To Use or Not to Use: Supplemental Technology in an Undergraduate Anatomy Lab

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Abstract

Basic Human Anatomy at Indiana University is a large undergraduate anatomy class with nearly five hundred students in twelve lab sections. In the fall of 2018, we added the Virtual Human Dissector software on an interactive Sectra table to our lab to help students fill the gap between idealized anatomical models and fully prosected cadavers. We evaluated this new technology using a cross-over study design with pre- and post-module quizzes, exam questions related to the modules, and a survey of student perceptions. Results indicate that while not all students enjoyed using the new technology, even those who did not report enjoying it could still identify gaps that the technology helped to fill. Quiz results showed greater increases in knowledge for those who completed the modules, particularly during the second semester. However, exam results did not demonstrate a longer-term difference in knowledge between those who completed a specific module and those who did not.
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Key words: virtual human dissector, Sectra table, digital learning technologies, undergraduate education, anatomy laboratory

Introduction

Most undergraduate anatomy laboratories use models and bones to demonstrate to students the structures and concepts that they teach. At Indiana University, we incorporate these traditional methods in our lab, as well as two prosected cadavers. However, how are students to make the leap from an idealized, color-coded model of a single anatomical region to a full-prosected cadaver of varying shades of pink with variation across individuals? This was a challenge that we (and our students) had struggled with for many years, but in the summer of 2018, we purchased a Sectra table with Virtual Human Dissector (VHD) software from Touch of Life Technologies. Our hope was that this technology might help to fill the gap between our color-coded models and the prosected cadavers.

The technologies available for use in anatomical education are varied and numbered. Options include 2D/3D image viewing, 3D printed models, augmented reality (AR), virtual reality (VR), and even resources on YouTube (Trelease et al. 2020; Santos et al. 2021). Each technology presents its own advantages and disadvantages, and these must be individually assessed (Pickering 2017). Implementing the use of technology does not guarantee better learning for students and has the potential to provide little to no value depending on how the technology is used. Wilson (2020) further noted that technologies need to be selected with consideration to the base knowledge of the students. Undergraduates in a 200-level course and professional students have completely different sets of base knowledge. Therefore, when evaluating digital tools, student groups need to be assessed independently. Given these caveats and in the interest of brevity and relevancy, we have focused our background literature on the use of virtual dissection tables in undergraduate anatomy courses.

Previous research on virtual dissection tables, such as the Sectra or Anatomage tables, have generally been perceived positively by undergraduates (e.g., Fyfe et al. 2018; Narnaware and Neumeier 2021). Benefits have included viewing the relative size and relationships of organs (Fyfe et al. 2018) as well as decreased anxiety (Bianchi et al. 2020). Fyfe and colleagues (2018) also mentioned that students' perceptions of the technology improved as instructors became more familiar with the table and its functions. Narnaware and Neumeier (2021) found that, while their students did report positive perceptions of the dissection table, the students still would have preferred an actual cadaver. Knowing that students can perceive the table to be beneficial, what do students cite as the more important benefits? In interpreting three-dimensional relationships? In more generally active learning? In more realistic representations than plastic models? Furthermore, are these perceptions supported in assessments?

Additional research has assessed the effectiveness of dissection tables for undergraduate learning and student outcomes. Bianchi and colleagues (2020) as well as

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Narnaware and Neumeier (2021) found significant increases in exam scores with students who utilized dissection tables over students who did not. These results were also supported by the meta-analysis of Wilson and colleagues (2019), who found better scores in anatomy for students in courses with student-centered learning and computer-aided instruction (e.g., dissection tables). However, it must also be noted that the meta-analysis did include multiple student populations including several studies on medical students.

Additional research by Hilbelink (2009) found that students who were given three-dimensional images had higher lab practical exam scores than students who were given only two-dimensional images. These results further suggest that the use of a virtual dissection table with the ability to rotate images in three dimensions may also result in higher assessment scores in our undergraduate anatomy class. However, this new technology required consideration of the following curricular questions: how would our students interact with the new technology? How would they perceive its benefits? With these questions in mind, we undertook the present research.

