Table 1

Response to Reviewers

Reviewer	Reviewer's Suggestions	Action Taken
#1	Replace the word "modalities" in the title with a clearer and more commonly known word	The word "modalities" was switched to "methods."
#1	The word "contradicts" is used too often in literature review	Two instances of the word "contradicts" were changed to synonyms.
#1	Change "relevance" to "relevancy" in methods section	The wording was changed as suggested.
#1	Use "25-question" instead of "25 question" in the methods section	A hyphen was added as suggested.
#1	The citation for Cambridge University Press is missing a period	A period was added as suggested.
#1	Change "biological object in order to study" to "biological object to study"	The wording was changed as suggested.
#2	Suggested that the word "combining" be changed to "physical and virtual" in the paper's title.	I chose not to change this because I am also looking at 3D models in this study. Additionally, I am specifically looking at combinations of two methods, not just a single method and I feel this change might make that unclear.
#2	Check proper use of first-person language throughout the paper	A check for first person pronouns was done and any instances found were changed to reflect different language.
#2	Specifically, call out methodology on page 3 when using the phrase "results of these tests"	The word "achievement" was added to reference my methodology.
#2	Change the "Physical versus Virtual Dissection Efficiency" section of the literature review to chronological.	I chose not to change this because the rest of my literature review is organized topically, and I want to keep that consistent.

The effect of combining dissection methods on the academic achievement of students

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Research Methods in ISLT

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The effect of combining dissection methods on the academic achievement of students

Background and Significance of the Research

The use of physical dissection as a tool for anatomy education is a topic that has been fiercely debated throughout history. In the early 13th century, the dissection of human cadavers and other dead animals became an increasingly popular method to teach people about the internal structures of living organisms (Brenna, 2022). Many argue that the physical dissection of organisms is necessary for students to achieve a true understanding of the complexities and varieties that exist within the anatomy of living organisms (Korf et al., 2008). Conversely, there are many educators and researchers that have opposed the use of these methods citing ethical, religious, and logistical concerns (Madrazo, 2002).

Despite the longstanding debate on their use, physical dissection activities are often included in the curriculum of high school courses that seek to teach students anatomy such as biology, health, and animal science classes. In recent years, teachers and educational researchers have proposed many alternative methods to the physical dissection of organisms such as virtual dissection activities, 3D model dissection, and video-assisted teaching (Elizondo-Omaña et al., 2005). Questions about the efficacy of these alternatives have led to differing opinions among researchers about the best implementation methods to utilize in anatomy education (Fancovicova & Prokop, 2014; Boscolo-Berto et al., 2021). Opinions also differ greatly on the best ways to maximize student learning and produce results comparable or better to those gained through physical dissection alone (Scheckler, 2003). This study seeks to examine the largely unexplored possibilities of combining different physical and alternative dissection activities on student achievement.

Problem Statement

There is clear controversy surrounding the inclusion of physical dissection activities in anatomy curriculum and a lack of consensus among researchers about the ability of alternative modalities of dissection to promote learning. Given these issues, continued research is needed that explores the effectiveness of different modes of dissection activities and best practices regarding their implementation. There is not much research available on the impact of alternative dissection modalities, such as 3D model dissection, on student learning. This is particularly true when these activities are applied to high school classrooms. The differences between using multiple dissection activities compared to single activities have been explored by some researchers, but a large gap exists in research examining the effects of coupling different dissection activities on academic achievement.

Purpose of The Study

The purpose of this study is to examine the impact that different combinations of dissection activities have on high school student learning outcomes. The study sample will include three classes of 9-12 grade students enrolled in an introductory Biology course at public schools in Southwest Missouri. Participants will be divided into three groups. Group A will consist of students that complete a virtual dissection followed by a physical dissection. Group B will consist of students that complete a 3D model dissection followed by a physical dissection. Group C will consist of students that complete a 3D model dissection followed by a virtual dissection. A 25-question assessment will be given to each group of students prior to dissection and again after they have completed the dissection activities assigned to their group. The results of these achievement tests will be compared to determine if there are significant differences in learning outcomes between each of the three groups. Based on previous research into the use of different modalities

of dissection and their implementation, this study hypothesizes that there will not be a significant difference in the assessment scores of the three groups analyzed.

