Published in final edited form as:

Anat Sci Educ. 2018 September ; 11(5): 445–460. doi:10.1002/ase.1784.

The Use and Effectiveness of Interactive Progressive Drawing in Anatomy Education

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Abstract

Anatomical relationships are challenging concepts for first-year medical students. The use of progressive drawing, where an image is created from a blank template, has long been utilized for outlining anatomical relationships and continuity from one region to another, and has shown positive outcomes for student learning. More recently, computerized progressive drawing has been introduced; however, challenges, including issues with visual clarity, have been described. In this study, 17 computerized screencasts of drawings covering neurovasculature of the limbs, abdomen, pelvis, head, and neck were created and provided to first-year medical students at Morehouse School of Medicine. An animated method for drawing was utilized to increase visual clarity. Surveys were provided to 181 first-year medical students to collect feedback about these screencasts. Sixty percent ($n = 108$) of students completed at least one survey. Respondents rated all 17 screen-casts with a minimum of 4.7/5 for helpfulness in learning the material for course examinations. A majority of students (77.8%) reported viewing the screencasts more than once on at least one survey, and students reported varying methods for utilizing the screencasts. A majority of students provided positive feedback relating to technical quality. Some significant differences in course performance were seen based on screencast usage. The positive responses from students indicate that this is a useful method in medical education.

Keywords

gross anatomy education; undergraduate education; medical education; screencasts; anatomy drawings; animation

INTRODUCTION

Gross anatomy is a challenging yet integral component of undergraduate medical education. One challenge posed by regional anatomical dissection is that distal distributions of vessels and nerves might be studied before the origins of those structures have been encountered. Because of this logistical problem, students may struggle with gaining a holistic understanding of the continuity of structures from their origins to destinations. This may challenge their understanding of more detailed anatomical relationships. A long-utilized method for connecting individual regions into broader patterns of organization has involved

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drawing large-scale diagrams of anatomical schemes on the chalkboard using progressive drawing, where a live drawing is created in a stepwise manner from a blank template.

Much of the literature related to drawing in education has focused on the effectiveness of student-generated drawings from text (Gobert and Clement, 1999; Van Meter and Garner, 2005; Leutner et al., 2009; Leopold and Leutner, 2012; Schmeck et al., 2014), while instructor-guided progressive drawing has received less attention. Both learner-generated drawing (Azer, 2011; Nuag et al., 2011; Balemans et al., 2016; Backhouse et al., 2017) and instructor-guided drawing (Nayak and Kodimajalu, 2010; Noorafshan et al., 2014) have been demonstrated to be effective and well-received methods for teaching in the anatomical sciences. Drawing methods have not only been shown to increase learning and retention of material (Nayak and Kodimajalu, 2010; Alsaïd and Bertrand, 2016; Balemans et al., 2016), but also to be effective in increasing learner engagement with material (Kotzé et al., 2012). This makes sense in the anatomical sciences, as drawing allows for the demonstration of continuity from one region to another without the necessity of dissecting each region, or the use of multiple static images.

Progressive drawing can serve as a means to encourage metacognition (Dempsey and Betz, 2001; Van Meter, 2001). Metacognition is students' self-monitoring and awareness of their own learning, and can include making adaptations in study strategies as needed (Flavell, 1979; Schraw and Dennison, 1994; Winne and Hadwin, 1998). Such self-regulation has been shown to be an important contributor to student academic success (Van Zile-Tamsen and Livingston, 1999; Ross et al., 2006; Coutinho, 2007; Young and Fry, 2012). The suggestion that drawing is important to students' meta-cognitive processes as they learn new material specific to the anatomical sciences (Naug et al., 2011) is therefore not surprising. In addition to supporting student metacognition, generated drawings may also provide a useful means for formative assessment of student knowledge by faculty (Ranaweera and Montplaisir, 2010; Slominski et al., 2017). Given the evidence of the importance of drawing, a plea for maintaining drawing within the anatomy curriculum has been set forth by experts in the field (Clavert et al., 2012; Pickering, 2014).

However, there are some challenges to incorporating progressive drawing into lectures, particularly with reduced time in the classroom. These may include reduced visual clarity in large classrooms, and discerning illegible handwriting on the chalkboard (Jabeen and Ghani, 2015). Another challenge of classroom drawing is that students can only view the progressive process of creating an illustration as many times as the faculty will draw it, which is likely limited. The use of computer presentations might remedy some of these issues, although they have their own set of disadvantages, such as the incorporation of complicated images and increased pace of presentation (Shallcross and Harrison, 2007). However, with advancing technology, computer generated screencasts of drawings are a possible solution for maintaining drawing within the curriculum while utilizing minimal classroom time. A screencast is a video capture of a computer screen while information is being presented, which can include both screen activity and sound or voice recording. This technology also lends itself to catering to the needs of individual students by allowing for more clarity, replication of drawings, multiple views of the progressive drawing process, and less time devoted to drawing in the classroom.

The use of diagrams (Cuevas et al., 2002; Fiore et al., 2003), computer animation (Blankenship and Dansereau, 2000; Ke et al., 2006), and screencasts (Evans, 2011; Green et al., 2012; Lloyd and Robertson, 2012; Morris and Chikwa, 2014; Gambari and Hassan, 2017) have demonstrated a positive effect on learning various subjects. A recent publication introduced the use of screencasts of anatomical drawings as a means for maintaining drawing in anatomy education, and an overall positive student response to this learning tool was reported (Pickering, 2015). However, issues remained with clarity of handwriting and improvement of the downloading process, suggesting a need for further evaluation of the methods for creating screencasts.

