was completed, students were given the Posttest and the Student Survey. These two tools were both designed to quantitatively gather data on whether students learned from their models. Upon completion of the model, students were asked a final set of interview questions that assessed how well they were able to connect the anatomical structure of a neuron to its ability to carry impulses. These interview questions were used to support the findings of the qualitative data analysis with authentic quotes from students. The Posttest, Student Survey, and Student Interview contributed to determining whether modeling via STEAM improved student understanding of the anatomical and physiological functions of a neuron.

Data Collection and Analysis Strategies

Data was collected from various sources to determine how modeling impacted students' knowledge about the nervous system. For this project, data was collected using both qualitative and quantitative methods. This combined use of qualitative and quantitative data is called a

mixed-method design (Melter, 2020). A mixed methods approach to the research helped provide evidence for a claim by presenting a deeper understanding of the data.

Data Collection Methods

The data collection methods for this project are identified below (Table 1). Each method helps collect data for at least two different research questions. Quantitative data was collected through student surveys and the student pretest/posttest design. Student interviews and Student Journals were used to collect qualitative data.

Table 1. Data Triangulation Matrix.

Data Collection Instruments	Focus Questions		
	Does STEAM learning by modeling increase the understanding of the human body?	Does STEAM learning increase the understanding of the human anatomy among different groups of students (i.e., males, females, 504, ELL)?	Do students enjoy STEAM learning and modeling?
Pretest/Posttest Design	X	X	
Student Interview Questions		X	X
Student Survey	X	X	X
Student Journals	X	X	X

Pretest/Posttest Design. The first data collection method was the Pretest/Posttest Design (Appendix B). The Pretest/Posttest Design asked students the same questions before and after treatment to determine if there was an increase in understanding after the treatment. This type of analysis was helpful because the purpose of the research was to determine the effectiveness of a

particular program (Spector, 1981). This is fitting since the purpose of action research is to determine how a change in pedagogy affects student learning. The comparison data from this tool can specifically target data between groups of students, such as those on 504 plans, to see if modeling increased their understanding of the anatomical content. Due to the need to compare groups of students, the test could not be anonymous. However, efforts were made to minimize the number of identifiers for the students. The Pretest/Posttest Design allowed various research questions to be assessed by analyzing students' scores before and after the modeling treatment.

Student Interview Questions. The Student Interview Questions were conducted using a semi-constructed interview format to gauge both students' understanding of the model and whether they enjoyed this type of learning (Appendix C). Semi-constructed interviews follow a list of questions but still allow for follow-up questions instead of sticking to a rigid set of questions (Kvale, 2007; Mertler, 2020). The increased flexibility allowed for deeper probing of the topic, which increased the accuracy and authenticity of the answers. Semi-constructed interviews provided evidence about the level of student understanding throughout various parts of the project.

The interview was conducted in two parts, one during the treatment ($N=45$) and one upon completion of the treatment ($N=35$). The first part consisted of questions relating to whether students liked the modeling and STEAM projects and if students found modeling beneficial in enhancing their learning. The second phase of interviewing focused on the anatomical content, and each response was graded for accuracy. The accuracy of students' answers was determined by a rubric known as the Student Interview 3-point rubric (Appendix D). The purpose of this phase of interviewing was to determine whether students were learning from making a model.

The data already collected from the Pretest/Posttest instrument further supported the interview data.

Student Survey. The final quantitative data collected method was a Likert scale survey called the Student Survey (Appendix E). Students determined whether students *strongly agreed*, *agreed*, *disagreed*, or *strongly disagreed* with a topic relating to the project. The scale measured agreement and satisfaction of students' learning by questioning their opinions about specific topics (Santino et al., 2021) Students' satisfaction level or agreement was analyzed to determine how well modeling helped students understand the structural relationship of neurons to their physiology. This data was supplemented with the interview data since students could not provide further explanations about their chosen answers.

Data from the Likert scale was easily separated into groups that can be compared to the whole class data. This type of data was helpful in answering all research questions for the project. The Student Survey targeted whether students liked modeling, if they better understood the nervous system, and if they could make sense of the relationship between the structure and physiology of specific organs of the nervous system. This information is based on the total satisfaction or agreement once the scale is converted to numerical values.

Student Journal. The data collection tool that provided context to all other instruments is the Student Journal (Appendix F). These journals were a living document for students that the researcher used to gain information on the students' overall ideas and perspectives of the anatomical content (Mertler, 2020). Journals played a vital role in the project's qualitative data collection. Journals and other written artifacts have been shown to provide context for a study while also tracking change and development over time (Billups, 2021). The journal showed

students continuously redefining their understanding of the content through modeling. Students reflected on questions about their modeling project and provided data on whether they had a strong or weak understanding of the nervous system from modeling.

The Student Journals were a powerful source of data for this project. This journal collected qualitative data that was used to supplement the research questions. This journal asked content questions that targeted students' understanding of the human body. The Student Journals assessed the various groups of students on their level of understanding compared to the norm, focusing on their responses regarding anatomical structures and physiology. The journals also assessed the enjoyment level of students participating in the modeling project by reviewing their responses and interactions with anatomical structures and physiology. Therefore, the amount of information that can be gathered from these journals makes it possible to answer all research questions for this study.

Analysis Strategies

This project utilized a triangulation form of mixed methods research. Triangulation mixed methods use multiple data collection sources to verify the research results (Mertler, 2020). Triangulation mixed methods is an effective way to analyze action research because it applies a deeper meaning to the results through various instruments and analysis strategies.

