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An Analysis of the Effectiveness of Incorporating Virtual Cadaver Study on Student Performance in Human Anatomy and Physiology

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THE EFFECTIVENESS OF INCORPORATING VIRTUAL CADAVER STUDY ON STUDENT PERFORMANCE IN HUMAN ANATOMY AND PHYSIOLOGY

By

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A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

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Approved by

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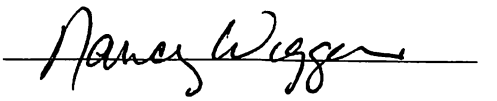

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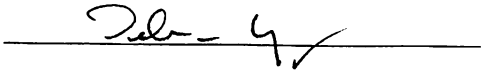

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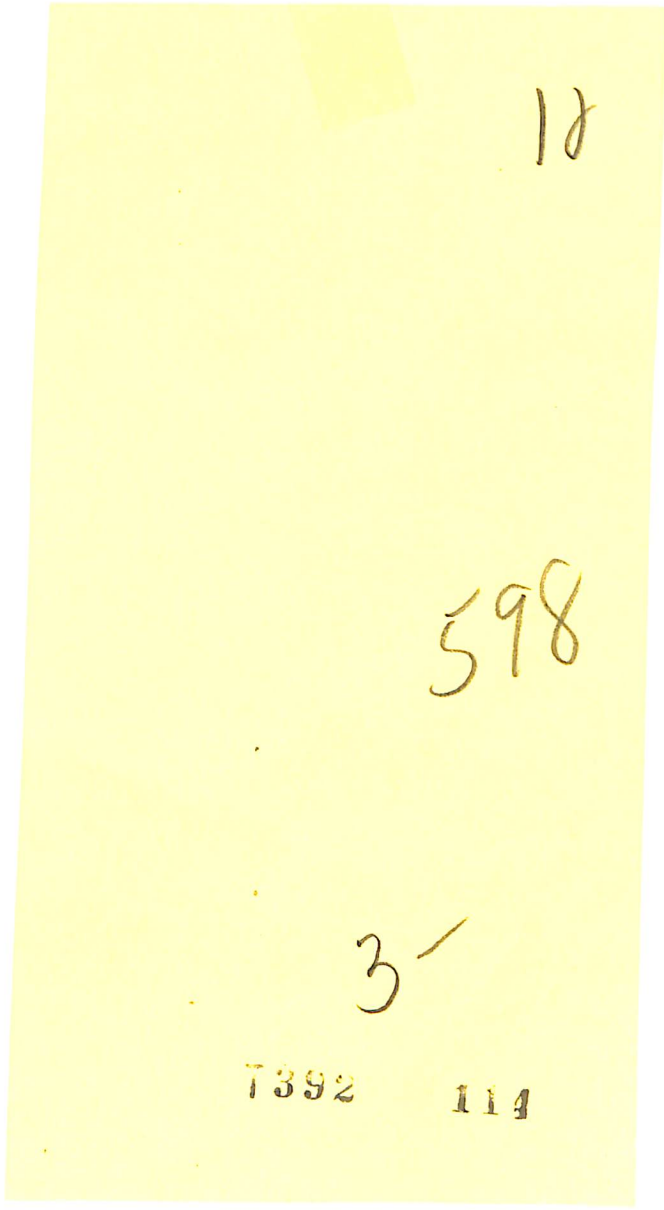

ABSTRACT

In an ideal Human Anatomy & Physiology (Human A&P) laboratory, students would use human cadavers for study. However, due to the limited supply of human cadavers and high cost of constructing and maintaining laboratory facilities, many institutions choose to use various animal organs and models to teach human anatomy. Dissections are an irreplaceable tool to help students understand human anatomy because models often have garish colors that allow easy discrimination of structures but do not show the colors and textures associated with real tissue. Additionally, cadavers, organs, and models must remain within the laboratory, so students have limited access. The use of virtual cadaver software is an innovative way to provide students with unlimited access to a more holistic approach to human anatomy, as well as tools to study the structure and function of the human body. While some universities are choosing to completely replace dissections with virtual cadaver software, The University of Mississippi Human Anatomy & Physiology I (BISC 206) course uses virtual dissections to supplement, not substitute, for dissections. Prior to the initiation of this study, it was hypothesized that incorporating virtual cadaver software into Human Anatomy and Physiology courses helps the students study, increases their understanding of the human body, and improves their retention of the material learned both in the classroom and in the laboratory. BISC 206 students are required to use Anatomy & Physiology Revealed® (APR) software during the required laboratory period. In addition, they dissect animal organs and examine models, when plausible. APR provides online access to a layered virtual cadaver dissection as well as quizzes, organ descriptions and functions, and even imaging such as X-rays and CT scans. In the current study, all

students in Human A&P I during the fall semester of 2012 were asked to participate. Three surveys were administered during the laboratory sessions, at the beginning, middle, and end of the course. In order to maintain anonymity, the students were asked to qualitatively evaluate how APR affected their interest in Human Anatomy and Physiology and whether virtual cadaver software supplemented with dissection and models, improved their grades in the course. A significant majority of students felt that APR not only improved their grades in the course, but also made the material more interesting and would like to use virtual cadaver software in future courses. Therefore, using virtual cadaver software to supplement laboratory dissections and models assists the students in preparing for test and quiz material in Human A&P I by giving them unlimited access to real human tissue and providing additional learning aids in the form of histology, organ descriptions and functions, quizzes, animations, and imaging.

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After nearly one and a half years of researching, collecting data, performing analysis, and editing, I am thrilled to present this body of work on the effectiveness of virtual cadaver software in a Human Anatomy & Physiology I course. However, I could never have completed my thesis without the help of Dr. Carol Britson. She is not only an incredible Human A&P professor, but also a wonderful thesis advisor. Dr. Britson spent countless hours meeting with me as we discussed the direction of the research and all the possible angles from which to view the data. Her editing and suggestions helped me turn a good thesis into something that I am incredibly proud of and cannot wait to defend. I also want to thank my second reader, Dr. Nancy Wiggers, and my third reader, Dr. Debra Young, for providing non-science perspectives for a topic that I believe concerns scientists, educators, and students alike. Also, special thanks to Dr. Stephen Threlkeld for allowing me to use his counting box for the past year, which made hours of tabulating much easier. Furthermore, I would like to thank the Department of Biology for supporting this project.

Finally, I wish to thank the Honors College for providing me with so many wonderful experiences and friendships over the past four years. The main reason I decided to attend the University of Mississippi was because of the Sally McDonnell Barksdale Honors College. I love how students can get the advantages of a large university, such as plentiful campus organizations, community involvement, and diversity, with the added benefit of having classrooms with only twenty students and instructors who encourage you to think creatively and critically. The Honors College strives to create leaders not only in the classroom, but also in the community, and I can

honestly say that I am a better person and a stronger student because of this program. I never thought that I would have the opportunity to interview Holocaust survivors at the U.S. Holocaust Memorial Museum in Washington, D.C., or spend Christmas break in New York City on the sophomore service trip. I definitely would have never imagined that the shy, timid person I was freshman year would be the confident person standing up in front of professors, family, and friends defending my thesis. All of these amazing experiences were made possible by the Honors College, and I cannot thank them enough. As I begin medical school at the University of Mississippi Medical Center in the fall, I plan on continuing along the path of scholarship, leadership, and service that the Honors College began instilling in me four short years ago. I would also like to thank my family and friends for encouraging me through this lengthy process and providing me with support. I am incredibly blessed to be surrounded by people who push me to be the best student and person I can be, and I would not be where I am today without each and every one of you.

INTRODUCTION

For most undergraduates, computers are a part of typical classrooms. Instructors are showing videos demonstrating key concepts, and textbooks provide online materials to support interest in the material and understanding. In human anatomy courses, it is particularly difficult to convey information about intricate organ systems with two-dimensional textbook drawings or photographs. According to Brenton et al. (2007) human anatomy is the broad term for the "study of the form, position, size, and relationship of the structures in the body" and can encompass gross anatomy, histology, embryology, and neuroanatomy. In order to enhance student performance and understanding in the Human Anatomy and Physiology I (BISC 206) course, the University of Mississippi began incorporating virtual cadaver software into the required laboratory component in the fall of 2012. The software program, Anatomy & Physiology Revealed ® (APR), provides students unlimited access to a virtual human cadaver where they learn about structure and function of organs and organ systems through virtual dissection, histological photomicrographs, CT, MRI, X-Ray, etc. APR was never intended to replace the dissection of animal organs and examination of models; rather, the 3-D imaging software was meant to supplement the laboratory models and dissections.

Real dissections provide students with experiences and perspectives that they cannot receive from multimedia or models alone. The Human Anatomy & Physiology Society (HAPS) is an organization whose goal is to set minimum curriculum guidelines for human anatomy and physiology courses in universities throughout the world so that

students may excel both within the classroom and in their respective fields. According to HAPS, use of computer simulations, models, and other teaching tools should never replace animal dissection (2008). For example, virtual cadaver software does not allow students to work with real tissues and determine the texture or weight of the organs they are studying (Brenton et al. 2007). Some studies, such as Predavec's research at Monash University in Australia, are suggesting that virtual dissection can be an alternative to animal dissection and provides students with a way to learn the material without blood and smells that inhibit their learning of the information (2001). However, most students in Human A&P I are interested in health-related professions, and many will have to deal with blood, odors, or tissues either in professional school or in their careers. Therefore, the need to become accustomed to things that may be unpleasant is necessary for success.