Our research questions were as follows:

- How did students in our course perceive the virtual dissection table and associated software?
    - In what ways did they find the table and its associated software beneficial?
    - What gaps did students perceive the table and associated software to fill?
    - How long did it take for students to become comfortable using the table?
- How effective was the table and associated software for learning?
    - How did students perceive their learning using the table and software?
    - How effective was the table and associated software for short-term learning (assessed via pre- and post-quizzes at the beginning and end of the week)?
    - How effective was the table and associated software for longer-term learning (assessed via exams given at the end of a unit/block in the course)?

Materials and Methods

The Course: Anatomy A215

Anatomy A215, Basic Human Anatomy, is a 5-credit hour, one-semester, systems-based anatomy course offered at Indiana University-Bloomington for undergraduate students. During the course, students attend a large 50-minute lecture session three times per week, as well as a smaller 105-minute laboratory session (approximately forty students per lab) that meets two times per week. The lecture portion is taught by a professor of anatomy while graduate teaching assistants and undergraduate teaching assistants teach the laboratory component. This course is a required or recommended course for students who are seeking a degree in health sciences or are following a pre-health science professional degree pathway.

Gross anatomy and histology are presented in both the large lecture setting and the laboratory component of the course. Traditionally, the laboratory component consisted of a brief PowerPoint presentation at the beginning of the lab period, followed by independent learning time to study using traditional materials (i.e., models, books, prosected cadavers, and lecture materials). In the 2018-2019 school year, a large touchscreen terminal with virtual dissection software was implemented as a study resource made available during the independent learning time. Assessment of the lab included four practical exams with 40 short answer questions. During these examinations, students were tasked with identifying structures on models, prosected cadavers, and histology slides. Each of these exams was worth 100 points, for a total of 400 points.

All students in the fall 2018 and spring 2019 semesters were invited to participate in the following study. However, not every student completed the course, nor the post-course survey, so sample numbers are smaller than the initial enrollment of 480 students. While specific demographics were not collected in the interest of anonymity, the demographics of the A215 course are quite consistent from semester to semester. The course is predominantly taken by students interested in health-related professions (e.g., nursing, pre-physical therapy, pre-occupational therapy, pre-physician assistant) and the majority of students are freshman and sophomores. A few upper classmen do also enroll in this course. This project was approved by the Indiana University Human Subjects Institutional Review Board as protocol #1808797361.

The Technology: Sectra table with Virtual Human Dissector software

The Virtual Human Dissector (VHD) software for Undergraduate education was developed from the Visible Human Project data provided by the National Library of Medicine (https://www.nlm.nih.gov/research/visible/visible_human.html). This dissection software allows the user to add and subtract anatomical layers, move and twist the body in

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three-dimensional space, and section the body along any plane at any location.

For the purposes of A215, ten modules were created using this software. The modules were created by a graduate student (J. Bendinger, working with the authors S.D. & P.H.) who had previously taught in the lab several times and were based on a template for VHD modules created by Jeffrey Fahl for the University of Nevada Las Vegas School of Medicine. Having our own modules specifically created for A215 allowed us to make sure that each module covered information that was already available to students in their lab guide. Each module began with a basic introduction and list of learning objectives for the module and included a link to the image on which the module was to begin.

The Sectra table is a large touch screen terminal (~30" x 63" x 30") situated on a base with four sets of wheels for easy movement around the classroom or building. The screen itself can be oriented in a vertical or horizontal position depending on the desired situation. In the A215 lab, instructors could use the vertical position to demonstrate table functions or anatomical structures to the entire class and could use the horizontal position for a smaller group of students.

Students approached the table in groups of approximately six students to work through a module. Once they reached the initial image of the module, students could then follow step-by-step instructions to add and remove layers and label various structures that they were also seeing on the models and prosected cadavers in lab. With each step, students could use the touch screen to zoom in and out or turn the image to view from a different angle. Students were also encouraged to discuss the information that they were seeing with the other students in their group. The modules also included practice questions for students that utilized the images from the module and integrated them with other content from the class. Each module was estimated to take between five and fifteen minutes depending on how much time the students spent adjusting the images to view from different depths/angles.