Literature Review

This literature review seeks to explore the effects of different dissection methods on the learning outcomes of students studying anatomy. Three modes of dissection are explored- physical, virtual, and dissection activities that utilize physical three-dimensional models. Sources were chosen based on their relevance to the topic. Relevant articles were collected utilizing keyword searches and by reviewing the literature cited in articles that were found. Articles were located using Google Scholar and databases accessed through the University of Missouri. The primary databases used were ERIC, Ebscohost, Wiley Online Library, and ScienceDirect. Both old and new studies were included to provide a thorough picture of changes in ideas on this topic over time. Literature was organized thematically. Themes explored include research on the efficacy of physical vs. virtual dissections, physical 3D model use versus physical and virtual dissection activities, student and teacher opinions on dissection modality, and a review of literature supporting the "combination method" of dissection activities.

Defining Dissection

Within the context of this review, physical dissection is defined as the "action of cutting something open, especially a dead body or plant, in order to study its structure" (Cambridge University Press, n.d.). Two frequently discussed alternatives to physical dissection are the use of three-dimensional physical models and the use of virtual dissection tools. For this literature review, a physical three-dimensional model is defined as any model of an organism or part of an organism that can be handled and taken apart by a student for the purpose of studying the physical relationships of component parts (Preece et al, 2013). A virtual dissection will be

defined as an interactive activity that takes place on a computer or related device, utilizes 2D or 3D models of objects, and requires the user to actively participate in "taking apart" components of a biological object to study its structure (Havlíčková et al., 2018).

Physical vs. Virtual Dissection Efficiency

Research related to the effectiveness of dissection simulations versus in-person dissections on student learning outcomes reveals conflicting opinions on efficacy. Guy and Frisby's 1992 study of college nursing students was one of the first to set the historical basis for the idea that there are no significant differences in learning outcomes between learners utilizing virtual dissection and learners utilizing hands-on dissection. In 1993, Kinzie et al. came to similar conclusions in their research with high school biology students. The results of a study conducted by Lalley et al. (2010) further support the idea that both of these dissection methods result in similar outcomes. Even though their research was conducted over a decade after the previously mentioned studies, they found that virtual dissections and physical dissections result in similar outcomes in terms of both learning about anatomy and the retention of that learning over time.

But many studies contradict the findings outlined above. Research conducted by Velle and Hall in 1999, led authors to conclude that students who participated in virtual dissections perform better on academic measures than students participating in physical dissections. Data reported by Matthews (1998), however; directly contradicts the conclusions of Velle and Hall. He found that students who performed a physical dissection performed better on exams than peers that completed a virtual dissection. A study by Cross and Cross (2004) lends further credence to the conclusions of Matthews. An analysis of their data suggested that knowledge gained via virtual dissection does not transfer directly to knowledge of organic frog anatomy,

therefore; physical dissection may be more effective for real-life learning scenarios. Researchers Biasutto et al. (2006) reported conclusions that support the findings of both Cross and Cross and Matthews. Their research revealed that students who utilized traditional cadaver dissection methods scored better on assessments than students who used comparable virtual methods. The diverse conclusions reached in the literature on this topic demonstrate a need for further study into the reasons behind these contradictions. What factors might be at play that account for these differences?

Physical 3D Models versus Physical and Virtual Dissection

Inconsistencies also exist in research surrounding the effectiveness of using physical three-dimensional models for anatomy education compared to the use of traditional physical dissection and virtual dissection. Garas et al. (2017) concluded that undergraduate students performed significantly better on an anatomy post-test when they used a 3D printed plastic model compared to students that dissected an organic specimen. Preece et al. (2013) compared plastic model use to virtual dissection and reported results that support the findings of Garas et al. They concluded that students who used physical models performed better than those using virtual dissection activities. The research of Lombardi et al. (2014) expanded upon these findings and revealed that students had better learning outcomes when using plastic 3D models compared to students participating in either physical dissection or virtual dissection activities.