Qualitative Analysis Strategies. An inductive analysis called a coding scheme was used to analyze the data from the student's journal and the student interview. A coding scheme is used to group similar data into codes or categories (Mertler, 2020). These similar words pop out of the data to create cohesive themes for analysis. These words or phrases are sorted into categories, and a narrative of the data begins to form (Charmaz & Belgrave, 2012). This

narrative from the data is representative of the researcher's questions. These codes synthesize a large amount of data into manageable pieces that are analyzed to make conclusions (Charmaz & Belgrave, 2012). More manageable data allowed informed conclusions to be drawn without overwhelming or complexity of data. To remain unbiased, the researcher should read through the entire data set once before identifying codes (Silver & Lewins, 2017). Within the journal, words or phrases relating to the like or dislike of modeling were coded together to conclude the overall attitude of the students (Mertler, 2020). Codes were also put together based on the learning students thought took place each day. These codes showed the level of understanding each student had about the content needed to create and finish their model.

Codes were also created from the interview data. The first part of the interview asked students for their opinions on modeling and STEAM learning. These answers were coded and analyzed to determine student attitudes toward the treatment. The same process was applied to the second part of the interview where students answered questions about the content related to anatomy. These questions were coded for accuracy based on students' understanding changing. This accuracy determined the improvement of student understanding as they continued to work on the model.

Quantitative Analysis Strategies. The Student Survey and the Pretest/Posttest Design are two examples of tools that require quantitative analysis strategies. Upon the completion of the pretest ($N=49$) and posttests ($N=42$), the data was analyzed using an unequal t-test to determine if there was a significant change in the students' understanding of the learned nervous system before and after the treatment (McKinley et al., 2016). If there was a statistically significant

increase in scores, it could show support for modeling as an effective tool for learning anatomy.

The comparison between the two tests will demonstrate if learning took place after the treatment.

With the Student Survey, categories can be converted into numbers to find total satisfaction among students (Thomas, 2004). For example, *strongly agree* could represent a "4," while *strongly disagree* represents a "1," and a higher total score would represent more agreement or satisfaction. The average score from each question can be calculated and analyzed to check for student understanding. The scale can also be used to rate their satisfaction with their modeling project.

The rubrics from the Student Interview can be used to determine the accuracy of student responses. These rubrics target the content of the second portion of interview questions. With this data, individual scores and class scores can be determined and compared to one another to see if there was an overall trend in improvement of understanding. This tool will also be used to compare other groups, such as males, females, ELLs, and students on 504 plans. Overall, the student content interview questions were analyzed quantitatively to determine whether students understand the relationship between the structure and function of a neuron.

CHAPTER FOUR

DATA ANALYSIS

The purpose of the study was to determine if modeling was an effective way to teach students about the human body. Data collection was done with both qualitative and quantitative methods. Student interviews, surveys, pretest and posttest scores, and student journals were all used to collect data on the treatment. A t-test was used to determine the significance of both the pretest/posttest data as well as the part two student interview data.

ResultsModeling and the Human Body

During the treatment, several different data collection tools were used to collect data about the research questions, starting with how modeling affected students' understanding of the human body's interconnectedness. The treatment included having students make an expressed model. An expressed model requires students to construct their understanding of the topic when building a model (Chittleborough & Treagust, 2009). Upon the completion of the treatment, pretest and posttest scores were analyzed for students to determine if there was an increase in understanding. The average score for the entire sample for the pretest was 45% ($N=49$), while the average score of the posttest was 64% ($N=42$) (Figure 3). The null hypothesis for this data is that there is no difference between the pretest and posttest scores for students.

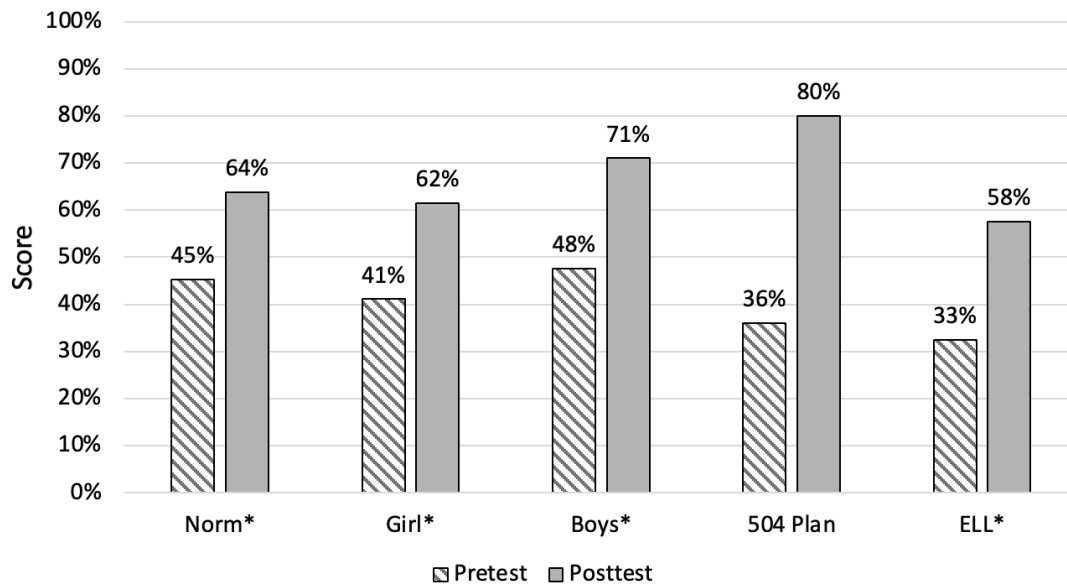


Figure 3. Average student scores on the pretest ($N=49$) and posttest ($N=42$) for the modeling project * indicated a significant difference between the two scores.

The 19% increase between the pretest and posttest of the entire group was shown to be significant ($p=0.00004$) using a t-test of unequal variance. This initial data shows that the null hypothesis can be rejected, and an alternative hypothesis of modeling does help students understand the human body is supported.

In addition to the pretest and posttest data, the student survey also showed support for an increased understanding of the human body. When surveyed, 78% of students *agreed* or *strongly agreed* that creating a model helped them better understand how the structure of a neuron relates to its function (Figure 4). This demonstrated that the majority of students believed they benefited from modeling. Students were also asked other questions about whether modeling seemed to increase their understanding of the nervous system.