Pre and Post Quiz Analysis

This research utilized a crossover design. The students enrolled in the course were divided evenly into two cohorts during their laboratory sessions throughout the semester: cohort A and cohort B (i.e., approximately twenty students per cohort in each lab section). Due to the crossover design of the study, the cohorts switched between intervention group and control group throughout the semester. The intervention was the addition of the new technology, while using only the traditional lab manual, models, and two prosected cadavers was the control.

Throughout A215, students took a pre-quiz at the beginning of each week prior to covering a topic to allow for an assessment of baseline knowledge. At the end of the week, a post-quiz was administered to assess learning. Upon completion of the course, quiz data was categorized as either intervention group or control group for that week and de-identified. The mean difference between pre-quiz and post-quiz scores was calculated using SPSS, version 25 (IBM Corp., Armonk, NY). Independent samples t-tests were also completed using SPSS to compare the mean differences in pre- and post-quiz scores between the intervention and control groups.

Post Course Survey

A post-course survey that consisted of Likert scale questions and free response questions was administered upon completion of the course. The results of the survey were then entered into an electronic database. Measures of central tendency and response frequencies were calculated for each survey question using SPSS. Spearman Rho correlations were also completed in SPSS to examine the strength of association between answers to survey questions and Chi-square analyses were utilized to examine relationships between the answers to categorical variables in each semester.

Knowledge Retention

Retention of knowledge was evaluated using ten questions on each of the four A215 laboratory exams. These questions were consistent for all students in the class and answers to these questions were covered with both the traditional learning modalities and the new technology so that students from both cohorts A and B had access to the information regardless of whether they were the intervention or the control group for that week.

For students in A215 during the spring semester only, a determination of correct or incorrect on each of these questions, alongside completion of the VHD module associated with the question was entered into an electronic database. A generalized estimating equation (GEE) was completed to assess association between correct/incorrect answers on these select lab exam questions and completion of the modules. GEE was selected because it allows for correlated data from repeated measures on the same population, is tolerant to missing data, and works with binary measures (e.g., correct/incorrect, completed/not completed). GEE modeling determines statistical significance of selected factors. For this study, factors of interest included: completion of VHD module, topic of the question, and the interaction between completion and topic.

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Results

Student Perceptions

During the fall semester, 374 students participated in the study, while 330 students participated in the spring semester, for a total of 704 students during the 2018-2019 academic year. Student perceptions of the tools were collected via the post-course survey with 53.9% of students in the fall semester and 54.4% of students in the spring semester stating that they would not recommend use of the new technology in future semesters of A215. Overall, 54.1% of students did not recommend using the new technology in future semesters.