Research completed by Chen et al. (2017), however; denies the conclusion that 3D model use always results in better learning outcomes than physical dissection. They found that, while medical students who used a 3D model of a skull did better than those that used a cadaver skull on lab tests, when tested on their understanding of anatomical theory there were no significant differences between the two groups. This suggested that 3D models may only result in better

outcomes for certain types of learning gains. Overall, though the contradictions within the literature on this topic are less severe than in literature related to physical versus virtual dissection outcomes, research that clarifies the relationship between 3D model use and specific types of learning outcomes may help to further understanding of this topic.

Opinions on Dissection Modality

While much of the literature supports that there may be viable alternatives to the physical dissection of plants and animals for anatomical study, teacher and student opinions on the value and experience of using these options vary greatly (Balcombe, 2001). The research of Havlíčková et al. (2018) suggests that teachers view both virtual and physical dissection positively and that differences in the value teachers place on the two methods are not significantly different. Research conducted by Jan Oakley (2012) refutes these findings. Through interviews and surveys with secondary science and Biology teachers, she found that educators did not feel that alternative methods of dissection "measured up" to physical dissection in terms of pedagogical value (Oakley 2012). Osenkowski et al. (2015) came to similar conclusions when analyzing the results of their survey of data collected from middle school and high school Biology teachers.

Research on student opinions about physical dissection and its alternatives tends to align best with the findings of Oakley (2012) and Osenkowski et al. (2015) findings on teacher opinions outlined above. Spernjak and Sorgo (2017) found that physical dissection was preferred by secondary students over other methods. They also found that most students desired more hands-on (physical) dissection opportunities. The survey data of Osenkowski et al. (2015) revealed that students requested organ dissection twice as often as other alternatives. Adding on to this idea, researchers Lombardi et al. (2014) found that students who either dissected physical

organs or used three-dimensional plastic models more strongly agreed with the phrase “science is fun” when compared to those that participated in virtual dissection activities.

The literature on the topic of opinions about dissection modality from the perspective of both teachers and students leads is diverse. Some teachers see the value in dissection alternatives, but others do not. Students seem to prefer physical dissection despite research supporting the efficacy of the virtual and 3D dissection methods, but the factors affecting their opinions are unknown.

The Combination Method

The “combination method” theory in which teachers combine multiple methods of dissection into learning plans has been proposed by many researchers to mitigate contradictory findings regarding the efficacy of dissection alternatives. This method may also be relevant for addressing the gap between the opinions of teachers and students and the data about the efficacy of different dissection modes. Akpan and Andre (1999), published one of the first studies on this topic. Their research focused on the benefits of completing a virtual dissection prior to a physical dissection. They found that middle school students' knowledge of frog anatomy was greater when students completed a virtual lab before a physical dissection than when they completed a physical dissection alone. The results of research by Biasutto et al. (2006) support that these results are consistent for older students as well.

Other researchers have confirmed that these findings continue to hold true in more recent years. A 2021 study completed by Boscolo-Berto et al. found that adding virtual dissection prior to the traditional hands-on dissection of human cadavers in medical student training improved students’ performance on an anatomy post-test. Even with learners exploring topics outside of anatomy, the support of a mix of physical and virtual manipulatives appears to be evident.

Olympiou and Zacharia (2012) completed a study dealing with lab activities in introductory physics and found that a combination of methods resulted in the highest performance.

While very little literature exists that deals with the combination of dissection modes as it applies to physical models, findings from Fancovicova and Prokop (2014) support the idea that a combination of methods still results in the best learning outcomes in these scenarios. The data from their research suggested that students who used physical 3D models paired with physical dissections scored better on achievement tests than students who performed either method separately. Replicating this and similar studies would be helpful to further explore the idea of the combination method and its effectiveness amongst different populations and in different settings.

