Exploring the Changing Learning Environment of the Gross Anatomy Lab

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Abstract

Purpose
The objective of this study was to assess the impact of virtual models and prosected specimens in the context of the gross anatomy lab.

Method
In 2009, student volunteers from an undergraduate anatomy class were randomly assigned to study groups in one of three learning conditions. All groups studied the muscles of mastication and completed identical learning objectives during a 45-minute lab. All groups were provided with two reference atlases. Groups were distinguished by the type of primary tools they were provided: gross prosections, three-dimensional stereoscopic computer model, or both resources. The facilitator kept observational field notes. A prepost multiple-choice knowledge test was administered to evaluate students' learning.

Results
No significant effect of the laboratory models was demonstrated between groups on the prepost assessment of knowledge. Recurring observations included students' tendency to revert to individual memorization prior to the posttest, rotation of models to match views in the provided atlas, and dissemination of groups into smaller working units.

Conclusions
The use of virtual lab resources seemed to influence the social context and learning environment of the anatomy lab. As computer-based learning methods are implemented and studied, they must be evaluated beyond their impact on knowledge gain to consider the effect technology has on students' social development.

With the continuing advancement of technology, there has been an explosion of computer-based educational materials in medicine.[1–3] In the domain of anatomy learning, for example, many educators are turning to three-dimensional (3D), computer-generated models as a supplemental or even alternative teaching resource.[4] Surveys indicate that the majority of medical schools desire to include, or have already implemented, more computerized learning as a substitute for lectures and dissections.[5,6] However, the search for empirical evidence concerning the use of computer-generated anatomy models relative to traditional options has mixed results. Null findings are not uncommon,[7] and studies demonstrating enhanced learning[8–11] are counterbalanced by those reporting a hindrance to learning.[12,13] In part as a response to these findings, both Friedman[14] and Cook[15] have suggested that to bring about more meaningful evaluations of computer-based learning, research should shift from media-comparative studies (which compare computer-based education resources with noncomputer instruction) toward studies that compare and evaluate the different features of computer-based instruction.[14,15] Echoing the work of Friedman,[14] Cook[15] suggests that comparing different formats of computer-based learning will enable its most effective use.

Although the approach suggested by both Friedman and Cook has merit, it is worth noting that the evaluation they describe is focused very heavily on outcome measures such as knowledge of anatomy content. It has long been recognized, however, that the role of anatomy training extends well beyond gains in anatomy knowledge as measured by traditional content tests. In particular, anatomic dissection has been credited with several socializing factors occurring during physician training. For example, the literature describes various coping mechanisms that students develop in dealing with the emotions they confront in the gross dissection lab.[16–19] The experience of confronting these emotional challenges has been identified as having broad significance for subsequent patient interactions through the development of detached concern.[20]

Additionally, cadaveric dissection has traditionally been one of the earliest experiences of collective or team learning for medical students. Irby and Wilkerson[21] note that learning in small groups facilitates the development of students' cognitive processes through their engagement in the active construction of meaning and socially negotiated understanding. Eighty percent of medical schools in the United States and Canada now report the use of small-group instruction,[22] and the last survey of Canadian anatomy departments noted an increase in small-group learning.[6] But medical educators have recently drawn important distinctions between group learning and team learning.[23] A casual group transforms into a high-performance team when members are intentionally grouped and managed, work together over an extend time, are given a challenging common task, and

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are made accountable for individual preparation and team contribution.[23] Authors making these distinctions would likely argue that the benefits described by Irby and Wilkerson are more properties of team learning than of group learning. Interestingly, the learning conditions of the traditional anatomic dissection context seem particularly well structured to develop team learning rather than group learning experiences. Thus, as we begin to shift toward computer-generated models in lieu of cadaveric dissection, it will be important to study not only the amount of anatomy content learned but also how this shift affects the social learning context and the way students interact. Yet, most studies assessing new technologies in anatomy education have involved a single learner at an individual computer station[1,7–9,13,24–26] and, thus, have likely missed this critical social factor in the educational processes associated with anatomy learning.[27]

The objective of this study, therefore, was to assess the impact of non-dissection-based educational tools such as virtual models and prosected specimens in the context of anatomy learning. We hypothesized that students would perform similarly when using either the prosections or the 3D model and that, when combined, the use of both models would improve students' scores on the knowledge exam. However, the focus of this paper is not on the anatomy knowledge gained from these learning modalities but, rather, on the unanticipated social interactions that arose as teams were learning in the context of these models. That is, although we did evaluate and compare the anatomical knowledge gained within each of the learning modalities (and have presented the data here), the goal of this paper is not to determine whether one modality or the other was a better tool for learning anatomy but, rather, to improve our understanding of what team interactions in the anatomy lab look like when these types of prepared models replace cadaveric dissection.