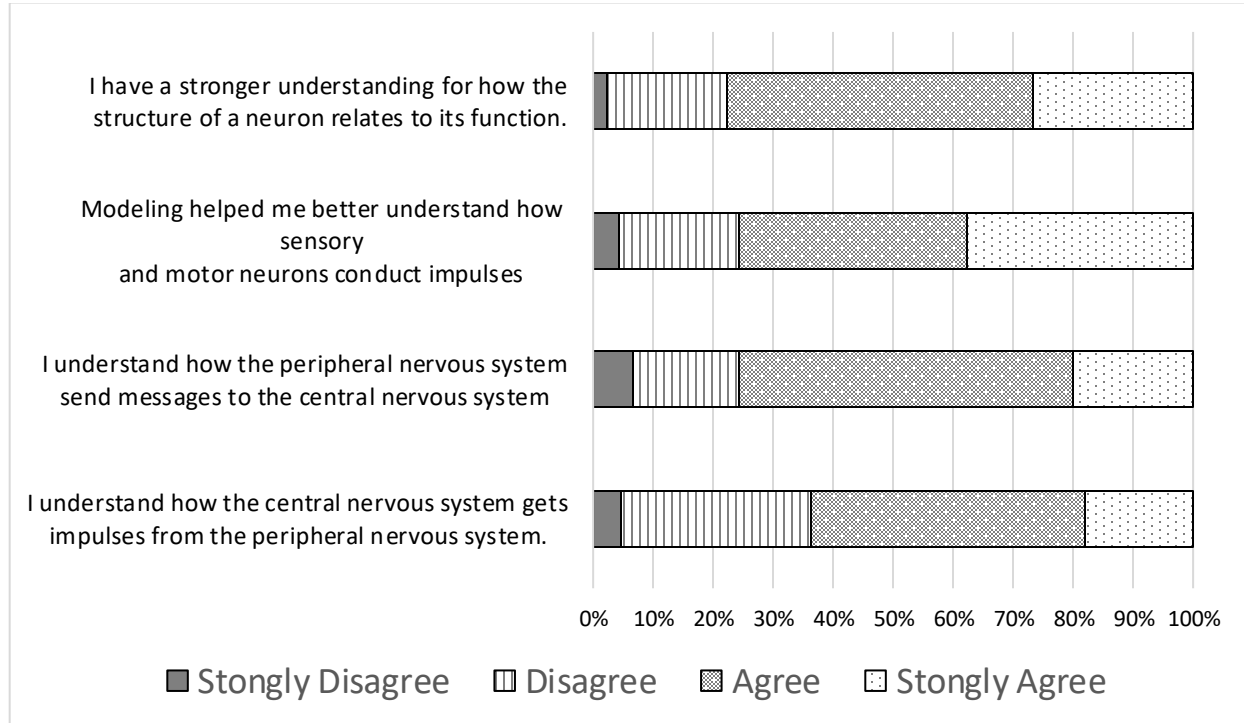


Figure 4. Student survey data shows if modeling helped students better understand the human body, ($N=45$).

In addition to students agreeing modeling helped relate the structure and function of a neuron, 64% of students thought that modeling helped them better connect the central nervous system and the peripheral nervous system. A majority of students agreed that modeling increases their understanding of the nervous system overall. Students seemed to agree with the previous data that modeling seems to help students make better connections to the human body.

One final piece of data used to support student learning about the human body via modeling was the student journals. The student journal showed that students thought they had an understanding of the nervous system after they completed their model. From the student journals, 88% of students ($n=31$) thought that making a model helped them better understand the relationship between the structure and function of the nervous system upon the completion of the

treatment (Figure 5). One student reported in their journal that "I actually have to like know what I was talking about to do it, instead of just faking my way through it." The student was referring to their need to have a clear grasp of the material so they can put the model together in a meaningful way, supporting their increase in knowledge after modeling.

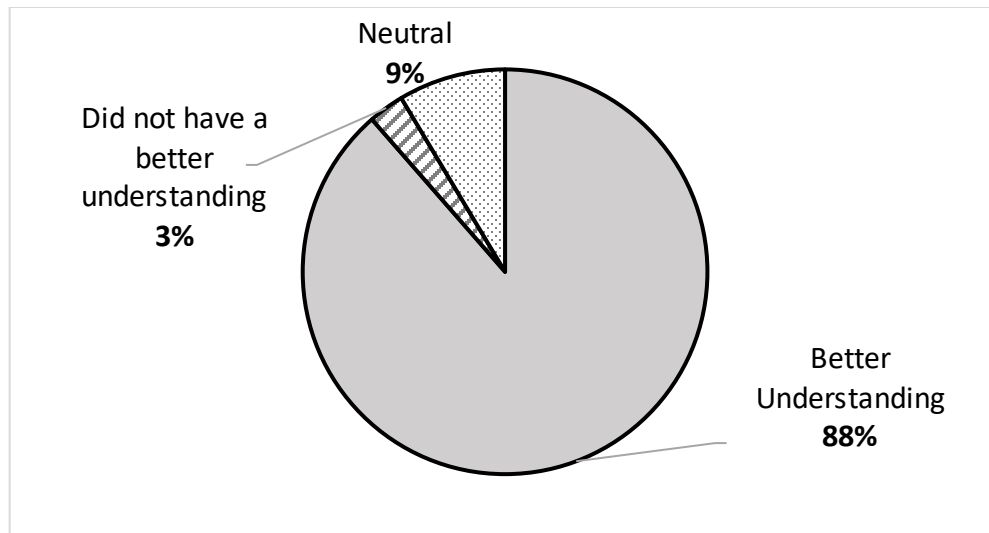


Figure 5. Student journal data on whether modeling increased understanding compared to traditional learning methods, ($N=35$).