Furthermore, whether students are interested in nursing, physical therapy, medicine, dentistry, or other health fields, they will need to learn to work with others in order to help their patients. Since dissections involve students working together in pairs or small groups, students also learn to collaborate. Franklin et al. (2002) found that most of their students (71%) viewed the cat dissection as more useful in creating co-operative learning skills, than the computer-based dissection (47%) when 80% of the students used real dissections, 15% used computer-based dissection, and 5% used neither learning tool. However, this is only true if all of the students in the dissection group are actively participating and focusing on learning the material.

Ideally, undergraduate students would work with cadavers to examine human anatomy, but each cadaver costs approximately $1,000 once embalming and cremation costs are included (Fallik 2005). This figure does not include the cost of laboratory

renovations to accommodate cadaver dissections. The Department of Biology at Arizona State University replaced a laboratory based on fetal pig dissections with one that utilizes human cadavers, simulation software, as well as plastic models. The cost of physical renovations was $303,000, not including equipment costs of $70,000, to implement all changes from improved room ventilation to meet environmental safety standards to creating a laboratory where cadavers could be housed (Harrison et. al 2001). Although these are final costs for building a laboratory with cadavers as well as computers and models as teaching tools, it provides a rough estimate of the amount of money involved in creating a laboratory suitable for cadaver dissections. More recently, Philadelphia University built an on-campus full-dissection gross anatomy laboratory in 2004 for approximately $210,000 (Goldman 2010). Many modifications were needed so that cadavers could be housed and safety standards obeyed. For instance, the air handling system must keep the temperature cold enough to prevent the cadavers from decomposing and reduce mold growth, and the air must constantly be filtered to limit formaldehyde exposure. Also, the benches, cabinets, sinks, and tables must be stainless steel, and supplies such as bone saws, gloves, and special dissecting tools must be provided (Goldman 2010).

Virtual dissection is a way for professors to bridge the gap between models or dissections and human cadavers. McGraw-Hill, Inc. developed a software package, Anatomy & Physiology Revealed®, which allows students to view and manipulate virtual human cadavers, with a focus on the endocrine, urinary, digestive, respiratory, reproductive, skeletal, muscular, nervous, and cardiovascular systems (Nasr 2007). Students create online accounts after purchasing the software so that they may access the

material from any Internet source. To create manageable lists of required structures from the 1400 identified structures, the instructor creates a weekly list accessible by entering a short code. This code limits the amount of information available so that it is not too overwhelming for the students and corresponds to the material learned in the classroom and the laboratory. In addition, the program provides access to online quizzes, which require the students to know specific names, including spellings, of anatomical structures. Students may hear audio pronunciations and examine MRI, histology, and X-ray imaging (Nasr 2007). APR allows students to not only rotate the images of real cadavers to see anatomy from all angles, but also highlights specific structures, and provides their functions.

Since the cost of cadavers is so high, labs often use animal organs as cadaver substitutes. However, use of animal organs does not allow students to see the bigger picture. Many human structures, such as bones or joints, are difficult to understand the whole structure when parts are viewed individually. Virtual dissection shows preserved human cadavers at multiple angles, and students can peel away varying layers of tissue to see the organs. Additionally, during a dissection, students are often unclear about which structure to locate due to differences between the idealized textbook or model structure and the real form. According to Franklin et. al. (2002), "realism of the 'fresh' virtual material is in contrast to the real cat cadaver, which is preserved with all organs and structures uniformly brown in colour, making them harder to differentiate."

Although physical dissections help students familiarize themselves with dissection tools and techniques, many students do not have the time or proper training to dissect organs or cadavers properly. They are often cutting tissues and destroying some

important features of the organ or cadaver. Once cuts are made, they cannot be undone. However, as Donnelly points out, with virtual dissections cuts can be made and changed many times, and cadavers may be viewed from multiple angles (2009).

This study surveyed undergraduate students in Human Anatomy & Physiology I, a three credit hour lecture course with a one credit hour laboratory. Due to the large number of students (390), attendance in lecture is not taken, but attendance in the laboratory is mandatory. The lecture portion of the course consisted of the instructor using visual media to explain topical material during each of the three 50 minute classes per week. Each weekly laboratory session consisted of two contact hours with approximately 30 students each. Laboratory sessions began with the teaching assistant (TA) giving a short quiz on the basic information needed to complete the upcoming lab. Next, the TA introduced the week's lab and used plastic models and APR software to familiarize the students with the current organ system. If an animal organ corresponding to the lab was available, students dissected the organ and used APR software and textbook diagrams to identify anatomical structures. At the end of each two-hour lab, students would complete an activity to ensure comprehension of the relevant anatomy. Students also participated in two laboratory practicals, one in the middle, and one at the end of the semester.

The University of Mississippi Human A&P I course has employed blended learning in the laboratory sessions by using APR, as well as models, dissections, "wet-lab" experiments, and teaching assistant instruction. Blended learning assumes that there are benefits to both face-to-face interaction and online methods of teaching, and strives to find a balance between the two different teaching styles (Osguthorpe and Graham 2003).

Osguthorpe and Graham go on to describe six goals that most educators have when employing blended learning in the classroom, "pedagogical richness, access to knowledge, social interaction, personal agency, cost effectiveness, and ease of revision" (2003). The overall goal of blended learning is to improve the comprehension and retention of the material the students are learning (Osguthorpe and Graham 2003). One of the main questions this study examines is whether APR in a blended learning environment improves the "pedagogical richness" of the Human A&P I course. Use of multimedia in the classroom provides the students with access to more content than just the models or organs available in the laboratory or the drawings available in the textbook. APR allows students to view the system or organ they are studying in the laboratory manual from multiple angles and with varying layers of tissue exposed. Students can also click on the name of a structure, which simultaneously highlights the structure on the cadaver and describes the function. To assess mastery of the material, students can take online quizzes, which quantifies knowledge of function, structure, location, and even spelling of relevant organs or tissues.

The use of multimedia in the classroom, under the instruction of a teaching assistant or professor, provides far more benefits than the use of software by students working alone. Examination of the virtual cadaver during the laboratory allows students to interact with each other, as well as the teaching assistant, and is what Osguthorpe and Graham refer to as improving "social interaction" (2003). Additionally, the instructor encourages students to determine the answers to their questions or the week's laboratory questions on their own, promoting "personal agency" (Osguthorpe and Graham 2003). Students learn to trust their own instincts and may use the software to test their

knowledge and search for answers. Although this study is not particularly concerned with cutting costs by using blended learning, Osguthorpe and Graham mention that multimedia allows teaching assistants to replace full-time faculty in blended learning environments because students are encouraged to use their own investigation of the material, as well as receive information from the instructor (2003). Additionally, the use of blended learning, such as APR, adds instruction to the course for a small price, thus promoting cost effectiveness. Finally, APR allows an "ease of revision," where teaching assistants may respond to the student inquiries during laboratory by showing them future material, or even material that the textbooks and models do not sufficiently show, which allows the blended learning environment to be "flexible, responsive, and spontaneous" (Osguthorpe and Graham 2003). Therefore, the purpose of this study is to investigate whether or not the use of APR, as well as dissection and models, in the Human A&P I laboratory, will improve comprehension and retention of human anatomy and physiology.

MATERIALS AND METHODS

In the fall semester of 2012, the Anatomy & Physiology I (BISC 206) students were asked to complete a total of 3 paper surveys regarding the APR virtual cadaver software. The timing of each survey was chosen carefully so that the students would have enough knowledge of the software to be able to answer the survey questions. Responses to the surveys gauged the students' attitudes toward the software as they became more experienced with the technology. The initial survey (Appendix A) was given before the first laboratory to collect background information about the students' prior experiences with virtual cadaver software and dissections, as well as their interests in human anatomy. The second survey (Appendix B) was administered in the middle of the semester during a laboratory with a large focus on histology. This survey focused on aspects of APR that the students found most beneficial, for example how often the students used the software, and whether the students preferred using virtual cadaver software, dissections, or both in the lab. The third survey (Appendix C) was given during the final lab, which was the brain dissection. The main goal of the final survey was to ascertain whether APR was effectively implemented into the laboratory and if the software helped students with comprehension and retention of human anatomy. According to C.A. Britson, the instructor of the course, by the end of the semester, students should be able to accomplish four goals, "identify selected structures of the human body using correct terminology; correlate structure with function for the systems covered in the course; reason through cause-and-effect within physiological processes;

and describe the role of homeostasis in the living human for all systems covered in the course" (Britson, pers. comm.).

A majority of the survey questions asked students to qualitatively rate their attitudes towards specific aspects of the software, using the responses "strongly disagree, somewhat disagree, neutral, somewhat agree, and strongly agree" on the five-point Likert scale (Göb 2007). Survey responses were anonymous to protect identities of the students, and to ensure that the students' responses could not affect their grades in the course. Students were required to purchase the $40 software, but not all students purchased course materials. However, at least one student in every lab group (approximately 4 students per group) had access to APR, so students could at least access the material during each laboratory period. After surveys were collected, responses were scanned into a PDF, and results were tabulated using a counting box. Data was entered into an Excel® spreadsheet, which was used for statistical analysis. A Chi-square analysis was then conducted on the results for selected survey questions to determine whether or not the data was statistically significant (Siegel & Castellan 1988). Many responses were excluded from statistical analysis because the questions dealt with student background. The level of significance was set at $\alpha \leq 0.05$. This study was approved as exempt by the University of Mississippi Institutional Review Board under 45 CFR 46.101(b)(2) and was given the Protocol number 12-307.