Methods

Study design

This study was a randomized controlled trial supplemented with observational field notes to report on the integration of a 3D anatomy model and/or gross prosections into the small-group learning environment of the gross anatomy lab. The study took place over the course of one week in October 2009. We employed three experimental conditions that varied only in the anatomy resources available to the learning groups.

Groups in all three conditions completed the following lab objectives: (1) Identify the bony features of the skull listed in the lab handout and describe their locations with respect to each other, (2) locate and name the articulating surfaces of the temporomandibular joint, (3) identify the muscles of mastication and state their functions and attachments, (4) describe the location of the four muscles of mastication with respect to each other and the bony structures of the skull, (5) define the structures contributing to the formation of the zygomatic arch, and (6) explain the main actions of the temporomandibular joint and which muscles contribute to each.

Each group had access to two standard anatomy atlases as part of their learning tools. However, groups were distinguished by the anatomy model of the head and neck they used as their primary learning tool. In addition to the pair of atlases available to learning groups in all three conditions, learning groups in the first condition worked with prosections (predissected cadaveric tissue) and skulls, learning groups in the second condition used a 3D stereoscopic anatomy model (3D model), and learning groups in the third condition had access to both prosections and the 3D model (hybrid). Time restrictions and limited availability of cadaveric specimens precluded the use of a condition that offered traditional cadaveric dissection as the supplemental learning tool.

The 3D model was produced and supplied by the Corps for Research of Instructional and Perceptual Technologies (CRIPT) at the University of Western Ontario (UWO). The details of the model are described more extensively elsewhere,[28] but, briefly, the components of the projection system included dual projectors, two linear polarized lenses, a silver screen, and linear polarized glasses to be worn by the observer. The overall effect was that images appeared to be "jumping" off the screen. Participants could add and remove structures to and from the model using specific keyboard commands on a wireless keyboard. Students were able to manipulate the model on the screen by zooming in and out, translating in any direction, and rotating in any plane with a wireless mouse. A sufficient number of polarized glasses were available for each learning group so that all could observe the 3D images together.

In the prosection and hybrid conditions, groups had access to three prosections along with two skulls with articulating mandibles. These predissected specimens included the head and neck region and provided both superficial and deep dissections. The specimens, produced and provided by the Department of Anatomy and Cell Biology at UWO, were embalmed cadaveric tissue. Students could touch, manipulate, and position these specimens to their learning preference.

Participants

All medical students enrolled in an undergraduate gross anatomy course were invited to participate in the study. One investigator (R.H.) made an announcement regarding the study during class lecture and asked volunteers to sign up electronically for a small-group lab session using a Web-based course tool, Web CT. There was a maximum of six participants in each group, and students were blind to the various potential anatomy lab instructional tools available to the other groups. Students did not receive additional credit or compensation for participating.

Procedures

Lab sessions involved groups ranging in size from three to six participants. After completing a 14-item multiple-choice pretest individually, each participant received a general lab handout containing the learning objectives for the session, and an instructor (R.H.) gave the group a brief demonstration of the learning tools available in the lab. The learning objectives on the lab handout were identical for each lab session. The prosection groups had access to three head and neck prosections and two skulls. The 3D model groups used only the 3D computer model. The hybrid groups could use both prosections and the 3D model. All groups had access to two atlases as a reference for students to identify structures on the learning tool provided in their lab session.

The same instructor (R.H.) was present in every group learning session. Her role was to explain lab procedures, administer pre- and posttests, and observe and record field notes for the duration of the lab session. The instructor asked students to progress through the lab handout using the learning resources provided. The anatomical structures studied were the muscles of mastication and related osteology; these materials had not yet been addressed in the participants' anatomy course. No specific learning strategy was suggested.