Only one student thought that building a model did not help them increase their understanding of the nervous system. Based on the data from the pretest and posttest, the student survey, and the student journals, modeling seemed to help students better understand the relationship of the human body.

STEAM and Different Groups

One of the main questions in this study was to analyze how the process of building a model affects the learning of different groups of students. Four groups, in addition to the whole group, including males, females, students with a 504 plan (for academic purposes, not medical), and English Language Learners (ELL), were analyzed. For each group, the pretest and posttest

scores were compared for growth between scores. The most considerable difference in the data was found between the pretest and posttest scores. The students with a 504 plan scored 44% higher between the pretest ($n=5$) and posttest scores ($n=2$). Though this initial data demonstrated an upward trend, the lack of sample size in the posttest prevented the data from being significant ($p=0.142$), so the null hypothesis failed to be rejected. The other groups (males, females, and ELL) showed a significant increase ($p<0.05$) in the learning of the nervous system (Table 2). Each group improved by at least 20% between the pretest and posttest scores (Figure 3). This shows that, generally, modeling seems to be beneficial to most groups of students in supporting their learning of the nervous system and the human body.

The pretest/posttest scores show an upward trend within the groups regarding the understanding of the human body. The student survey data showed how each group of students perceived their own learning upon the completion of treatment. The student survey showed that male and ELL students thought that modeling improved their understanding of the nervous system the most compared to other groups. Students on a 504 plan consistently scored themselves lower when asked if modeling increased their understanding compared to other groups (Figure 6). Students seemed to agree with a majority of the statements, indicating that they believed modeling increased their understanding of the nervous system.

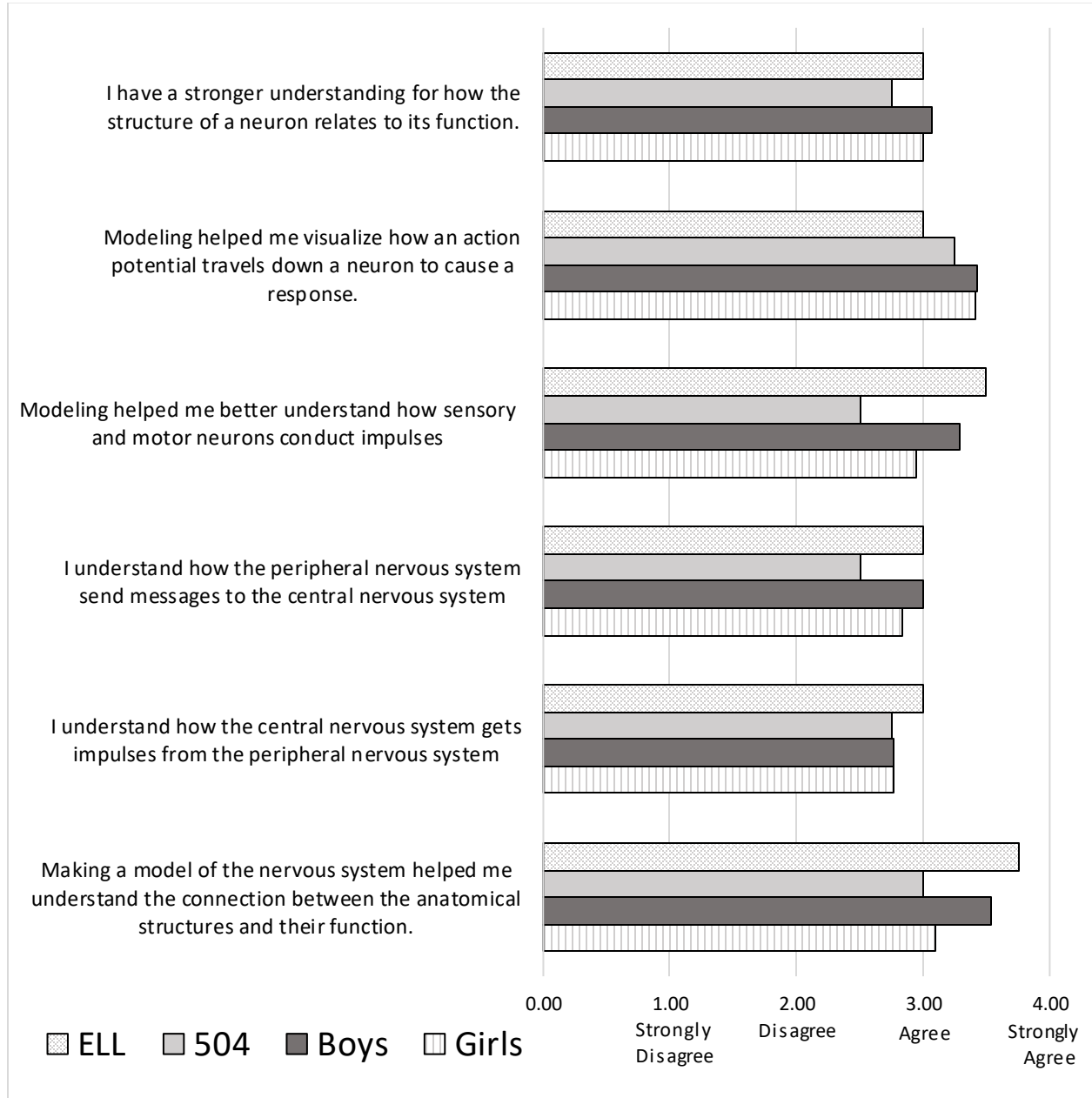


Figure 6. Average student agreement on the student survey data of the different groups, including males ($n=13$), females ($n=31$), 504 ($n=4$), and ELL ($n=4$).