RESULTS

Many of the questions in Survey 1 were used to obtain background information before the semester began, including how familiar the Human Anatomy and Physiology I students were with both dissections and multimedia as teaching tools. At the beginning of the semester, most of the students were interested in pursuing nursing (45%), physical therapy (16%), nutrition (8%), or medicine (6%). Out of the 373 students present at the beginning of the semester, 90% took the class because it was required, 4% took the class because they were interested in anatomy, and for 6% the class was required, but they were also interested. Although 89% of the students had previously performed dissections, only 8% of the students had prior experience with simulation software. Concerning the students' expectations for grades in the course, a significant majority anticipated getting A s (71%), with a much smaller percentage of B s (27%), and only a few C s (2%) (χ^2 = 73.23, df = 2, $p<0.001$). The students were given grade options of A, B, C, D, and F, but chi-square analysis was only done on the A, B, and C options. It was assumed that no students would enter a course with the expectation of making a D or F, and in fact, no students chose these options. When the students were asked what they felt a fair price for the APR software was, most of them chose the retail price of $40 (33%), followed by $30 (28%), $20 (21%), $50 (16%), and lastly $60 (2%) (5 survey responses disregarded due to multiple or no answers).

Out of the students that had previously performed dissections, a significant majority (χ^2 = 92.2, df = 4, $p<0.001$) strongly agreed (49%) that they enjoyed the

educational experience (Figure 1). When asked if they would feel more comfortable with virtual dissections than physical dissections, the largest response was in the neutral category, but a significant majority ($\chi^2 = 34.1$, df = 4, $p<0.001$) either strongly agreed (14%) or somewhat agreed (18%) that they would prefer virtual dissections (Figure 1). Since most of the students in Human A&P I had never used virtual cadaver software before, students were asked if cadaver images would disturb them in any way. A significant majority ($\chi^2 = 125.5$, df = 4, $p<0.001$) strongly disagreed (63%) that cadaver images are disturbing (Figure 2).

In the second survey, the initial question asked how much time per week was spent using APR, 15% said never, 39% said less than 1 hour, 34% said 1-2 hours, 9% said 3-4 hours, and 3% said 5 or more hours. The students who claimed to have never used the software (49 students) were then removed from all future analyses for the second survey because they did not possess enough knowledge about APR to answer the survey questions. Next, questions were also asked to determine why the students used APR and what aspects of the software they found most beneficial. For these questions, students were able to select multiple responses, so percentages were calculated by dividing total responses for each category by the total number of responses, not the total number of students. Out of the 279 students who used the software, 45% used it to study for the lab quizzes and/or practicals, 23% used it to reinforce information presented in lab, 21% used it to view topical animations, and 11% used it to clarify points made in lecture (2 surveys blank). The features of the software that best helped the students accomplish these goals were: self quizzes (31%), seeing actual human anatomy (27%), locating organs (25%), and reading the descriptions, including pronunciation (16%), while 1% did not use the

software. Again, in the previous question, students could select multiple responses, and the previously explained method of percent calculation was used. Even though APR was only required during the lab portion of the class, 43% stated that the software helps them in both the lecture and the lab, 54% stated it helps them during the lab, and 3% showed it helps them during the lecture. When asked if the students felt that the software was difficult to learn, the highest response was in the neutral category (33%), but a significant majority ($\chi^2 = 34.5$, df = 4, $p<0.001$) either strongly disagreed (11%) or somewhat disagreed (30%) (Figure 3). A large percentage of students (41%) stated that they use APR for their own curiosity, and not for merely learning the material on the practicals and exams. Additionally, if students were given the choice between physical histology (using microscopes) and/or virtual histology (using the computer), 46% would use both, 40% would use virtual, and 14% would use physical. After a few months of using the software, 92% stated that the software was an efficient use of their time, and only 8% believed it was an inefficient use of time.

During the last laboratory session, the students were asked to complete a final survey to determine whether the use of APR helped them comprehend and retain the material, and evaluate how well Human Anatomy and Physiology I incorporated both virtual and physical dissections. A small number of students answered neutral to all of the survey answers, so their surveys were disregarded (17 student surveys). All neutral responses indicated that the students either did not know enough about the software to adequately answer the survey questions or were simply rushing to turn the survey in and did not take the time to process each question. According to the 263 student responses, a significant majority ($\chi^2 = 60.8$, df = 4, $p<0.001$) of the students strongly agreed (21%) or

somewhat agreed (46%) that the software has become easier to use over the course of the semester; additionally, a significant majority ($\chi^2 = 46.9$, df = 4, $p<0.001$) strongly agreed (16%) or somewhat agreed (39%) that they have grown to like using the software (Figure 4). In order to keep the surveys anonymous, the students' grades were not linked to their responses, but according to respondents, a significant majority ($\chi^2 = 42.0$, df = 4, $p<0.001$) strongly agreed (11%) or somewhat agreed (34%) that they have seen rewards from using APR in terms of higher grades (Figure 5).

When the students responded by circling all of the reasons why they did not use the software regularly, 55% claimed they did not have the time, 24% stated the software was too confusing, 18% said the software did not help them, while only 3% claimed that the images disturbed them. For this question, a total of 189 surveys were included, 74 were blank, and 17 were excluded due to all neutral answers. The students who left the surveys blank either use the software regularly, found that none of the given options applied, or just did not take the time to read the question. Additionally, the wording of the question is important to the results, because some students who use the software rarely or not at all claimed that they did not have the time. Therefore, lack of time may not be the problem, as much as lack of motivation for the course or for software use.

The students were given a list of the lab exercises for the semester and asked to rank the top three for which APR helped the most. A majority of the students showed that the virtual dissections improved their comprehensions of the axial skeleton (16%), appendicular skeleton (16%), and the bone structure and function (10%) (Table 1). Since multiple answers could be circled for each of the prior two questions, the percent

response was calculated as previously explained, with responses for each category divided by the total responses, not the total students, for each question.

When the students were asked to evaluate how virtual dissections and physical dissections worked together in the class, a significant majority ($\chi^2 = 54.8$, df = 4, $p<0.001$) strongly agreed (9%) or somewhat agreed (39%) that the software helps them compare and contrast human anatomy to the anatomy of the organisms they are dissecting (Figure 6). Additionally, a significant majority ($\chi^2 = 46.5$, df = 4, $p<0.001$) felt that the lab incorporated both physical dissections and virtual dissections very well (18%) or somewhat well (35%) (Figure 7). A significant majority ($\chi^2 = 55.9$, df = 4, $p<0.001$) of the students either strongly agreed (11%) or somewhat agreed (44%) that APR helped them meet course objectives (Figure 8). Finally, when asked about future use of the understanding of human anatomy gained through Human A&P I and APR use, a significant majority ($\chi^2 = 58.0$, df = 4, $p<0.001$) strongly agreed (38%) or somewhat agreed (36%) that they will use their knowledge outside the course, and a significant majority ($\chi^2 = 26.2$, df = 4, $p<0.001$) strongly agreed (19%) or somewhat agreed (37%) that they would like to use multimedia as a learning tool in future classes (Figure 9).

DISCUSSION

When performing a study, it is important to obtain background information about the students' prior knowledge on the topic; therefore the goal of the first survey was to ascertain how familiar the Human A&P I students were with the two modes of teaching, dissection and virtual cadaver software. Since most of the students in BISC 206 were interested in health-related professions, these students took Human A&P I because it was a required course. Interestingly, while nearly all of the 373 students present at the beginning of the semester had previously performed dissections, only a small number of students had prior experience with simulation software. This reinforces the commonality that the conventional approach to anatomy is through physical dissections. While some studies suggest that virtual histology can completely replace physical histology (Predavec 2001), the data from this study showed that a significant majority of the students who had previously performed physical dissections strongly agreed that they enjoyed the educational experience. It was also important to determine whether the cadaver images would disturb the students in any way because an inability to look at or use the software would hinder its effectiveness as a learning tool. However, a significant majority of the students strongly disagreed or somewhat disagreed that they would be disturbed by cadaver images, so this was not an issue. Additionally, a significant majority strongly agreed or somewhat agreed that they would feel more comfortable with virtual dissections than physical dissections. Hence, it was established that not only were

students not disturbed by virtual cadaver software, but also they preferred the software to physical dissections.

One major question that this study addressed is, "How well can virtual cadaver software be implemented into a laboratory that uses both dissections and models, to create a blended learning environment?" When the students were asked whether they prefer virtual or real histology, nearly half of the students would use both, followed by virtual, and a small percentage would use real. By the middle of the semester, almost half of the students preferred this blended learning environment. Additionally, even though the virtual cadaver software was only required in the laboratory portion of the course, approximately half of the students stated that APR helped them in both lecture and laboratory. This indicated that for a large portion of the students, the virtual cadaver software not only helped them prepare for the weekly quizzes, lab activities, and practicals, but also aided them in studying for the exams in the lecture course.

Due to recent advancements in virtual cadaver software, researchers have been testing the effectiveness of blended learning strategies, specifically for human anatomy courses. A study of first year biology students at Pompeu Fabra University in Barcelona showed that the students who used blended learning to study the anatomy of the locomotor apparatus had clear progress in their academic performance, which was evident in their grades and the number of students who passed the assessment in one attempt (Pereira et. al 2007). Virtual cadaver programs, such as APR, have even developed ways to combat disadvantages that researchers associate with using multimedia. For instance, Kerka (1996), states that virtual learning can cause students to feel isolated and overwhelmed with access to too much information. However, in BISC

206, the instructor provided the students with codes to access each week's list of relevant topic upon entering the lab, and the material was then available to the students until the 24-month subscription had lapsed. Therefore, the students did not see the new material until it was explained in either the lecture or laboratory, and the material was tailored to what was tested in the class. Additionally, by incorporating APR into the weekly laboratory sessions, students no longer experienced the social isolation that Kerka (1996) referenced. Students were encouraged to work in groups on both the virtual cadaver software and the dissections, so they could consult each other with questions or concerns. Finally, each week the professor gave the teaching assistant a schedule of laboratory objectives, as well as teaching tools that should be used, whether it was software, models, or dissections. This blended learning teaching style allowed the instructor to promote a sense of cohesiveness among what the students are learning, which allowed fair assessment through quizzes, lab practicals, and examinations. A study on virtual learning effectiveness by Stonebraker and Hazeltine (2004) carried out on individuals taking the Certified in Production and Inventory Management (CPIM) exam showed that "any improvement in the perceptions of cohesiveness and task and social interaction would be expected to improve perception of learning, satisfaction, and course persistence." Therefore, since each laboratory session followed the same structure, the overall knowledge of the class and sense of fairness among the students should be improved.