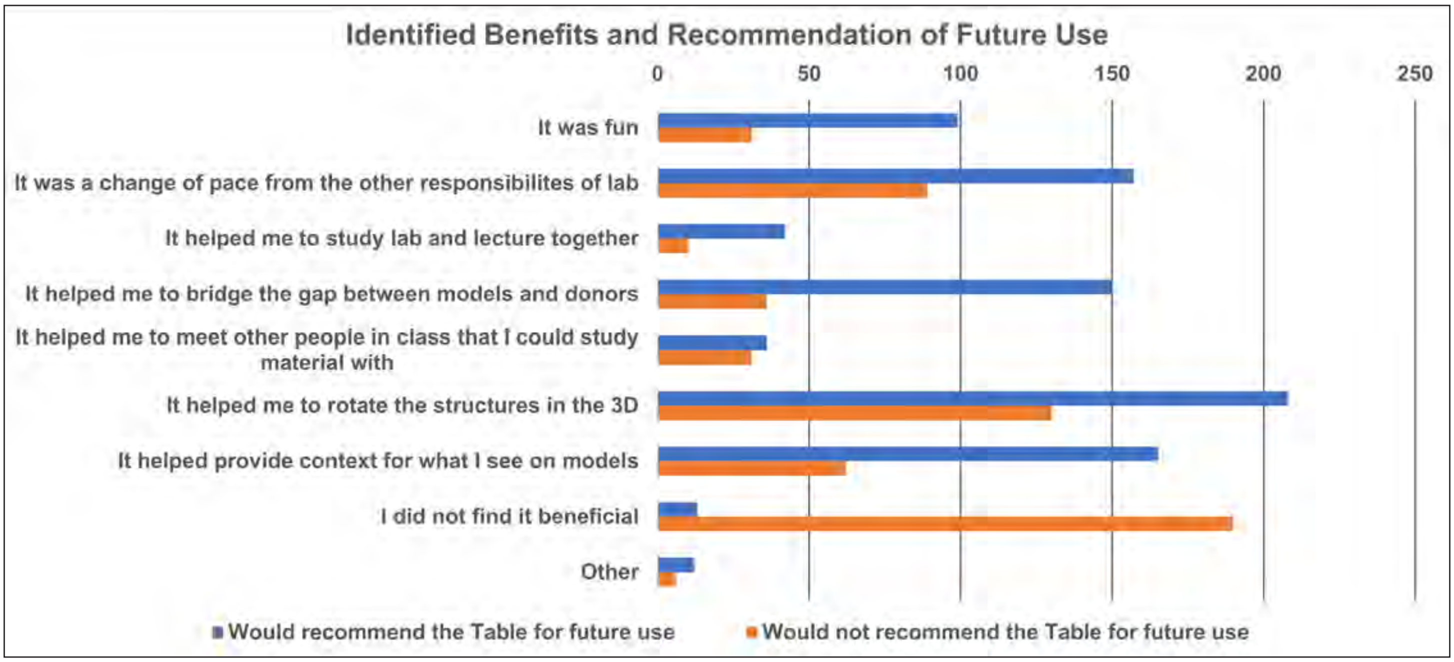

Figure 1. *Benefits of the Sectra Table identified by students who would or would not recommend the table for future use.*

However, benefits of using the technology were also identified on the post-course survey. Among students who recommended using the technology in future semesters, the most frequently identified benefit (64.8% of students) was that the ability to rotate structures in three dimensions helped them learn. Furthermore, 51.4% of students that recommended future use identified that the technology provided context for what they were seeing on models as a reason of recommendation for future use and 48.9% identified that it was a change of pace from other lab responsibilities. Among the students who did not recommend future use, 50.1% identified no benefit to using the technology. However, 34% of them did cite a benefit of being able to rotate structures in three dimensions and 23.4% identified the benefit that it did change the pace of other lab responsibilities (Figure 1).

The survey also sought to identify the number of times students used the technology prior to becoming comfortable with its use (Table 1). In the fall term, the most frequent answer choice was two with 39.6% of students saying it took them two uses to become comfortable using the table. Students in the spring term also most frequently (34.8%) identified two uses. Some students in each semester responded that they never felt comfortable using the table with 14.7% and 17.6% of students responding as such in selecting that response in the fall and spring semesters, respectively. Chi-square analysis revealed that they survey responses were not statistically different (p=0.259) between the fall and spring terms.

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	Fall 2018 n (%)	Spring 2019 n (%)	2018-2019 n (%)	Chi-square results (Fall & spring semesters)
1 use	66 (17.6)	76 (23.0)	142 (20.2)	$X^2 = 5.292$ *p* value = 0.259
2 uses	148 (39.6)	115 (34.8)	263 (37.4)	
3-5 uses	96 (25.7)	74 (22.4)	170 (24.1)	
6-10 uses	9 (2.4)	7 (2.1)	16 (2.3)	
I never became comfortable using the table during A215.	55 (14.7)	58 (17.6)	113 (16.1)	
Total	**374 (100)**	**330 (100)**	**704 (100)**	

Table 1. *Distribution of student survey responses to the question: "Approximately how many uses did it take you to become comfortable using the table?".*

Students were asked to rank their level of enjoyment when using the new technology and perceived learning efficacy on a scale of 1-10 (Tables 2 & 3). Mean enjoyment rating was 5.2 and 5.0 during the fall and spring semesters, respectively and the median was 5.0 for both semesters. The mean perceived learning effectiveness was 4.8 and 4.8 in fall and spring, respectively and the median was 4.0 for both semesters. A positive correlation was found between enjoyment using the technology and perceived learning efficacy with a Spearman Rho correlation coefficient of 0.794 ($p<0.01$). A negative correlation was found between number of uses to become comfortable with the technology and perceived learning efficacy with a Spearman Rho correlation coefficient of -0.222 ($p<0.01$).