When asked on the survey to rank, *Making a model of the nervous system helped me understand the connection between the anatomical structures and their function* on a score from 1-4, the average score for the ELL student was 3.75, indicating that most of the students agreed and

strongly agreed with the statement ($n=4$) (Figure 6). When students on a 504 plan were asked the same question, their average score was a 3, meaning students also agreed with the previous statement. When asked if students think this project helped them, one student on a 504 plan stated, “Yes, 100%. I've always been a hand[s] on learner. Sitting in class, and doing notes, then taking tests do[es] not teach me anything.” Even though the 504 plan students surveyed themselves slightly lower, for the most part, they still agreed that modeling helped them better understand the nervous system and provided a meaningful experience to students.

Though students may have felt that they were learning more via modeling, as indicated by the student surveys, there are some contradicting results to the data. When scoring the responses to the Student Interview Part 2 Questions using the Student Interview Question 3-point Rubric (Appendix D), students scored below proficiency in their answers. The rubric provided the criteria to grade students' answers on a scale from 1-3, where one is novice, two is proficient, and three is master. The whole group of students ($N=45$) was scored, and each group was analyzed for significance against the norm using a t-test of unequal variance (Table 2). No group of students showed significant improvement or decline compared to the norm.

Table 2. Average score of the Student Interview Part II was broken down by subgroups on a scale of 1-3 and compared to the norm for significance.

	How do sensory and motor neurons work together in the peripheral nervous system?	Can you explain the primary role of sensory neurons in the nervous system?	How do sensory neurons transmit information about temperature and touch to the central nervous system?	How does an action potential facilitate all the sensory and motor input and output of the nervous system?	p-Value
Norm N=40	1.95	1.83	1.40	1.60	-
Males n=12	1.92	1.75	1.42	1.60	0.45
Females n=28	1.96	1.86	1.30	1.61	0.48
504 n=3	1.67	1.67	1	1	0.09
ELL n=3	2.00	2.33	1.67	2.00	0.08

The null hypothesis for this data analysis was that there was no significant difference in understanding between the various groups of students. Based on the data, the null hypothesis could not be rejected, and modeling did not significantly improve the understanding of any group of students. For example, males ($p=0.45$) scored relatively the same compared to the norm. Students on a 504 plan and ELL students had a low sample size, so the data comparison cannot be significant, but it does show a general trend of ELL students doing slightly better than the norm and 504 students doing slightly worse than the norm (Table 2). Even though this data is not significant, it fits with the student's perception of their learning from the student survey (Figure 6). ELL students ranked their learning higher than the other groups, and the 504 plan students ranked themselves lower. Even though proficiency was desired for students' learning, students of all groups learned approximately the same from modeling as the norm.

Enjoyment of STEAM

Data collection tools also measured overall student enjoyment throughout the treatment. Students often get more out of a learning experience when they enjoy what they do (Kang & Wu, 2022). When surveyed upon completion of the treatment, 80% of students *agreed* or *strongly agreed* with enjoying making models with STEAM (Figure 7) ($N=45$). Students who reported liking STEAM in their student journals stated that they particularly enjoyed the creativity and freedom that the project allows.

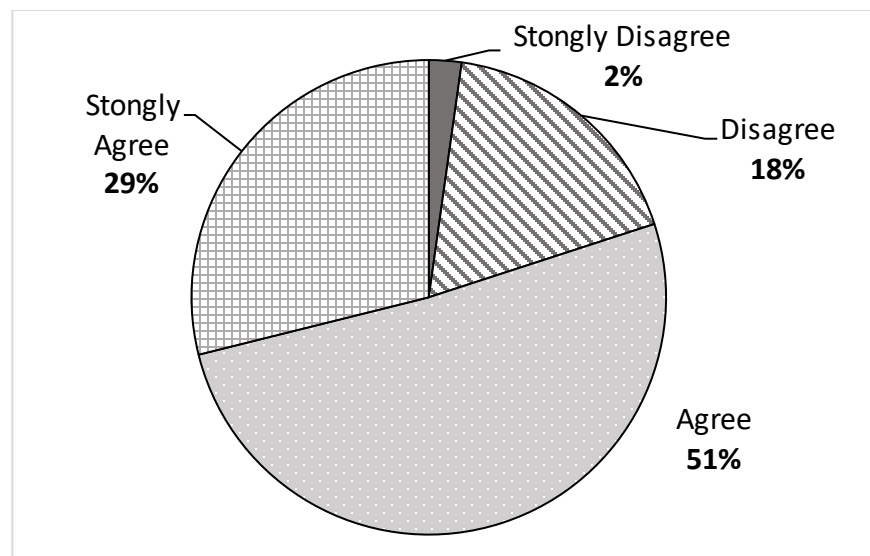


Figure 7. Student Survey data showing whether students enjoyed modeling via STEAM, ($N=45$).

When asked whether they liked STEAM learning one student said, “I did enjoy this kind of project. I feel that it allowed us to use lots of our strengths. It also pushed us to use things out of our comfort zone.” In student interviews, 30% of students reported that they enjoyed STEAM learning or modeling because it allowed them to be creative; 18% of students thought that making a model was better or easier than traditional learning methods like notes or tests (Figure

8). Students were not subjected to specific requirements on the medium to demonstrate their understanding of this project, which likely contributed to their enjoyment.