Several questions on the last two surveys dealt with the main topic of the effectiveness of incorporating virtual cadaver software into BISC 206. One goal of virtual human dissections is to allow the students to see similarities and differences between human anatomy and the anatomy of the animal organs they are dissecting.

Nearly half of the students either strongly agreed or somewhat agreed that APR helped them compare and contrast human anatomy to the anatomy of the organisms they were dissecting. Additionally, 55% of the students stated that the virtual cadaver software helped them meet the course objectives, such as identifying structures, functions, cause-and-effect, and homeostasis in the human body (Britson, pers. comm.). Furthermore, a significant majority of the class felt that the lab incorporated both physical dissections and virtual dissection very well (18%) or somewhat well (35%). The results indicated that the BISC 206 course provided students with a more well-rounded view of anatomy through physical and virtual dissections and gave the students irreplaceable experience with tissues, while at the same time providing human cadavers that are otherwise not feasible for many institutions.

One feature of the virtual cadaver that models or dissections do not have is unlimited access to this learning tool from almost any Internet source. Therefore, many of the survey questions tried to establish the frequency of software use outside of class, as well as whether or not students were exploring aspects of the program that might not be used during the laboratory sessions. By the middle of the course, 34% of the class was using the software 1-2 hours per week, 9% was using it 3-4 hours per week, and 3% used the software over 5 hours per week. Interestingly, when students were asked why they did not use the software more frequently, the main response was because they did not have the time. Thus, most of students not only use the software outside of class, but also would use the software more regularly if it were not for their other obligations. Additionally, this means that it was not features of the software that kept the students from using APR more every week. When the students are outside of the laboratory,

nearly half of them use the virtual cadaver software for their own curiosity to explore features of the software such as quizzes, organ descriptions, imaging, or histology that they might not have time to use during each two hour lab.

After it was determined that students were using APR to study for the lecture and laboratory, several survey questions were studied to see which aspects of the software the students found most beneficial for the Human A&P I course, as well as why the students were using the software features. The most popular feature of the software was the self quizzes (31%), followed by seeing actual human anatomy (27%), locating organs (25%), reading the descriptions (including pronunciation) (16%), while 1% did not use the software. These percentages were similar to those of a study on virtual cadaver software using first year medical students at the University of Munich, where students ranked seeing 3-D human anatomy first (31%) and the quiz module second (26%) (Adamczyk et. al. 2009). As previously mentioned, clearly students were using APR to study for not only the laboratory portion of the class, but also the lecture portion, and the animation feature allowed the students to view how the organ would function if it was in a human body, something which is necessary in health-related fields and cannot be easily learned from models or physical dissections. Using the animation feature and viewing the whole cadaver, rather than parts through dissection, would especially be valuable in looking at moving or large structures. This would help explain why students found APR most helpful with the topics of the axial skeleton, appendicular skeleton, and bone structure and function.

When interpreting the results, it should be noted that some students chose not to purchase the software. While students were required to use the APR software during the

laboratory by either using their own account or sharing with another student, students without their own account could not access the virtual cadaver software outside of the laboratory. Therefore, limited access to APR might have inhibited the effectiveness of the software because the student did not have adequate time to use the features such as the viewing human cadavers, completing quizzes, or locating organs and determining their functions. Additionally, future studies should ask students who do not feel that they have used the software enough to accurately complete the survey, to indicate so on the survey and not answer the questions. In this study, each student survey that showed no software use (Survey 2) or neutral responses to all of the survey questions (Survey 3) was disregarded. It was assumed that these students were not familiar enough with the software features to answer questions about the strengths and weaknesses of the software, or if they simply answered neutral, then they were not taking the time to honestly answer the survey.

The students were asked what they would change about the APR software if they could in an open-ended question, and 26% wanted quizzes to be less specific in grading and information, 23% wanted more specific explanations, 20% wished that APR followed the class more closely, and 13% asked for more animations or videos. Many quiz questions in APR required the student to click on the exact spot of the structure, which was often difficult to do. Additionally, the grading for quizzes is very strict and does not accept misspelled words, which is frustrating to some students. Other students wished that the list of required structures in APR followed the lecture material more closely. However, APR is meant to elaborate on and provide varying views of the structures presented in lecture, not merely to repeat the material. In regards to those

students who wanted the software at a lower price (13%), when asked what a fair price for the software would be, 49% chose below the retail price and 33% chose the actual retail price of $40. Therefore, a majority of the students showed that the price of the software was not their main complaint. However, if the software could somehow be made available for free, more students might have acquired the software and had access to APR outside of the laboratory.

Another area of improvement in the software might be in ease of navigation. Even though a significant majority of the students stated that they strongly disagreed (11%) or somewhat disagreed (30%) that the software was difficult to learn, the results indicated that 24% of the students do not use APR regularly because it is too confusing. Adamczyk et. al (2009) addresses this concern as well because their results indicated that students might feel overwhelmed by the free structure of the software. However, one feature that their virtual cadaver software had that APR lacks is hypertext linking the program to the Internet, which might be more confusing than it is helpful. APR allows the instructor to submit required organ names and structures so that students are given some direction. Additionally, one day a week the students could come to the laboratory with a teaching assistant to become better acquainted with the software and ask questions about human anatomy. Perhaps some students who claimed to be confused did not take advantage of this opportunity or did not use the software enough to become familiar with the features. For instance, in the final survey, the students were asked if the software had become easier to use over the course. A significant majority of the students strongly agreed (21%) or somewhat agreed (46%) that the software was easier to navigate as the course progressed. Therefore, most of the students who used the software became

acquainted with the features over the course of the semester and found it easier to use. In future studies, perhaps the amount of time spent using the software could be linked to the results of the survey questions to determine whether the students who answered the survey questions were familiar enough with the software to adequately do so.

The hypothesis that incorporating virtual cadaver software into Human Anatomy and Physiology courses helps the students study, increases their understanding of the human body, and improves their retention of the material learned both in the classroom and in the laboratory was supported. An overwhelming 92% of the students stated that the software was an efficient use of their time. This indicated that the time that the students spent using the software both in class and outside of class helped them prepare for the course and learn the material. Additionally, a significant majority of the students strongly agreed (16%) or somewhat agreed (39%) that they have grown to like using the software. In this study, student grades were not linked to software use in order to keep the surveys anonymous, but 45% of the students strongly agreed or somewhat agreed that they have seen rewards from using APR in terms of their grades. Also, asking students if they felt APR helped their grade may be a better indicator of virtual cadaver software effectiveness than linking grades to students because many factors other than hours spent using the software affect the grades. For instance, some students may use APR for hours but may retain the same amount of material as a student that used it for one hour. In both cases, the virtual cadaver software is helping the students study and improving their understanding of the material, but students learn at different rates, which would cause contradictions in the data. However, future studies could address this issue with a co-variate analysis studying the strength of the relationship between time spent using the

virtual cadaver software and the grades received in Human A&P I. Finally, a significant majority strongly agreed (19%) or somewhat agreed (37%) that they would like to use a software similar to APR in their science classes in the future. Clearly, using virtual cadaver software in conjunction with physical dissections and models provides students with a blended learning environment that increases student knowledge, retention, and enjoyment of the course.