Conclusion

Research into the topic of dissection methods seems to indicate that using a combination of modalities for dissection activities may be best for student learning and retention (Boscolo-Berto et al., 2021). Using a combination of techniques to mitigate the inconsistent findings on the efficacy of virtual versus physical dissection seems to be the preferred method reported by researchers (Cross & Cross, 2004; Lalley, et al., 2010). Similarly, the findings of research on the effectiveness of 3D models versus physical and virtual dissection support the idea of a combination method (Lombardi et al. 2014; Chen et al., 2017). Additionally, the literature reveals that the "combination method" is well supported for both 3D models paired with physical dissection, as well as for virtual dissection paired with physical dissection (Fancovicova & Prokop, 2014; Boscolo-Berto et al., 2021). The results of student and teacher opinion surveys reveal differences between what research says about the effectiveness of physical, virtual, and 3D model dissection techniques and how people feel about the use of these methods. These

differences also make the “combination method” more attractive to educators (Osenkowski et al., 2015).

Given that the “combination method” of dissection is the most supported theory for efficient student anatomy learning, more research needs to be completed to discover the effects of different combinations of these techniques on achievement. There is a noticeable gap in the literature when it comes to the efficacy of combining virtual dissection with the use of physical 3D models. Additionally, no research exists that compares differing combinations of dissection activities. The effects of different dissection mode combinations on student learning should be studied to further understand and evaluate the best practices for anatomy education.

Methodology

Literature on the efficacy of dissection modalities supports that the combination of virtual and physical dissection activities and the combination of 3D model activities and physical dissection activities are more effective at increasing student anatomy knowledge than either method alone (Fancovicova & Prokop, 2014; Boscolo-Berto et al., 2021). There is a gap in the literature, however; regarding how different combinations of dissection activities compare to one another regarding learning outcomes.

Method and Rationale

This study utilizes a quasi-experimental quantitative research design. Quantitative research focuses on analyzing the relationships between variables to gather data that can be analyzed by statistical tests (Creswell & Creswell, 2018). Quantitative research is an excellent choice for a study that seeks to generalize its findings to a broader group of people (Holton & Burnett, 2005). This method was chosen because my research seeks to evaluate the relationship between combinations of dissection modes and student performance within a specific high-

school classroom and generalize those findings to other classroom settings. Quasi-experimental designs are often used in classroom research because of the variety of environmental and logistical factors which make true experimental design impossible (Gopalan et al., 2020). This study will take place in a classroom setting and present many variables that are beyond the control of the researchers, therefore; a quasi-experimental design is the most appropriate.

Research Question

Research on dissection methods indicates that combining multiple modes of dissection can lead to better learning outcomes for students studying anatomy (Fancovicova & Prokop, 2014; Boscolo-Berto et al., 2021). This study hypothesizes that there will not be a significant difference in learning outcomes for students who complete one dissection activity combination versus any other combination. As such, the following question is posed: What is the impact on student learning outcomes when different combinations of dissection modes are used in class?

Variables

This study will separate learners into three groups. Group A will consist of students that complete a virtual dissection followed by a physical dissection. Group B will consist of students who complete a 3D model dissection followed by a physical dissection. Group C will consist of students that complete a 3D model dissection followed by a virtual dissection. An assessment will be given to each group of students before dissection and again after they have completed the dissection activities assigned to their group.

The independent variable used in this study will be the types of dissection activity combinations that students participate in, as this is the variable that will be controlled by researchers. The dependent variable is the results of the student achievement tests.

Population

The population for this study is public high-school students studying anatomy in the United States. High school is defined as grades 9-12. The study of anatomy refers to any academic course or portion of an academic course that seeks to inform learners about the structure and function of the body of a biological organism.

The sample will consist of three introductory Biology classes at public schools in the southwest Missouri region of the United States. Due to the constraints of seeking whole classes to participate, convenience sampling will be used. The researchers will contact school administrators and Biology teachers to find volunteers that are willing to allow research to take place within their classrooms. Researchers will seek to identify three Biology classes that are taught by the same teacher, at the same level, and contain a similar number of students. Written permission will be sought from both the school administrators and teachers involved. Additionally, parental/guardian consent and student assent will be obtained for each student participant.

Data Collection

Researchers will compose a 25-question assessment to test student knowledge of anatomy. This same test will be administered by the teacher(s) of the selected classroom on two occasions. The assessment will be given to all students prior to completing any dissection activities and once again after they have completed all the dissection activities assigned to their group. The results of these tests will be submitted to researchers upon completion.