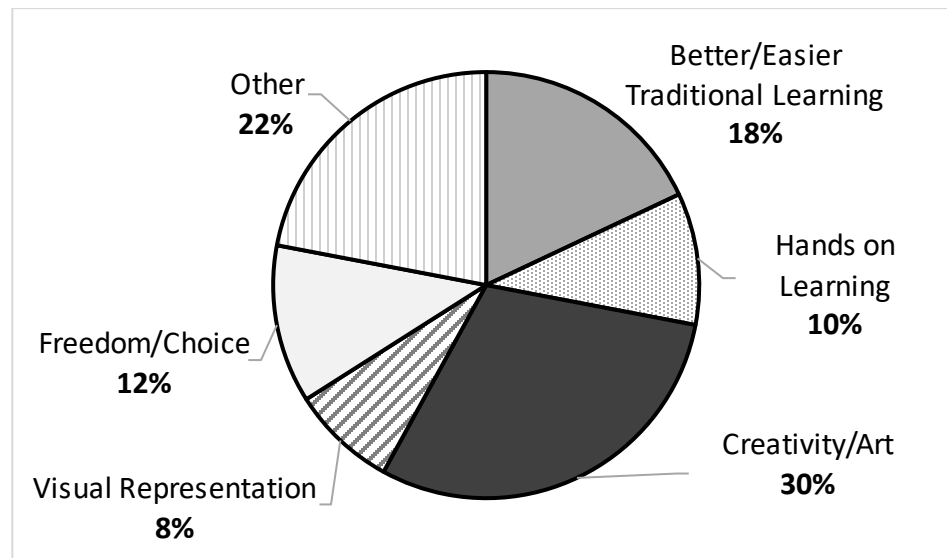


Figure 8. Student reasons for liking STEAM as reported in the student interviews, (N=45).

Other reasons reported for why students enjoy STEAM include the freedom they have to demonstrate their knowledge about a topic. One student stated, "I think it's fun, and we have a lot of freedom to do whatever we want to truly represent the model we are working on." Students enjoyed the artistic elements of STEAM and was a big motivator to complete the project well.

Even though a majority of the responses were positive regarding modeling and STEAM, some students did not enjoy the modeling project. When asked what they disliked the most about modeling, the most common response was that there was not enough time to complete the project. Notably, there were extensive absences by the majority of the class due to extracurricular activities. Some students found that they prefer more traditional learning methods than modeling. One student who disliked STEAM wrote in their journal, "I personally do not like STEAM. I find that my brain works better in traditional environments, like notetaking,

compared to creative projects.” This project did not take into consideration other types of learning or intelligence, which may be a factor in student achievement and enjoyment. Even though some students did not enjoy modeling overall, most students found that they enjoyed all or some of the parts of making a model.

Conclusion

With the decline of access to cadavers and the need for visualization in Anatomy and Physiology courses, modeling could be the pedagogical change needed in the content-heavy discipline. The purpose of this study was to find a better way to visualize complex structures in the human body. The results of this study support the effectiveness of modeling in teaching about the human body. Analysis of pretest and posttest scores revealed a significant increase in understanding post-treatment, supported by student surveys and journals indicating improved comprehension and appreciation for the structural and functional aspects of the nervous system. While different student groups showed varying levels of benefit from modeling, it was still found to be a beneficial tool for understanding and visualizing the human body, especially for the nervous system unit. However, some contradictions emerged between student perceptions and objective measures of learning outcomes, highlighting the importance of considering both qualitative and quantitative data when evaluating teaching methodologies.

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

Due to the heavy content load of a human anatomy course and the increasing lack of models available, modeling could be a tool to help bridge the knowledge gap for students (Cheung et al., 2021; Lieu et al., 2019; Naidoo et al., 2020). The purpose of this study was to determine how making a model impacted student learning. The data collected from the treatment consistently supported two claims: (1) Student scores improved on assessments for all types of learners, and (2) students generally enjoyed STEAM to help them visualize the human body.

Student Enjoyment

One prominent claim from this study is that students enjoy nontraditional, hands-on learning. Students expressed joy at being able to express and use their creativity in class and physically use their hands to learn. For this project, students created a variety of projects, including a roller coaster, a pop-up book, and many posters with interactive and moveable parts (Figure 9). Student journals, surveys, and interviews all support the idea that students enjoyed using STEAM to make a model.



Figure 9. Example of a student modeling project with moveable ion pieces and a pop-up book showing how signals move to and from the brain.

A few students did not enjoy STEAM because they preferred more traditional learning tools. All students who reported not liking STEAM were females, consistent with students who had extended absences from the project. Missing class time could be one reason for the dislike of modeling or a learning style preference not studied in this project.

The transition from STEM to STEAM within classrooms has increased student enjoyment. Adding art to science principles has increased the motivation and engagement of students participating in STEAM activities (Quigley et al., 2017; Taylor, 2016). This increased enjoyment is supported by the results of the study as well. When students enjoy their learning, they can gain more from it. Most students appreciated the opportunity to be creative and incorporate their artistic abilities into their projects. Therefore, adding art to the project showed to be a valuable tool for enhancing both the learning experience and overall student learning outcomes.

Human Body Visualization

Student learning increased after modeling, indicating better visualization of the human body. The differences between the pretest and posttest scores show a positive upward trend in the increase of knowledge about the human body. The average pretest and posttest scores show a significant improvement from the pretest scores after the treatment when using a t-test with unequal variance or a paired t-test. Students themselves thought that the treatment increased their understanding of the nervous system based on their modeling project. One student stated in their interview, "I think this project is a great way to show what we aren't that familiar with either. Sometimes it's hard to admit what we don't know, but this project helps communicate that. I also think it's a great way to show growth." Students are aware that creating models has been helpful in increasing their ability to visualize and conceptualize complex human anatomy. This is largely due to identifying steps they were unfamiliar with and working through those misconceptions to complete their final project.

Some groups of students struggled more than others when demonstrating their knowledge about the human body. This was particularly true for students with a 504 plan. One factor that influenced the data, especially within the student interview answers, was that students did not feel they had enough time to process or adequately answer the questions. This mainly affected students on a 504 plan, as they were not using all their available accommodations when answering the questions.

Though the student interview data is lower than expected, students still reported learning more from modeling than before the treatment when only traditional learning methods were used. Models have previously been shown to increase the comprehension and problem-solving abilities of students (Meli et al., 2022). The upward trend of the pretest and posttest scores

supports that modeling helped students better connect complex information about the nervous system. Therefore, this study provides additional support to the existing claims that modeling helps all students better visualize the human body.