	Fall 2018 n (%)	Spring 2019 n (%)	2018-2019 n (%)	Mann-Whitney U results
(Very dissatisfied) 1-2	46 (12.3)	58 (17.6)	104 (14.7)	Mann-Whitney U = 58510.5 *p* value = 0.231
3-4	105 (28.1)	95 (28.8)	200 (28.4)	
5-6	121 (32.3)	81 (24.5)	202 (28.7)	
7-8	68 (18.2)	69 (20.9)	137 (19.5)	
(Very satisfied) 9-10	34 (9.1)	27 (8.1)	61 (8.6)	
Total	**374 (100)**	**330 (99.9)**	**704 (99.9*)**	

Table 2. *Distribution of student survey responses to the question: "How much did you enjoy using the Sectra table?".*

	Fall 2018 n (%)	Spring 2019 n (%)	2018-2019 n (%)	Mann-Whitney U results
1-2 (Very ineffectively)	64 (17.1)	80 (24.2)	144 (20.5)	Mann-Whitney U = 58143.0 *p* value = 0.691
3-4	124 (33.2)	85 (25.7)	209 (29.7)	
5-6	73 (19.5)	68 (20.6)	141 (20.1)	
7-8	69 (18.4)	58 (17.6)	127 (18.0)	
9-10 (Very effectively)	44 (11.7)	35 (10.6)	78 (9.7)	
Total*	**363 (97.1)**	**326 (98.8)**	**689 (97.9)**	

*Note: Not all respondents answered this question.

Table 3: *Distribution of student survey responses to the question: "How effectively do you feel you learned using the Sectra table?".*

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Pre-/Post-quiz Changes & Knowledge Retention

Turning to the outcomes data (Table 4), there was no statistically significant difference (p=0.25) in quiz score change between those who did and did not complete the VHD module in the fall semester. In spring, there was a significantly larger change (p <0.01) in quiz scores for those students who completed the VHD modules. The combined data for the 2018-2019 academic year also showed a significantly larger change in quiz scores for students who had completed the VHD modules (p=0.034).

	Control Mean	Intervention Mean	t value	*p*-value
Fall 2018	1.18	1.13	1.14	0.25
Spring 2019	0.92	1.13	-4.17	< 0.01*
2018-2019	1.06	1.13	-2.12	0.034*

Table 4: *Comparison of quiz scores for students who completed that week's module (intervention) and those who did not (control)*

The GEE analysis for the spring data then examined student performance on unit exam questions related to the content discussed in the modules. This analysis found no statistically significant difference in a student's likelihood of correctly answering test questions based on whether or not they had completed the VHD modules. However, the GEE analysis did find that there were statistically significant differences between modules and the students' likelihood of correctly answering the corresponding exam questions. These results suggest that students were more likely to answer questions correctly based on which week's content they covered regardless of whether they completed the Sectra module for that week (or any other). Students were more likely to answer exam questions correctly if they were related to the skull (p=0.002), appendicular skeleton (p=0.05), muscles of the lower limb (p=0.022), the brain (p<0.001), the eye (p=0.007), or blood vessels (p<0.001) as compared to muscles of the upper limb, respiratory system, digestive system, or genitourinary system.

Discussion

Overall, our results showed that many students would not recommend the Sectra table and Virtual Human Dissector for use in our class, but many of them did still acknowledge the benefits that exist and the gaps that these innovations helped to fill. Students (both those who would recommend and those who would not) were aware that the software provided an opportunity for three-dimensional rotation of structures and that it provided a change of pace in the lab. Students who would recommend the tools also noted that it provided a context for the structures that they were viewing on models. Students also generally reported comfort with the tools within the first five uses.