Ethical Considerations

Because this study deals with minors, several ethical considerations must be made. First, the researchers will ensure that they have received all the proper permissions from

administrators, teachers, students, and their parents/guardians before beginning the study. This includes both consent forms and assent forms that inform participants of the nature of the study and its scope. Researchers will ensure that all parties involved understand that participation in the study is voluntary, and they are free to opt-out at any time without consequence (Nolen & Putten, 2007). Additionally, every effort will be made to ensure that all sensitive and/or identifying information received during the study is kept confidential.

Data Analysis Plan

First, according to the data analysis procedure outlined by Creswell and Creswell (2018), the researchers will report any relevant information or events that occurred during the pre/post-test data collection process (p. 158-159). This may include data about which students were present or absent for the pre/post-tests, notes about missing data and how it will be handled, or any other inconsistencies experienced. Descriptive analysis will be provided by calculating the mean score for all three groups, the overall mean, the standard deviation, and the range of the scores for all participants. Next, the researchers will analyze the data using inferential statistics. The results of the pre-test and post-test scores collected follow an interval measurement scale (Allanson, 2020). Since this study seeks to analyze all three independent groups regarding only one independent variable (type of activity combination) for all three independent sample groups, the most appropriate statistical test to use would be the One-Way Analysis of Variance (ANOVA) ("Which Statistics Test," n.d.).

To complete a One-Way ANOVA the researchers could utilize statistical software such as SPSS or SAS, or calculate the statistical results by hand and check them using a statistical program. After completing the computations, the researchers would then compare the calculated F value to the F critical value found in an F distribution table. This will allow a determination to

be made about whether there is a significant difference between the scores of the test groups. If the F value calculated is greater than the F critical value found in the table, it would be determined that there is a significant difference between the scores of the three groups and the hypothesis that there is no difference in the learning outcomes achieved by students using when using different combinations of dissection activities would be rejected (Zach, 2021). Additionally, the researchers would present all data in tables and figures for readers to review.

Timeline

Recruitment of participating classrooms will take place late into the spring semester of the 2022 school year and continue into the summer before the start of the next academic school year. The teacher/class selection process will be finalized before the start of the fall 2022 semester. Because most public schools in Missouri offer introductory Biology as a year-long course, a brief consultation will be held with the selected teacher(s) in the early fall to discuss their course schedule and when a dissection activity would make sense within their course flow. Depending on the needs of the teacher, dates will be scheduled to complete the study that works well for all parties involved. The researchers will request to consult with the teacher(s) once more to preview the lesson plans for each combination of activities to ensure that there are no factors that would harm the integrity of the study. The 25-question assessment and the teacher lesson consultation will be completed at least two weeks prior to the activity start dates. Data collection will take place over two-three class periods during the 2022-2023 school year. After data collection, data will be organized and analyzed by the end of the summer of 2023. Results will be submitted for publication early in the fall semester of 2023.

Conclusion

The incorporation of physical dissection activities into anatomy curriculum is controversial. Due to this controversy, many alternative methods of dissection have been proposed and researched to see if they offer comparable gains in learning (Elizondo-Omaña et al., 2005). Additionally, some researchers have explored the effect that utilizing a combination of dissection activities has when compared to single-use dissection activities (Fancovicova & Prokop, 2014; Boscolo-Berto et al., 2021). This study aims to explore the effect that different combinations of dissection activities have on student learning. The study will follow three high school Biology classes assigned to different treatment groups beginning in the spring of 2022. One group will consist of students that complete a virtual dissection followed by a physical dissection. One group will consist of students who complete a 3D model dissection followed by a physical dissection. A final group will consist of students that complete a 3D model dissection followed by a virtual dissection. A 25-question assessment will be given to each group of students before dissection and again after they have completed the dissection activities assigned to their group. The results of these tests will be statistically analyzed to determine if there are significant differences in learning outcomes between the three treatment groups, and the results will be submitted for publication by the fall of 2023.

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