As participants worked through the lab, the instructor took descriptive field notes of students' behavior as they interacted with the anatomical models and each other. For example, the instructor noted students' tendency to use the various learning tools available, their degree of engagement with each tool, their differing strategies and tendencies to work together as a group or separately, and how these different strategies and tendencies manifested throughout the learning period. In addition to these observational notes, the instructor made analytic notes both during and following each lab session as trends and consistencies in behavior became apparent.

At the end of a 45-minute time limit (or earlier if all students in a learning group felt comfortable that they had attained the objectives), the instructor administered a posttest of anatomical knowledge to each member of the group. The posttest was the same test instrument used at pretest with questions in a randomized order. Following the posttest, participants in the prosection and 3D conditions had the opportunity to experience the model not previously used by their group to allow for exposure to all of the available learning resources. Subsequently, participants had the option to complete a 13-item questionnaire noting demographic information as well as student opinions concerning the use of each model as an instructional tool.

Data analysis

Data were analyzed during the four months following the data collection period (November 2009 through February 2010). For the comparison of means among the experimental conditions, we performed statistical analyses using SPSS 16.0 (SPSS Inc., Chicago, Illinois). We used mean and standard deviation to describe student performance in knowledge tests for the three test groups. To explore differences between the raw knowledge test scores, we used repeated-measures analysis of variance. We computed the 95% confidence intervals around group estimates. Data are reported as group means (±SD).

To explore the social learning aspects of the various small groups while interacting with the learning modalities, the first author (R.H.) iteratively reviewed the field notes and coded them for recurrent themes. A second member of the research team (T.W.) subsequently verified major recurring observations drawn from the notes.

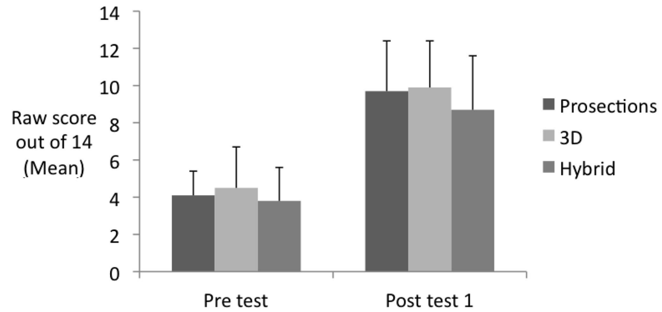

Figure 1 Knowledge test scores of 74 students who completed a pretest, lab session, and posttest using three different anatomy models (prosections n = 26, 3D model n = 23, hybrid n = 25), October 2009. Students showed a statistically significant improvement from pretest to posttest ($F_{1,71} = 255.12$, $P < .001$), with no significant effect of the lab model used ($F_{2,71} = 2.09$, $P = .13$).

Results

Quantitative data

Seventy-four students completed the pretest, lab session, and posttest (prosections n = 26, 3D model n = 23, hybrid n = 25) in 17 separate group learning sessions (with each participant attending in only one lab session). Of the 66 students who completed the follow-up questionnaire, 27 (41%) were male, 39 (59%) were female, and 64 (96%) had no prior experience studying the skull or muscles of mastication. As seen in Figure 1, students showed significant knowledge improvement from pretest to posttest ($F_{1,71} = 255.12$, $P < .001$), but there was no significant effect of the instructional tool used ($F_{2,71} = 2.09$, $P = .13$).

Qualitative data

Examples of field notes are presented in Appendix 1. Findings from the observational notes revealed three recurring behavioral trends.

First, although participants interacted together with the instructional tools for the first part of the learning period, there was a consistent behavior within each group for individuals to separately take several minutes at the end of the lab session, prior to the posttest, to review, reiterate, and memorize terms and structures from their lab handout. That is, in 11 of the 17 groups observed, participants abandoned the available learning resources and changed their learning strategy from group interaction and exploration to individual memorization in service of preparing well for the anticipated written posttest.

Second, whether manipulating the skull, the prosections, or the 3D model, participants frequently seemed to rotate the learning tool so that it mirrored the image they were referring to in the atlas. That is, they would often interact with the 3D objects by viewing them in their classic "cardinal" orientations. This activity only became apparent to the observer in the later part of the study. However, after having been noted, documentation of this phenomenon was noted in 5 of the last 12 sessions observed.