However, their perceptions of learning from the tools were varied. Perhaps not surprisingly, students who enjoyed using the tools reported higher perceptions of learning while students who took more interactions with the software prior to feeling comfortable reported lower perceptions of learning. These results correspond with the domains Pickering (2017) cited as measures of knowledge acquisition: efficiency, effectiveness, and enjoyment. In his commentary, the term "efficiency" refers to the ability to learn the same amount of material in less time while the term "effectiveness" refers to the ability to learn more information in the same amount of time. These domains both link to enjoyment in that students who enjoy a specific technology are likely to engage with it more often (Pickering 2017). Particularly in a class where students already have quite a bit of information to learn, if students are actively engaged with the tool this will correspond to how quickly they can learn the material and thus affect their perceptions of learning with it. That said, student assessments may demonstrate that some learning gains were occurring even if student perceptions of learning were not so positive.

When outcomes of table use are considered, there was an increase in knowledge gains between the pre- and post-module quizzes for those who completed the modules over those who did not. This was particularly true in the second semester that it was used in the class. These assessment results are largely consistent with the data presented in previous literature. For example, there was evidence for learning advances with these tools, especially as instructors became more comfortable with using them (Bianchi et al. 2020; Narnaware and Neumeier 2021; Wilson et al. 2019).

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These initial learning gains seen on the post-module quizzes corresponded with the results reported by Boscolo-Berto and colleagues (2021). They found that students who completed their gross lab dissections alongside a virtual dissection table reported better lab experiences and higher immediate post-test performance compared to students who completed gross lab dissections with only a textbook resource alongside. That said, it must be noted that this study was completed with actively dissecting first year medical students as opposed to undergraduate students. A learning curve for instructors was reported by Fyfe and colleagues (2018) in their study of use of the Anatomage table at Curtin University. They found that students' perceptions of usefulness for their Anatomage table increased significantly from the 2013 to the 2014 academic year and they attributed this increase largely to instructor familiarity and improvements in table function.

Furthermore, enjoyment expressed by some of our students is similar to the positive perceptions of nursing students seen by Narnaware and Neumeier (2021). In their study involving 148 nursing students at MacEwan University, they found that 86% of respondents indicated a positive experience with a virtual human table and 78% indicated that use of the table increased their understanding of the human body. While positive perceptions in our study were not as common as those reported by Narnaware and Neumeier (2021), we also had students indicate a positive experience and felt the table benefitted them, particularly by being able to rotate the structures in three-dimensions. However, 85% of their students recommended using the table with other nursing students as compared to only 46% of our respondents.

In addition to these similarities with previous studies, there were also several new findings in our study. First, using short-term and longer-term assessments following the module provides the most comprehensive effectiveness measure of virtual dissection software and tools that we have seen in an undergraduate population. Our GEE results indicated that students who completed each module did not perform significantly differently on related exam questions from students who did not complete the module. Thus, completing this module may increase short-term learning (as seen through our pre-/post-module quizzes), but this difference was no longer present by exam time, perhaps indicating only short-term gain or that the students who did not complete the table module were able to catch up prior to the exam.

However, this lack of difference in exam scores between students who completed the module and those who did not demonstrates that the table is neither an absolute benefit nor hinderance to their longer-term learning of the material. These results contrast with Bianchi and colleagues (2020) who did see a statistically significant increase in exam scores for first year nursing students who utilized a virtual dissection table compared to those who only participated in traditional didactic lectures. However, the present results were not comparing these virtual tools to didactic lessons, but to other lab approaches (e.g., models). In the study by Bianchi and colleagues (2020), only about 18% of their students participated in the optional dissection table sessions for a total of eight hours and agreed to participate in the study. Perhaps it should not be surprising if students who spent an additional eight hours interacting with the material were more successful on the exams.