FIGURES

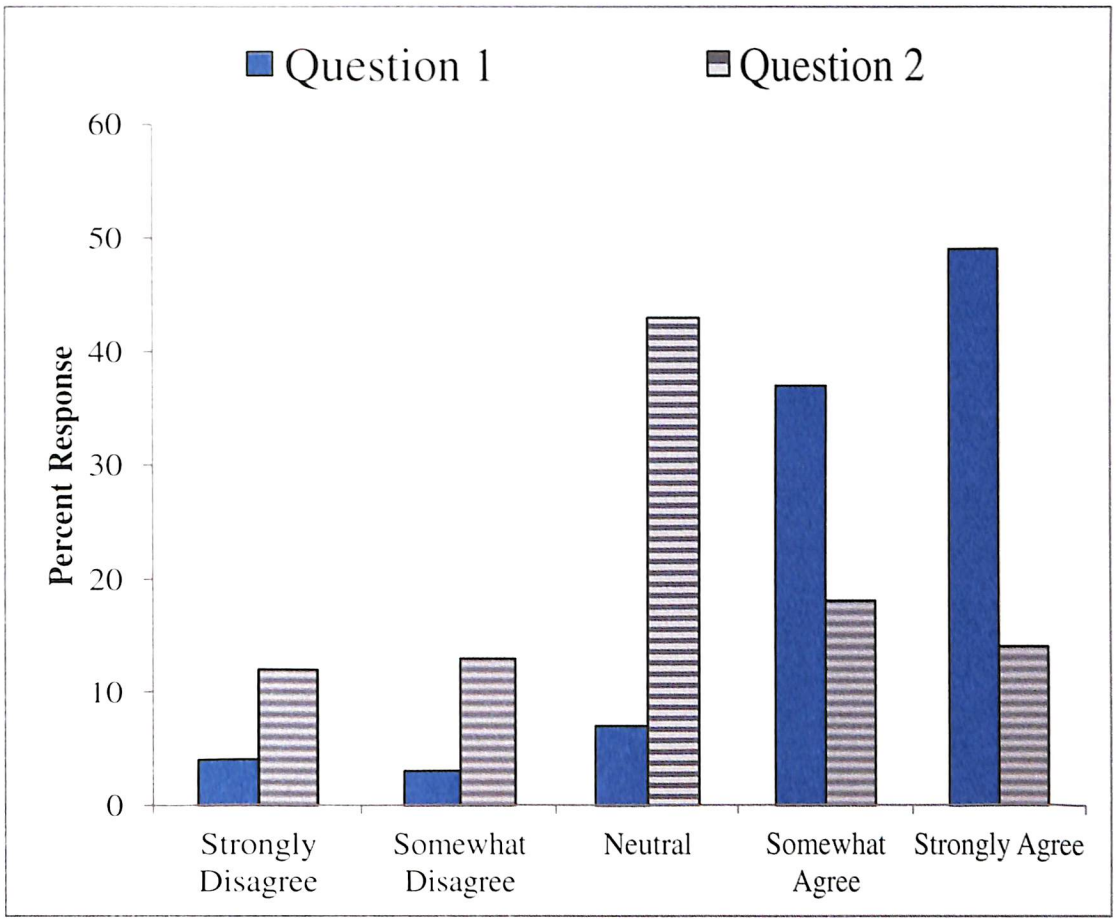

Figure 1. Student attitudes about the educational experience of performing a dissection when asked the following questions: "Did you like the educational experience of performing a dissection?" and "Would you feel more comfortable with the Anatomy and Physiology Revealed Software (i.e., virtual dissections) than with physical dissections?". In the first question, 324 responses were included, 28 were disregarded due to all neutral answers or answering the question despite no prior experience with dissections, and 21 students had never performed dissections and could not answer the question. For the second question, 358 survey responses were included, 14 were disregarded due to all neutral answers, and 1 was disregarded due to two circled answers.

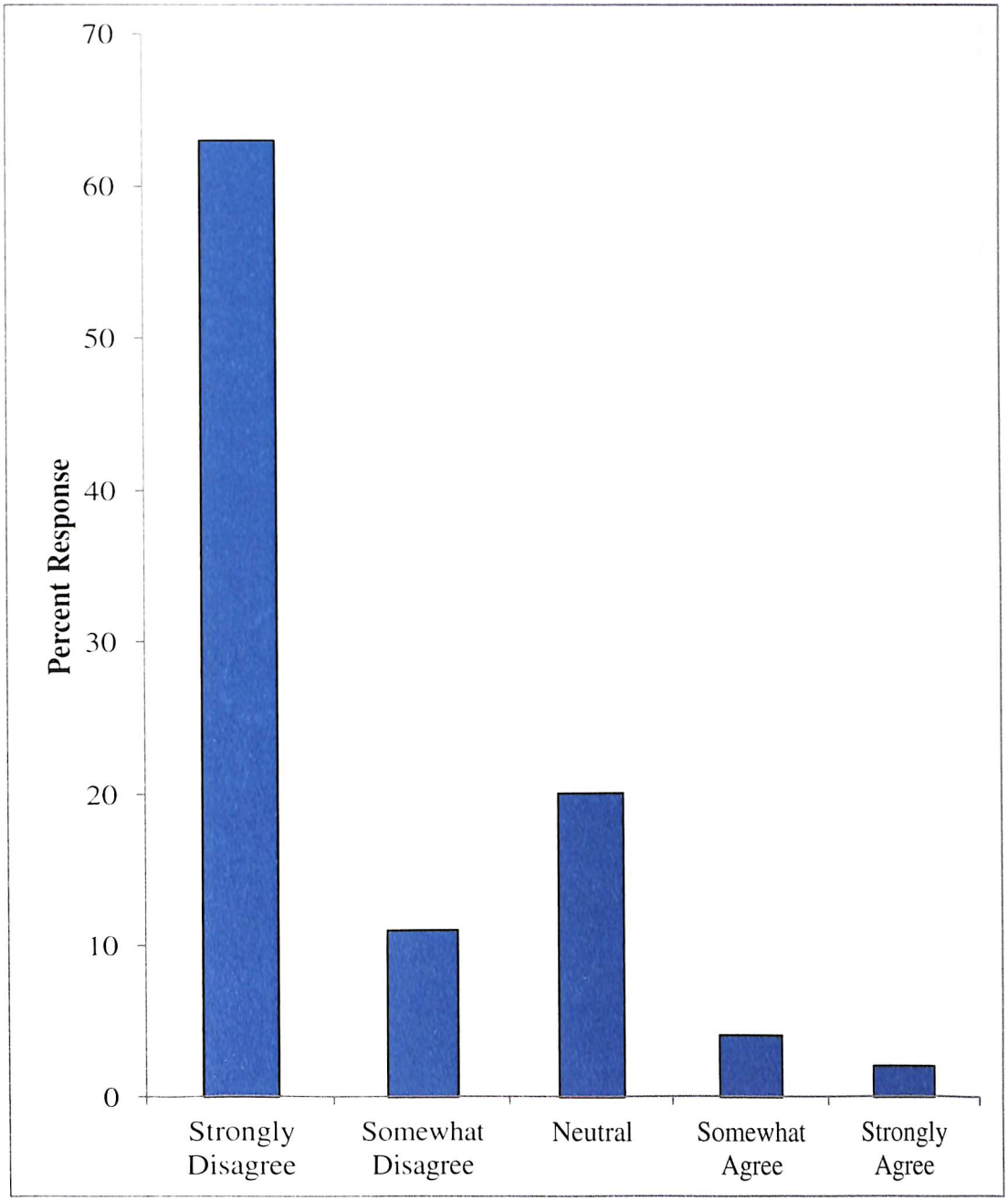

Figure 2. The A&P students' responses to the question, "Will images of cadavers disturb you in any way?" 359 survey responses were included, and 14 were disregarded due to all neutral answers.

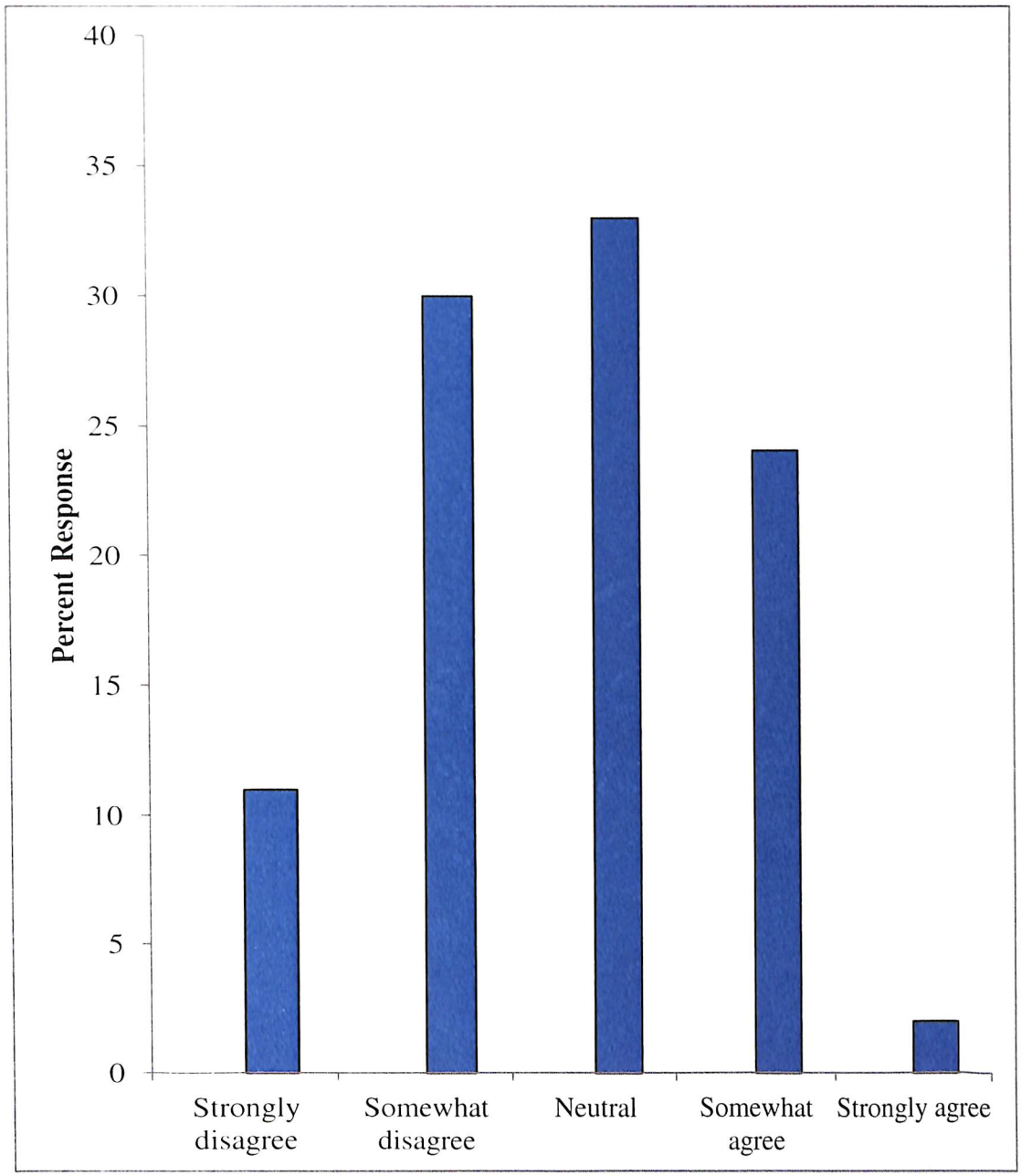

Figure 3. Determination of the ease of APR navigation, comprehension, and use when asked the following question, "Is the software difficult to learn?" A total of 277 surveys were included, while 49 surveys were omitted.