Third, regardless of group size (which ranged from three to six participants), participants in 14 of 17 learning groups chose to split and work independently as two or more subgroups with different learning agendas and timelines. Even groups of only three students divided into subgroups of one pair and one individual student. When a group had only the 3D computer model to interact with as a supplement to the atlases, the learning groups still dispersed into multiple smaller groups working independently, which resulted in conflict over the control of the model when groups began working at different paces.

Student feedback

Responses from the questionnaire revealed that 54 of 66 (82%) students preferred having both prosections and the 3D model, and 42 of 64 (66%) who answered the question felt they would learn more from having both available as learning resources in the lab. Students were generally satisfied with the conditions of the lab 64 of 66 (95%) responding students somewhat or strongly agreed that the lab instructions and objectives were clear, and 57 of 66 (86%) somewhat or strongly agreed that the lab was effective in helping them understand the skull and muscles of mastication. Responses to an open-ended prompt for comments at the end of the questionnaire demonstrated that students had no systematic preference for one lab model. Lastly, no comments expressed discontent with respect to working in segregated small groups, suggesting that students were unaware they were not working as a cohesive team.

Discussion

Consistent with the overarching theme of comparative research involving computer-based anatomy models, the quantitative analysis for this study showed no significant difference in knowledge gain among the three learning modalities. These null findings mirror Russell's[29] observations, after reviewing hundreds of media studies, that the majority of comparative studies show no significant difference. The observational data from this study offer two potential reasons why novel, computer-based models are generally found to be no better or worse than prosected anatomy resources.

First, the instructor observed that students often stopped interacting with the lab model to review material from the paper-based lab handout prior to the posttest. This observation is perhaps not surprising because it is well established that assessment has a strong influence on how students approach learning.[30,31] However, the change in behavior that we observed at the end of the learning session for many of the learners may be an important clue as to why we often see no significant difference in indicators of learning as a result of educational innovations. That is, it seems that the outcome measure had a dominating effect over the intervention, leading a majority of students in our study to default to their tried and true learning strategies, which involve independent memorization of facts to be recalled. This finding has important implications for future studies of educational resources such as computer-based learning models. Although our research generally focuses our attention on which model is better for student learning, the way students perform on the outcome measure may have little to do with their actual interaction with the model. It has been noted that outcome measurement in simulation-based medical education is one of the greatest challenges now facing the field.[27] To the extent that our observations are generalizable, they suggest that this challenge may be greater than initially anticipated. The methods often used for testing the efficacy of our innovations[7–13] may, in fact, be undermining our understanding of the impact of these innovations on learning because they assess students using testing methods that encourage them to default to individual learning activities that have been used for generations. Thus, any differential learning effects that might occur as a function of the innovative tools themselves are inadvertently overshadowed by the evaluation method.

The second observation that may shed light on the failure of media studies to demonstrate learning differences was many participants' tendency to manipulate the anatomical model to mirror views presented in the atlas. The instructor often observed that, to effectively transfer the identifying information provided in the atlas to the 3D resources (both virtual model and real specimens), students would move the resource to match the two-dimensional (2D) image in the atlas, essentially abandoning the affordances of the model as a 3D object. This, in turn, suggests that a substantial minority of students may not be exploiting the opportunity of 3D stereoscopy and real cadaveric specimens as beneficial but, rather, as a potential distraction. Interestingly, Garg and colleagues[25] observed similar tendencies toward key views when students controlled the presentation of 2D renderings of 3D objects. Our finding that this also seemed to be true with stereoscopic images and 3D prosected models implies that this may be an important phenomenon to be explored further in future work.