Narnaware and Neumeier (2021) also saw higher exam grades with students exposed to the Anatomage table, but again these methods were compared with passive, didactic teaching, not other hands-on lab practices. Furthermore, the intervention group (those who interacted with the table) were found to have a higher overall GPA than those in the control group. Thus, additional factors may have been at play. The results are also in contrast to the meta-analysis completed by Wilson and colleagues (2019) who found that students with computer-aided instruction generally outscored students with traditional didactic approaches but, as previously mentioned, this analysis also included other student populations (e.g., students in professional programs). Thus, the present results suggest that both short-term and longer-term learning gains do need to be further studied.

Our results do agree with those of Wainman and colleagues (2021). They also found no difference in exam scores between those who had access to physical models and those who learned using digital technologies (in their case, a virtual reality interface). They went a step further and asked their students to complete a mental rotation test for visuospatial abilities. They found that learning with the virtual reality platform did relate to lower exam performance for students with low visuospatial abilities. For students who learned using physical models no such differences were found related to high/low visuospatial abilities. These results from Wainman's team may further help to explain lower perceptions of learning for students who reported that they needed more uses to reach comfort and higher perceptions of learning for students with greater enjoyment of the technologies. One potential explanation might be that greater enjoyment corresponds with higher visuospatial abilities while more uses necessary to reach comfort corresponds with lower visuospatial abilities. Additional studies are needed to investigate these ideas.

It is also new to the literature that the majority of our students would not recommend the use of this technology for future semesters even though many of them did acknowledge some benefits. This is surprising given the positive perceptions reported by others (e.g., Narnaware and Neumeier 2021) and the general perception that younger adults of today prefer technology (Pickering 2017). Potential explanations for this include cognitive overload and expectancy-value theory. The A215 lab was already asking quite a lot of students by requiring them to work through a sizable amount of material at a self-regulated

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pace. It is possible that the addition of the new technology was felt to be just one more task that students were required to complete or that the technology created an increased cognitive load that eliminated the benefits that may have otherwise been achieved with the use of the virtual dissection table (Wilson 2020).

It is also possible that the students felt that this task was not a high yield use of their time since there were other study resources available covering the same content. Expectancy-Value Theory (Wigfield and Eccles 2000) posits that students' motivation to complete tasks is related to the likelihood that completing that task will significantly increase the likelihood of achieving their goal (e.g., performing well on exams). Since we have already seen that completing the modules did not correlate with higher scores on the exams, it is entirely plausible that students may not have had much motivation to complete these modules and thus did not perceive them as positively in our study as other studies report.

Limitations

As with most studies, there are several limitations to this work. The data presented here are only from two semesters of a single class. In addition, the first semester did have some growing pains associated with this research. During the fall of 2018, there was one pre-quiz where we had to discard a question and there were two quizzes that had to be rescheduled due to cancelled classes and instructor errors. Thus, the data from that semester may be imperfect and the spring 2019 semester should be considered the stronger data set of the two. Following that academic year, there was a pandemic that severely limited additional data collection. Other courses or additional follow-up in the future may reveal different trends.

Additionally, not all students in the course agreed to participate in this study. Thus, there may be some bias in our sample if the students who chose not to participate were also strongly in favor of or opposed to the new technology since their data is missing from the present work. That said, we did have approximately 75% of the students agree to participate so we believe that our sample size is relatively strong to help guard against these types of errors. In future studies, the direct collection of demographic information would also be beneficial to examine whether specific years, majors, or genders, for example, have different perceptions and outcomes related to these tools.

Finally, we did not receive as much qualitative feedback about the software and the table as we had initially hoped. Despite the inclusion of seven separate open-ended questions with textboxes on the survey, very few respondents were willing to include their reasoning behind their responses. Future studies should include individual interviews or focus groups to further elucidate students' experiences and reasoning.

Conclusions

Our results demonstrate that students perceived the benefits associated with the Sectra table plus virtual dissection software. However, students still had mixed reactions to the addition of these tools to our lab. This may be due to the amount of material that is being covered in the course, or it may represent the lack of value for this task on the exams at the time. Outcomes demonstrated that there was a significant change in knowledge from these modules during the week that they were implemented, particularly as instructors became more adept with the tools. However, exam performance on related questions did not show a difference between students who had and had not completed each module.