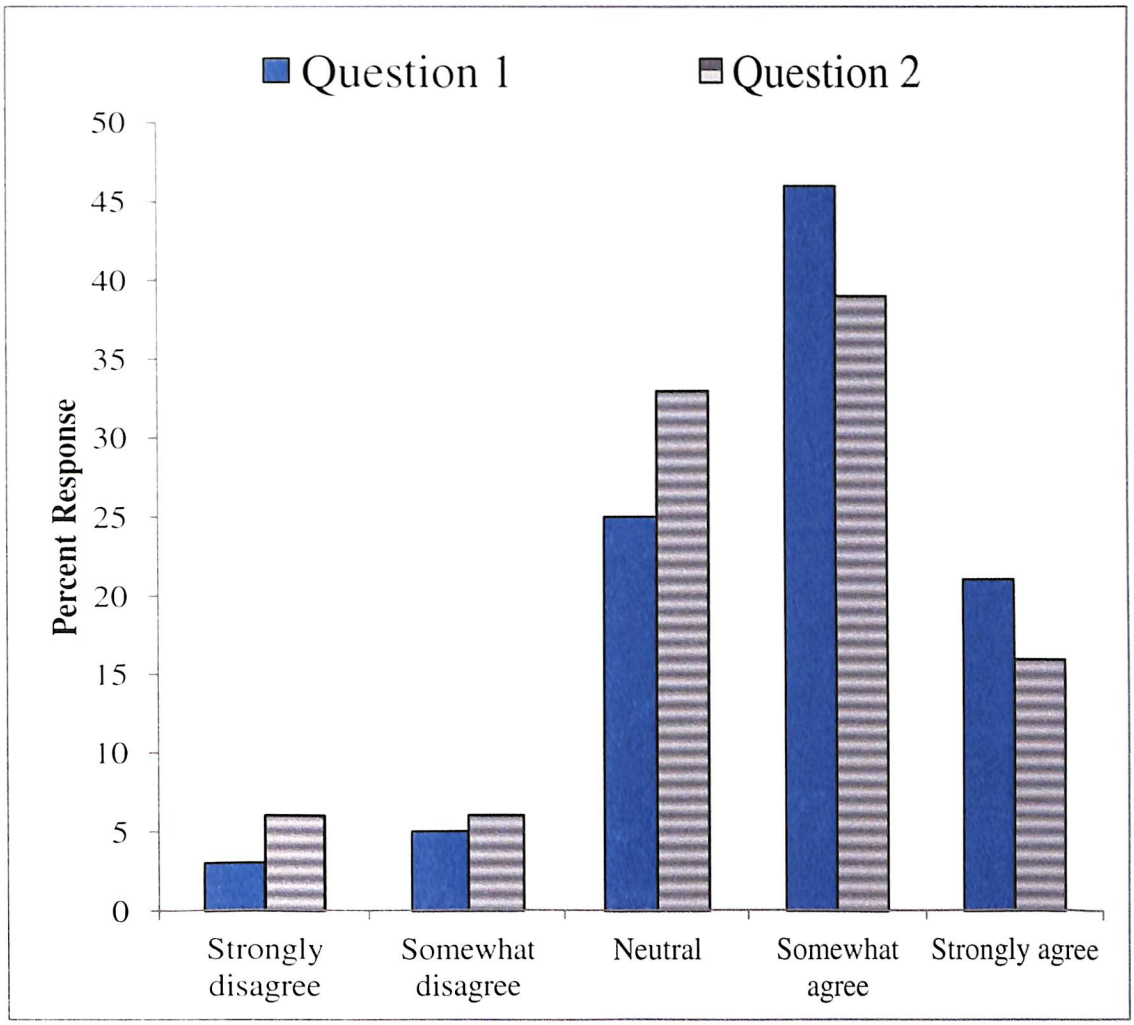

Figure 4. After using the APR software over the course of the semester, the students were asked if the software became easier to use, and if they began to like using the software. The first question read as follows, "Over the course of this lab, the software has become easier to use." Question 2 states, "Have you grown to like using the software?". A total of 263 surveys were included, and 17 surveys were excluded due to all neutral answers for all future figures.

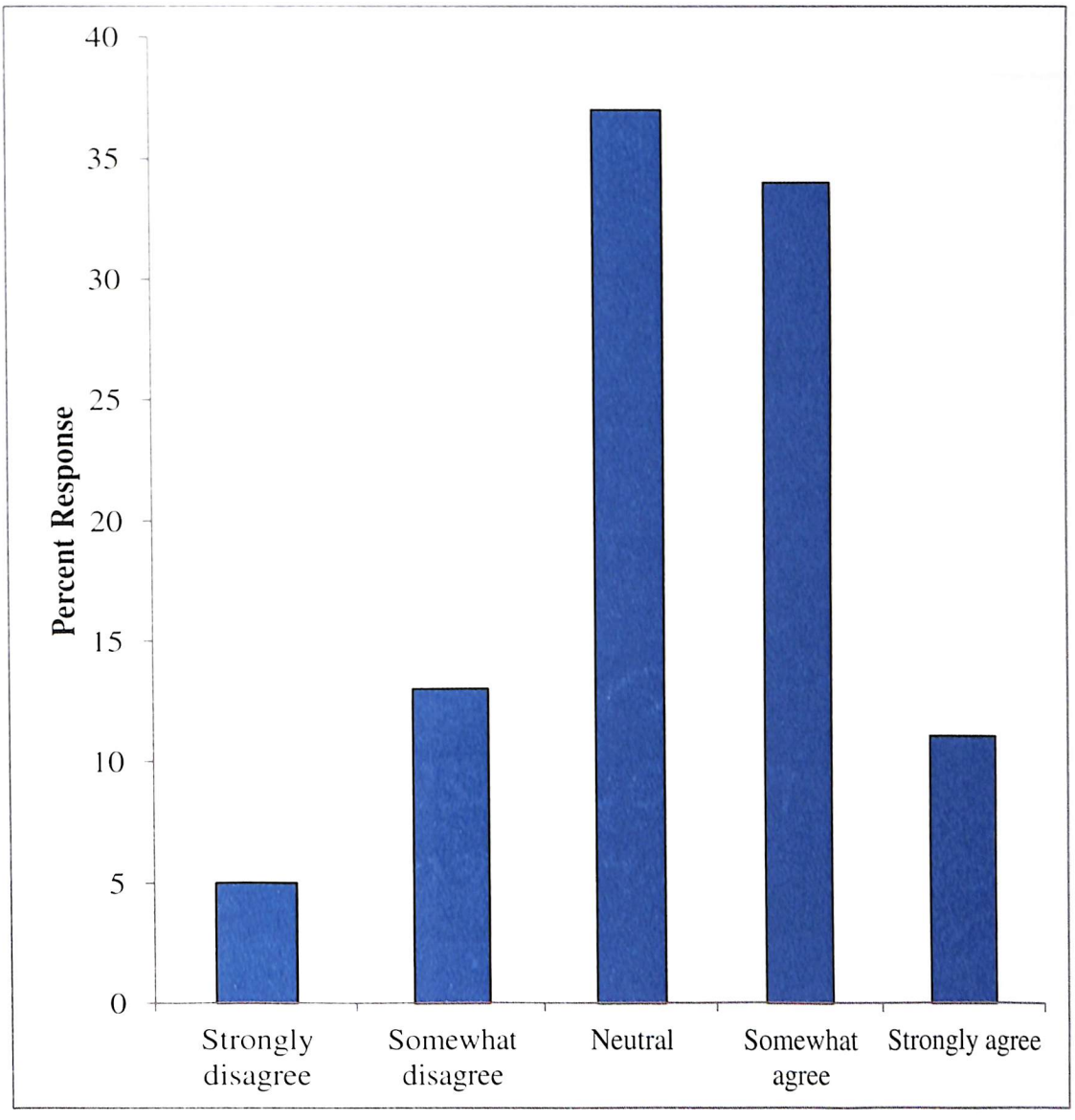

Figure 5. Determination of whether or not virtual cadaver software helps the students achieve their desirable grades by answering the question, "Have you seen rewards from using the Anatomy and Physiology Revealed Software in terms of your grade?" A total of 262 surveys were included, 17 were omitted due to all neutral answers, and 1 survey was blank.