Value of the Study and Consideration for Future Research

Using modeling in my classroom did seem to make an impact on student perception of learning. The results of the study are consistent with current research about teaching anatomy. Previous studies show support that models can help students in content-heavy courses like anatomy better understand the connection between material (Cheung et al., 2021; Lieu et al., 2019; Naidoo et al., 2020). Students were able to interpret complex information into a manageable visual display.

Future Research

One part of this study that should be considered for future research is the amount of scaffolding needed to prepare students for making a model. Students enjoyed this type of learning because it was different than what is normally done within the classroom. The main criticism of constructivism is that students teach themselves rather than be guided through the subject matter (McLeod, 2019; Shah, 2019). I made sure to scaffold my students into the specific parts of the nervous system. However, more support is needed to be part of the learning process for students. A project considering the modeling activities with more of these scaffolds built in would be of interest.

Impact of Action Research on the Author

Upon completing this research, I found that students enjoy hands-on learning and see value in being creative and having autonomy over their learning. This research has shown me that students rely on being able to visualize anatomical information to help connect how parts of the body work together. In the future, I plan to implement more modeling projects within my anatomy classroom. This is leading me towards a project-based learning classroom. Project-based learning (PBL) perfectly fits with the modeling philosophies of constructivism. PBL supports student-directed learning by understanding their prior knowledge and scaffolding them to express their learning (Jumaat et al., 2017). This was the primary structure of my action research and will work in my classroom to reduce the mental load of the course.

Pedagogy Shift

Action research has also led me to emphasize data collection within my classroom. While completing this project, I closely tracked student achievement in my other courses to identify patterns in their success and failure that could be analyzed. This focus on data collection in MSSE has improved my overall teaching because it has become significantly more data-driven than before, allowing me to identify strengths and weaknesses in both my students and my teaching.

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APPENDICES

APPENDIX A

IRB APPROVAL

IRB Protocol #2024-1154-EXEMPT APPROVED

NoReply@TOPAZTI.com <NoReply@TOPAZTI.com>

Thu 1/18/2024 8:04 AM

To: Anderson, Jessica <jessica.anderson40@montana.edu>; Windjue, Jenna <jenna.windjue@student.montana.edu>;
Beiswanger, Kelly <kelly.beiswanger@montana.edu>; Szott, Brenna <brenna.szott@montana.edu>

****External Sender****

Hello Windjue, Jenna,

Your protocol was reviewed by the IRB and has been approved.

PI: Windjue, Jenna

Approval Date: 1/18/2024

Title: Using STEAM to make Models for Anatomy and Physiology Classrooms

Protocol #: 2024-1154-EXEMPT

Review Type: Exemption

Expiration Date: 1/18/2029

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

- > Review Category designation determined by the IRB can be found in the final section of your protocol.
- > IRB-stamped active Consent Forms are attached within your protocol where applicable.
- > Any changes must be submitted via Amendment prior to implementation.
- > Per the Common Rule, research only requires Interim (annual) Review by the IRB if 1) it was reviewed via Full Committee or 2) is regulated by the FDA.
- > All research is subject to post approval monitoring.
- > All protocol types must be renewed 5 years after approval.
- > Inform the IRB once your research is complete so that the protocol may be inactivated.

Please contact your IRB Program Manager with any questions or if you are in need of assistance.
Thank you for your diligence in the care of human subjects research participants.

Institutional Review Board for the Protection of Human Subjects | Office of Research Compliance |
Montana State University

APPENDIX B

PRETEST/POSTTEST DESIGN

Instrument Design Pretest

Answer these questions to the best of your ability. This pretest will not affect your grade in this class. This is designed to see how much you already know about neurons.

Question 1: What is the primary function of the peripheral nervous system (PNS)?

- A. Integration and processing of sensory information
- B. Initiating voluntary muscle movement
- C. **Transmitting information between the CNS and the rest of the body.**
- D. Maintain consciousness

Question 2: Which of the following best describes the main function of sensory neurons within the PNS?

- A. they initiate muscle contraction
- B. **They transmit sensory information from the body to the CNS**
- C. they control voluntary bodily functions
- D. they integrate information within the spinal cord

Question 3: When a motor neuron sends an electrical signal to a muscle fiber, what neurotransmitter is typically released at the neuromuscular junction to initiate a muscle contraction?

- A. Serotonin
- B. Dopamine
- C. **Acetylcholine**
- D. Norepinephrine

Question 4: The synaptic cleft is the small gap between the motor neuron and the muscle fibers. What is its function in muscle contraction?

- A. **it allows the release of neurotransmitters to trigger muscle contraction**
- B. It prevents muscle fibers from contracting too quickly
- C. it stores extra energy for muscle contractions
- D. it cushions the muscle fibers during contraction

Question 5: What type of neuron is functionally described as efferent?

- A. **Motor**
- B. Sensory
- C. Interneuron
- D. None of the above

Question 6: Interneurons primarily function to:

- A. transmit motor commands to muscles and glands
- B. **connect sensory and motor neurons within the central nervous system**
- C. carry sensory input from the body to the central nervous system

D. control involuntary bodily functions

Question 7: Which type of nerve carries commands from the CNS to the muscles and glands controlling voluntary and involuntary movements?

- A. sensory nerves
- B. mixed nerves
- C. motor nerves
- D. Autonomic nerves

Question 8: What is the primary function of an action potential in a neuron?

- A. To transmit information from 1 neuron to another
- B. To generate an electrical signal within the neuron
- C. To release neurotransmitters into the synaptic cleft
- D. To initiate muscle contraction

Question 9: What role does the myelin sheath play in an action potential conduction?