Our recommendations for others, as well as ourselves moving forward, would be: 1) implement these tools on content that students already find particularly challenging as these may be areas where you can see the most improvement, 2) maintain use of these tools beyond just a single semester as some time is necessary to adapt to these instruments, and, 3) recognize that student enjoyment is only one factor in evaluating technology. Even if students do not all enjoy the tools, they may still be benefitting from it in their understanding of the content. Finally, we would also caution on the use of these tools for individuals with low visuospatial abilities. Future research is necessary to determine the learning effectiveness of these tools, especially for individuals with low visuospatial ability.

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References

Bianchi S, Bernardi S, Perilli E, Cipollone C, Di Biasi J, Macchiarelli G. 2020. Evaluation of effectiveness of digital technologies during anatomy learning in nursing school. *Appl Sci* 10(7):2357. https://doi.org/10.3390/app10072357

Boscolo-Berto R, Tortorella C, Prorzionato A, Stecco C, Picardi EE, Macchi V, De Caro R. 2021. The additional role of virtual to traditional dissection in teaching anatomy: a randomized controlled trial. *Surg Radio Anat* 43(4):469-479. https://doi.org/10.1007/s00276-020-02551-2

Fyfe S, Fyfe G, Dye D, Radley-Crabb H. 2018. The Anatomage table: Differences in student rating between initial implementation and established use. *Focus Health Prof Educ*19(2):41-52. https://doi.org/10.11157/fohpe.v19i2.215

Hilbelink AJ. 2009. A measure of the effectiveness of incorporating 3D human anatomy into an online undergraduate laboratory. *Br Jl Educ Tech* 40(4):664-672. https://doi.org/10.1111/j.1467-8535.2008.00886.x

Narnaware Y, Neumeier M. 2021. Use of a virtual human cadaver to improve knowledge of human anatomy in nursing students: research article. *Teach Learn Nurs* 16(4):309-314. https://doi.org/10.1016/j.teln.2021.06.003

Pickering, JD. 2017. Developing the evidence-base to support the integration of technology-enhanced learning in healthcare education. *Med Sci Educ 27*(4):903-905. https://doi.org/10.1007/s40670-017-0424-2

Santos VA, Barreira MP, Saad KR. 2021. Technological resources for teaching and learning about human anatomy in the medical course: Systematic review of literature. *Anat Sci Educ: Early view ahead of print.* https://doi.org/10.1002/ase.2142

Trelease RB, Lister J, Schettler S. 2020. Essential E-Learning Methods for Evolving Anatomy Laboratories. In: Chan LK, Pawlina W, editors. Teaching anatomy: A practical guide. New York (NY): Springer Publishing p. 275-287. https://doi.org/10.1007/978-3-030-43283-6_29

Wainman B, Aggarwal A, Birk SK, Gill JS, Hass KS, Fenesi B. 2021. Virtual dissection: An interactive anatomy learning tool. *Anat Sci Educ* 14(6):788-798. https://doi.org/10.1002/ase.2035

Wigfield A, Eccles JS. 2000. Expectancy-value theory of achievement motivation. *Contemp Educ Psychol* 25(1):68-81. https://doi.org/10.1006/ceps.1999.1015

Wilson AB, Brown KM, Misch J, Miller CH, Klein BA, Taylor MA et al. 2019. Breaking with tradition: A scoping meta-analysis analyzing the effects of student-centered learning and computer-aided instruction on student performance in anatomy. *Anat Sci Educ* 12(1):61-73. https://doi.org/10.1002/ase.1789.

Wilson TD. 2020. Role of image and cognitive load in anatomical multimedia. In: Chan LK, Pawlina W, editors. Teaching anatomy: A practical guide. New York (NY): Springer Publishing p. 301-311. https://doi.org/10.1007/978-3-030-43283-6_31.

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