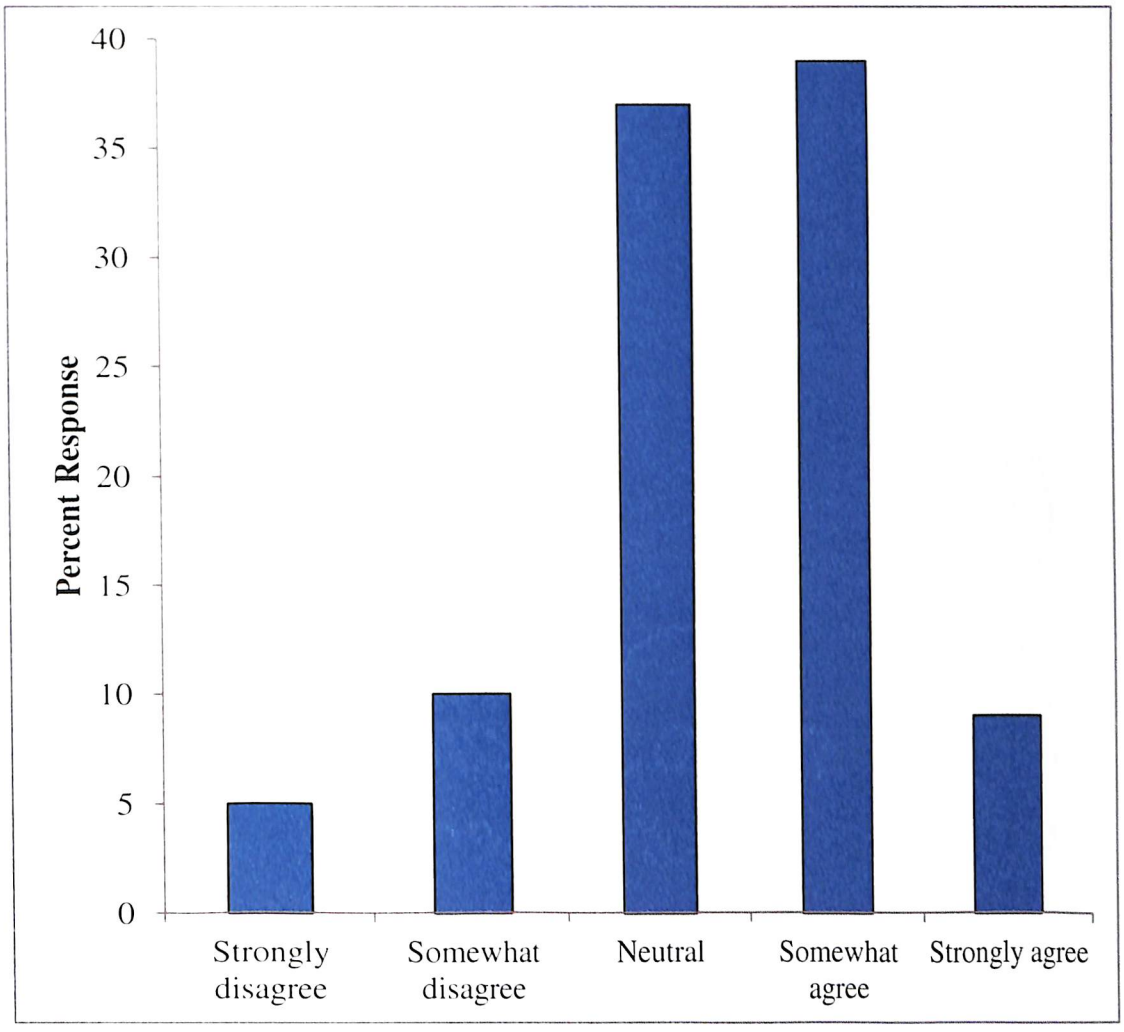

Figure 6. Determination of whether the virtual cadaver software aids students in seeing differences and similarities between human anatomy and anatomy of animal organs by responding to the statement, "The software helps me compare and contrast human anatomy to the anatomy of the organisms I am dissecting." A total of 263 surveys were included, with the previously mentioned 17 excluded due to all neutral answers.

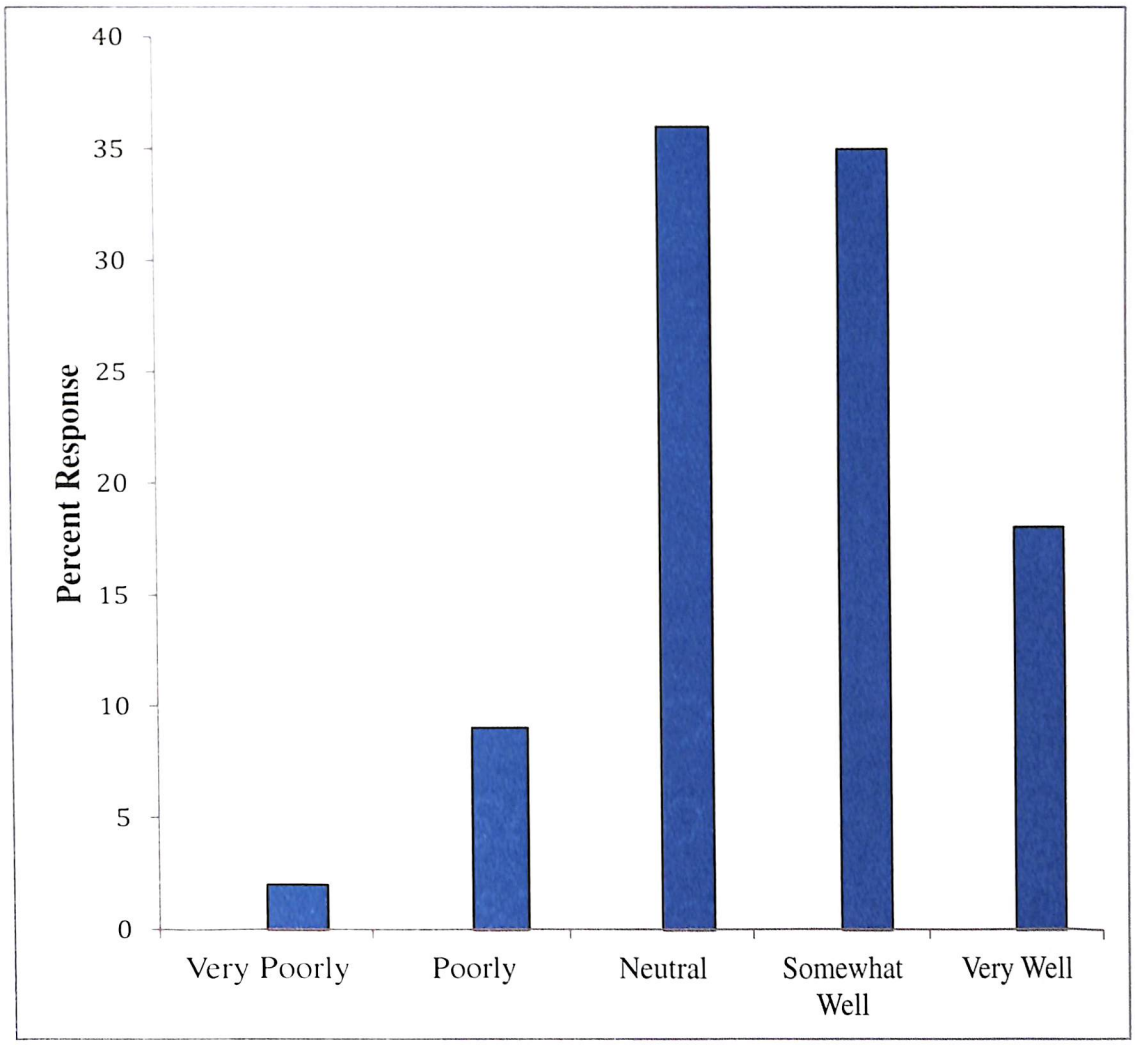

Figure 7. Indication of how well both physical dissections and virtual cadaver software were integrated into the classroom in order to improve student performance in Human Anatomy and Physiology through answering the question, "How well do you feel the lab incorporated both the physical dissections and virtual dissections (Anatomy and Physiology Revealed Software)?" A total of 263 survey responses were included, and 17 were omitted due to all neutral answers.

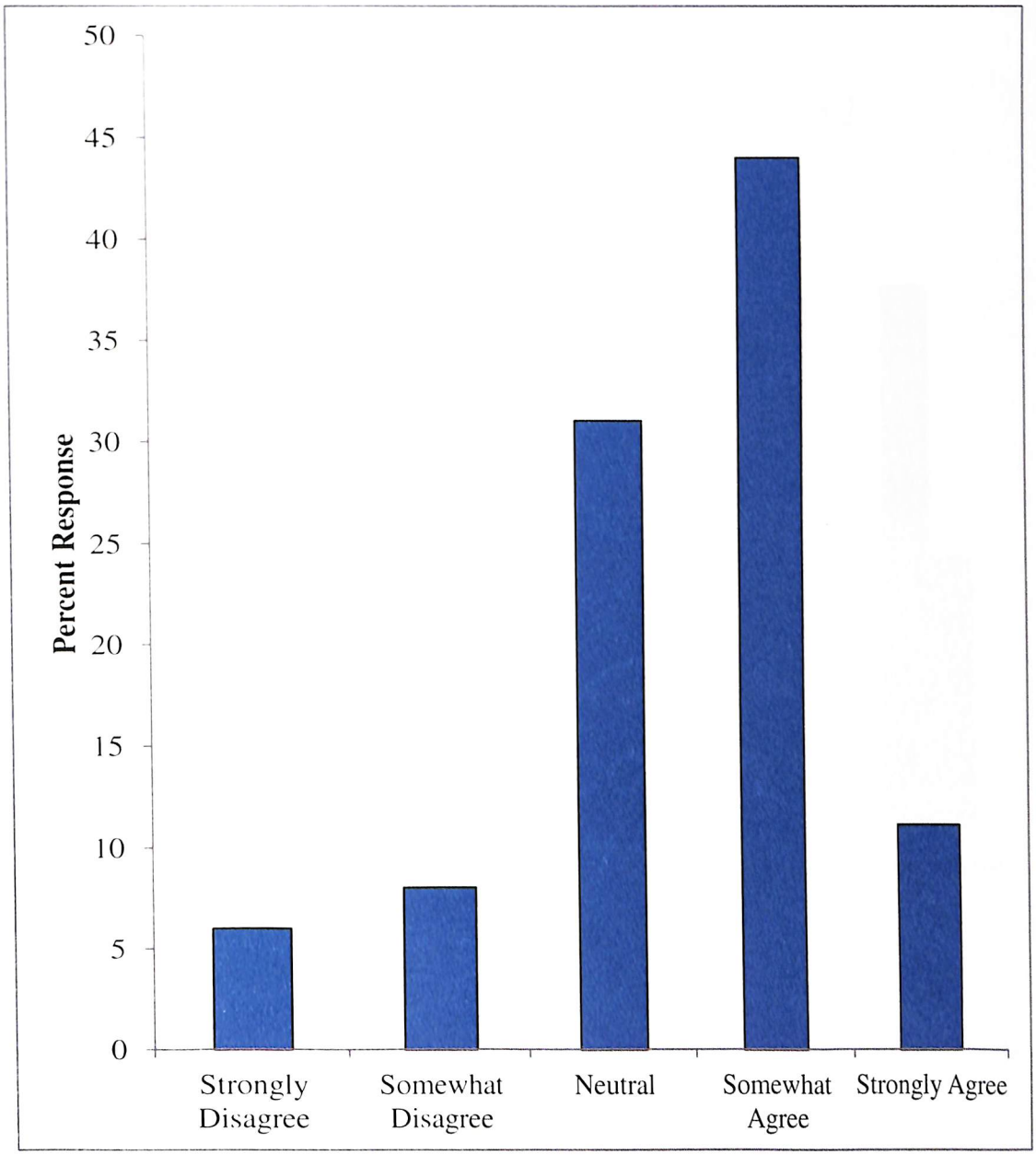

Figure 8. Description of how well implementation of virtual cadaver software, in addition to dissections, helped the A&P students meet the course objectives and excel in the class by answering the question, "Did the use of Anatomy and Physiology Revealed Software help you meet course objectives?" A total of 263 surveys were included in the data, and 17 were excluded due to all neutral answers.