- A. It generates action potentials
- B. It insulates the axon speeding up the conduction of action potentials
- C. It releases neurotransmitters at the synapse
- D. It initiates muscle contractions

APPENDIX C

STUDENT INTERVIEW QUESTIONS

Modeling and STEAM Questions, Interview Part I:

1. What materials are you using to make your model?
2. What challenges are you having when making your model?
 - a. How have you overcome the challenges?
 - b. What resources do you need to overcome these challenges?
3. What do you think is going well in making your model?
 - a. Do you enjoy making models?
4. What do you enjoy about it?
5. What do you dislike about it?
 - a. How would you change this project for the future?
6. Did making a model help you understand the connection between the types of neurons and their role in the nervous system?
 - a. Why or why not?

Content Question, Interview Part II:

1. How do sensory and motor neurons work together in the peripheral nervous system?
 - a. How do they convey information between the body and the central nervous system?
 - b. What anatomical features distinguish these types of neurons?
2. Can you explain the primary role of sensory neurons in the nervous system?
 - a. Can you give an example of a sensory input they transmit?
3. How do sensory neurons transmit information about temperature and touch to the central nervous system?
 - a. How is this information processed to produce the sensation of, for instance, warmth or pressure?
4. How does an action potential facilitate all the sensory and motor input and output of the nervous system?

APPENDIX D

STUDENT INTERVIEW QUESTION 3-POINT RUBRIC

Table 3: Content Question 1 Grading Rubric

	3	2	1
Understanding of Sensory and Motor Neuron	The response demonstrates a comprehensive understanding of how sensory and motor neurons collaborate in the peripheral nervous system. It includes clear and accurate explanations of their functions and interactions.	The answer provides a basic understanding of the roles of sensory and motor neurons in the peripheral nervous system but lacks some detail and clarity.	The response lacks a clear explanation of how sensory and motor neurons work together or contains significant inaccuracies.

Table 4: Content Question 2 Grading Rubric

	3	2	1
Understanding of Sensory Neuron Function	The response demonstrates a comprehensive understanding of the primary role of sensory neurons, covering their functions in detecting stimuli, converting them into electrical signals, transmitting information to the CNS, and the role of perception and response. It provides clear and accurate explanations.	The answer provides a basic understanding of sensory neuron function but may lack some detail and clarity in the explanation.	The response lacks a clear explanation of the primary role of sensory neurons in the nervous system or contains significant inaccuracies.

Table 5: Content Question 3 Grading Rubric

	3	2	1
Understanding of Sensory Neuron Transmission	The response demonstrates a comprehensive understanding of how sensory neurons transmit information about temperature and touch, including the roles of sensory receptors, action potentials, spinal cord, and brain processing. It provides clear and accurate explanations.	The answer provides a basic understanding of sensory neuron transmission but may lack some detail and clarity in the explanation.	The response lacks a clear explanation of how sensory neurons transmit information about temperature and touch to the central nervous system, or it contains significant inaccuracies.

Table 6: Content Question 4 Grading Rubric

	3	2	1
Understanding of Action Potentials	The response demonstrates a comprehensive understanding of action potentials, including how they facilitate sensory input, central processing, and motor output. It provides clear and accurate explanations.	The answer provides a basic understanding of action potentials and their relevance to sensory and motor functions but lacks some detail and clarity.	The response lacks a clear explanation of how action potentials work and their role in sensory and motor processes or contains significant inaccuracies.

APPENDIX E

STUDENT SURVEY

Likert Scale

This survey is voluntary. You may choose not to take this survey. That choice WILL NOT affect your overall grade or standing within the class.

1. **Making a model of the nervous system helped me understand the connection between the anatomical structures and their functions.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
2. **I enjoyed making models using the concepts of STEAM.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
3. **Modeling helped you visualize how an action potential travels down a neuron to cause a response.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
4. **You have a stronger understanding of the structure of how the structure of a neuron relates to its function.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
5. **I understand how the central nervous system gets impulses from the peripheral nervous system.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
6. **I understand how the peripheral nervous system sends messages to the central nervous system.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
7. **Modeling helped me better understand how motor and sensory neurons conduct impulses.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
8. **Modeling helped me visualize how an action potential travels down a neuron to cause a response.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)
9. **I have a stronger understanding of how the structure of a neuron relates to its function.**
1 (Strongly disagree) 2(disagree) 3 (agree) 4 (strongly disagree)

APPENDIX F

STUDENT JOURNAL

Welcome to your interactive Nervous System Design Journal.

Purpose: The purpose of this journal is to provide a space for you to reflect on your learning and knowledge about the nervous system. You will also reflect on the challenges and successes you have while making your model. You may also ask questions about the content or the process in this journal as well. You will need to reflect on your project every day and plan for the following class period. This will keep you on track and help you accomplish your goals.

Table 7. Student Journal Daily Prompts and Reflection Questions

Day	Questions	Reflection Questions on Content
Day 1	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	
Day 2	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	Reflection Question: In 3-4 sentences, describe how your initial impressions of STEAM learning and modeling. Why do you think your project is based on these two concepts?
Day 3	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	Reflection Question: In 3-4 sentences, describe a connection you have made since starting the modeling project to the nervous system content. What do you understand better? What is less confusing to you?
Day 4	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	
Day 5	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	Reflection Question: In 3-4 sentences, describe what you do and/or do not like about STEAM and modeling.

Day 6	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	Reflection Question: In 3 sentences or more, describe what you have learned from making a model about the nervous system. What do you understand better? What makes more sense?
Day 7	1. Date: 2. What was your goal/what did you accomplish for today? 3. What did you learn today? 4. What is your plan for tomorrow? 5. What more information do you need? 6. Any Questions?	

Final Reflection:

Please provide a complete answer to the following questions. Please use at least 3 sentences to answer each question.

1. Do you feel like you have a better understanding of the structure/relationship of the nervous system? Why or why not?
2. Did you like STEAM and modeling? Why or why not?
3. Do you think this type of project helped you learn more than traditional classroom methods? (i.e., notes, worksheets, labs)