Perhaps the most intriguing observation noted in this study, and contrary to the united focus of a single group dissecting a cadaver inherent in the traditional anatomy lab, was that students dispersed into more discrete independent groups in the presence of prepared resources. Particularly surprising was the behavior of groups who had only a single 3D computer model available to interact with, similar to how a group traditionally works around one cadaver. Even in this circumstance, the groups still dispersed into smaller numbers, resulting in tension over the control of the model when groups began working at different paces. Thus, it seems that altering the type of resources available in the anatomy lab had a considerable impact on the learning environment and the social interactions of students. The literature surrounding small-group learning versus team-based learning (TBL) offers an interesting perspective on this observed shift in behavior. TBL is a special approach to the use of small groups that takes teaching and learning to a new level of significance.[23] Several fundamental aspects of TBL are consistent with the traditional learning context of cadaveric dissection, including the need to interact with others on a challenging common task, a high level of commitment between members, a longer-term (semester-long) instructional strategy as opposed to a short-term learning activity, and the need to solve problems and resolve issues collectively.[23] In our study, the use of non-dissection-based teaching models initiated behaviors that were inconsistent with the literature's description of TBL. Rather, in the context of these models, students seemed to adopt the "casual use" of small-group learning strategies, with subgroups of students participating in a short-term, unstructured activity.[23] Again, to the extent that our observations in this setting are generalizable, these data point to a potential concern: that the increased opportunity for independent learning available through the use of digital resources may undermine the high level of cohesiveness that empowers formal teams to have greater capability than just casual groups. Educators would do well to pay attention to this possibility as they begin to integrate these non-dissection-based resources into the anatomy lab.

Conclusions

Despite recent recognition that the impact of change in instructional technology in medical education requires evaluation,[33] research efforts to understand the educational impact of replacing cadaveric dissection with virtual computer models have focused on knowledge acquisition[7–13] and have largely ignored any inadvertent influence of the models on social and professional development. Our work suggests that this may be an overly narrow construction of the problem of medical education.

Of course, we recognize that our findings are preliminary, being based on a single cohort learning a single anatomical region with specific resources. Additionally, we note that identification of the patterns of behavior seen here was emergent over the course of the study and that some of the observed patterns were not noted by the observer until the latter half of the study. For example, the trend of students rotating the model to mirror images in the atlas was not recorded until the fifth lab session. As a result, we are unable to note the full extent to which students may have resorted to this behavior during the initial lab sessions. Finally, we did not include a dissection-based learning group, so our speculations regarding the team-based nature of learning when using cadaveric dissection are based on our reading of the literature[34–36] rather than direct observation of students learning in this context. Clearly, additional qualitative studies should be carried out prospectively to explore these behaviors as well as to explicitly compare students' interactions between the use of prepared models and cadaveric dissection.

Despite these caveats, we believe that our results reinforce the idea that future work must aim not only toward a measurement of what knowledge gain or loss is associated with the introduction of learning resources such as prosections and computer models but also toward an understanding of what else is lost with the exclusion of cadaveric dissection.

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Appendix 1

Examples of Observational Field Notes Recorded by the Instructor During Group Learning Sessions in an Anatomy Course at the University of Western Ontario, 2008.

Seventy-six students worked in small groups to complete lab objectives using two anatomy atlases and one of three types of resources: prosections and skulls, a 3D model, or a hybrid of the two.

Date: Friday, Sept. 26, 2008
Time: 1:45–3:15 PM
Location: Meds Lab
Number of participants: 5
Lab group: Hybrid (003-006)

- At the start of the lab one participant suggests a lab strategy: *Do you want to look at both then compare?*
- Three participants working around one atlas (not using a lab tool)
- Two other participants working around the other atlas, using a real skull as a lab tool (not using 3D model)
- No one initially using 3D model
- Group of three move to using 3D (not using real skull)
- Group of two move onto muscles, immediately utilize prosections
- Both resources are available but it appears that both are not being fully utilized in the given time frame (i.e., this one group used prosections only, the other only used the 3D)
- No one used 3D to visualize the muscles, only osteology
- Students are individually reviewing and "memorizing" off sheets near the end, before the posttest

Date: Friday, Sept. 26, 2008
Time: 12:00–1:30 PM
Location: Meds Lab
Number of participants: 5
Lab group: 3D Stereo (002/005)

- One participant is working at atlas alone
- Other four participants are working together
- After approximately 10 minutes, the lone participant starts using computer and is putting the model in the same orientation as the atlas
- Putting muscles on/off model—completely stops, taking time to individually read through the lab instructions
- One participant sits on a stool completely apart from everything, reading lab handout (wants five more minutes to study paper only)
- Rest of the group decide they're done, and don't review structures