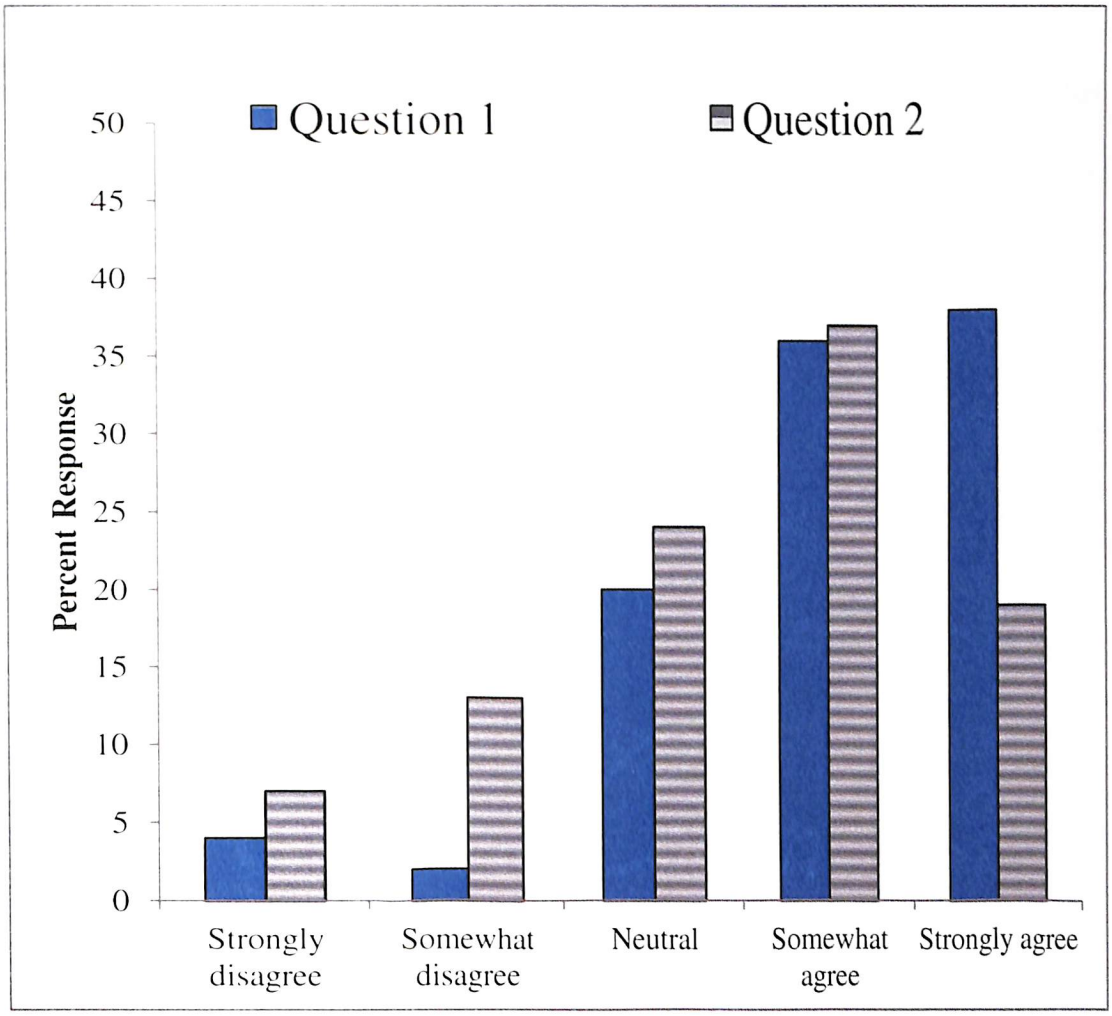

Figure 9. Whether or not students will use the information learned in A&P outside of the course, and if they would like to continue to use virtual cadaver software in any of their future classes. The questions read as follows, "Will you use the knowledge you gained in Anatomy and Physiology I outside of this course?" and "I would like to use Anatomy and Physiology Revealed Software in some of my science classes in the future." For question one, 262 student surveys were included, 17 were excluded due to all neutral answers, and 1 survey was blank. For question 2, 263 surveys were recorded, and 17 were omitted.

TABLES

Table 1: Ranking of the top three laboratory exercises for which APR was most beneficial, when given a list of topics ordered according to sequence during the semester. A total of 228 surveys were included, 17 omitted due to all neutral answers, 6 were blank, and 29 had more than 3 exercises circled and were removed from the data.

Laboratory Exercise	Percent Response
Anatomical Language	4
Organ Systems & Body Cavities	6
Compound Light Microscope	0.3
Cell Structure & Cell Cycle	4
Tissues	9
Integumentary System	2
Bone Structure & Function	10
Axial Skeleton	16
Appendicular Skeleton	16
Joints & Synovial Joint Movements	5
Surface Anatomy	4
Skeletal Muscle Structure	6
Contraction of Skeletal Muscle	3
Skeletal Muscles & Their Actions	7
Nervous Tissue	3
Spinal Cord Structure & Function	0.4
Spinal Nerves	1
Somatic Reflexes	0
Brain Structure & Function	1
Cranial Nerves	2

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APPENDIX A

Survey #1

1) Are you planning on entering a health-related profession? If so, which field are you interested in?

2) Are you taking this course because it is required or because you are interested in anatomy?

required elective

3) Have you used simulation software, similar to Anatomy and Physiology Revealed, in any of your other classes?
Yes No

4) The Anatomy and Physiology Revealed Software uses mostly images of cadavers to depict the structure and function of organs in the human body. Will images of cadavers disturb you in any way?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

5) What do you feel is a fair price for this software?

$20 $30 $40 $50 $60

6) Have you ever performed dissections?

Yes No

7) If you answered yes to #6, did you like the educational experience of performing a dissection?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

8) Would you feel more comfortable with the Anatomy and Physiology Revealed Software (i.e., virtual dissections) than with physical dissections?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

9) What grade do you anticipating getting in this course?

A B C D F

APPENDIX B

Survey #2

1) How much time per week have you spent using the Anatomy and Physiology Revealed Software outside of class?

Never Less than 1 hour 1-2 hours 3-4 hours 5 or more hours

2) How do you use the Anatomy and Physiology Revealed Software? Circle all that apply.

clarify points made in lecture
reinforce information presented in the lab
study for the lab quizzes and/or practicals
view topical animations

3) Do you ever use Anatomy and Physiology Revealed Software just for your own curiosity?

Yes No

4) What aspect of the software do you find most beneficial? Circle all that apply.

Self quizzes
Seeing human anatomy
The descriptions (including pronunciation)
Locating organs
I don't use the software

5) In what part of the course does the Anatomy and Physiology Revealed Software help you?

Lab Lecture Both lecture & lab

6) Is the software difficult to learn?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

7) What would you change about the software if you could?

8) If given the choice, do you prefer real (using the microscopes) or virtual histology (using the computer) to study tissues?

Real Virtual Both

9) Do you feel that using the software is an efficient use of your time?

Yes No

APPENDIX C

Survey #3

1) Over the course of this lab, the software has become easier to use.

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

2) Have you grown to like using the software?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

3) Have you seen rewards from using the Anatomy and Physiology Revealed software in terms of your grade?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

4) If you are not using the software regularly, why? Circle all that apply.

I do not have time.
The software does not help me.
The software is too confusing.
The images disturb me.

5) During what lab exercise did the Anatomy and Physiology Revealed Software helped you the most? Rank your top 3.

Anatomical Language
Organ Systems & Body Cavities
Compound Light Microscope
Cell Structure and Cell Cycle
Tissues
Integumentary System
Bone Structure & Function

Axial Skeleton
Appendicular Skeleton
Joints & Synovial Joint Movements
Surface Anatomy
Skeletal Muscle Structure
Contraction of Skeletal Muscle
Skeletal Muscles & Their Actions

Nervous Tissue
Spinal Cord Structure & Function
Spinal Nerves
Somatic Reflexes

Brain Structure & Function
Cranial Nerves

6) The software helps me compare and contrast human anatomy to the anatomy of the organisms I am dissecting.

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

7) Will you use the knowledge you gained in Anatomy and Physiology I outside of this course?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

8) Did the use of Anatomy and Physiology Revealed Software help you meet course objectives?

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree

9) How well do you feel the lab incorporated both the physical dissections and virtual dissections (Anatomy and Physiology Revealed Software)?

Very well Somewhat well Neutral Poorly Very Poorly

10) I would like to use Anatomy and Physiology Revealed Software in some of my science classes in the future.

Strongly disagree Somewhat disagree Neutral Somewhat agree Strongly agree