The purpose of this study was to build on previous studies that have evaluated the utilization of drawing screencasts in the anatomical sciences by both utilizing alternative techniques for the development and creation of the screencasts, as well as to further explore the effects of supplemental drawing screencasts on student learning. To do this, animated and narrated screencasts of neurovascular networks were created and provided to students to watch as optional supplementation to their learning. The issue of clarity of handwriting was addressed by utilizing a novel method for “drawing” and identifying structures, allowing for students to draw along with the screencast. This portion of the curriculum was evaluated during the 2015–2016 and 2016–2017 academic years in 181 first-year medical students at Morehouse School of Medicine. It was hypothesized that: (1) Overall, respondents would indicate that these drawings were helpful in learning material, (2) Students would not have difficulty with technical quality of the screencasts, (3) Simultaneous viewing of dissection videos would be important to student learning, and (4) Screencast viewing and utilization methods would have a positive effect on course performance.

MATERIALS AND METHODS

This study was classified and approved as exempt by the Institutional Review Board (IRB) at Morehouse School of Medicine.

Anatomy Curriculum at Morehouse School of Medicine

At Morehouse School of Medicine (MSM), the transition from individual courses by discipline to an integrated curriculum was strongly driven by the anatomy curriculum, and much of the time devoted to anatomy lecture and laboratory was maintained during this transition. Technological advances have shifted lectures from the chalkboard to the computer, as has been the case at many institutions. Lecture recordings have been made available to students in recent years, which students have felt to be important to their learning. However, the current technology at MSM only allows for visual and audio recording of lectures directly from a computer screen and not from a chalkboard, further reducing the use of chalkboard drawings. Therefore, the introduction of screen casted, progressive drawings for what once was drawn on the chalkboard during lecture time was introduced as an alternate means for providing this material to students.

Within the integrated curriculum, gross anatomy fell into the Organ Systems (OS) 1, 2, and 3 courses across the first year. During each course, 3–5 faculty members were available during the laboratory sessions, and all students participated in all dissection-based laboratories. The

OS1 course ran from September through December, and covered the back, upper limb, thorax, and abdomen, including approximately 63 hours of dissection and 47 hours of related anatomy lectures. There were two laboratory practical examinations and three computer-based examinations. There were 35 questions on the back and UL practical examination and 40 questions on the thorax and abdomen practical. On the computer examination there were 25 questions relating to anatomy of the UL, 16 questions relating to anatomy of the thorax, and 20 questions related to anatomy of the abdomen. The OS2 course ran from January through March, and covered the pelvis, perineum, and lower limb, including approximately 30 hours of dissection and 14 hours of related anatomy lectures. There was one practical and one computer-based examination on gross anatomy content. There were 40 questions on the practical examination. There were 16 questions relating to anatomy of the pelvis and perineum and 20 questions relating to anatomy of the LL on the computer examination. The OS3 course ran from March through May, and covered head and neck and neuroanatomy, including approximately 60 hours of dissection and 21 hours of related anatomy lectures. There was one practical and one computer-based examination on gross anatomy content relevant to the drawing screencasts. There were 50 questions on the practical examination, and 36 questions relating to anatomy of the head and neck on the computer examination. Across all courses, practical examinations were all fill-in answers, and included primarily identification questions and limited second order questions on dissections, bones, and models. Computer examination questions were multiple choice, and ranged from first order questions to board style clinical vignettes.

Blackboard curriculum management system (Blackboard Inc., Washington, DC) was used as the course management system to provide lecture and laboratory related materials throughout each course. Students utilized an online dissector and textbook for the gross anatomy component of the OS courses. Dissection videos were available within the dissector, and separate dissection videos were created internally at MSM that reviewed laboratory content by region. Course materials were made available throughout each course, and students maintained access to all courses throughout the first year.

Developing Screencasts

The purpose of creating these screencasts was to make them available as optional supplements to classroom and laboratory sessions, and not to replace such sessions. The methods utilized to create these screencasts evolved as challenges were identified, and new technology was made available. The author first selected the drawings (screencasts) that would be created for each body region. These initial drawings were selected based on their relative ease for basic line drawing, so as not to deter those uncomfortable with drawing complex images from drawing along. Selection was also based on the drawings that the author most frequently drew on the chalkboard for students previously, with the expectation that additional screencasts would be added over time if students found them to be useful learning tools. For the 2015–2016 course (referred to as Year 1 [Y1] of this study), drawings included: the brachial plexus, arteries of the upper limb (UL), arteries of the abdomen (celiac trunk, superior mesenteric artery, and inferior mesenteric artery), the portal system, arteries of the posterior abdominal wall, arteries of the pelvis and perineum, arteries of the lower limb (LL), arteries of the head and neck, ophthalmic division of trigeminal nerve (CN V1),

maxillary division of trigeminal nerve (CN V2), mandibular division of trigeminal nerve (CN V3), the facial nerve (CN VII), the glossopharyngeal nerve (CN IX), and vagus nerve (CN X). For the 2016–2017 course (referred to as Year 2 [Y2] of this study), all of the previous videos were provided, and additional modules were created, which included: Sympathetics of the thorax, vasculature of the thorax, and autonomics of the abdomen. For each of these topics, the drawing was first sketched on a piece of paper to determine the dimensions necessary for an 8½ × 11-inch piece of paper. These were simple line drawings that incorporated landmarks and relationships, and did not require a great deal of artistic ability to facilitate students' ability to draw along. A new color was used to: (1) Identify a name change or bifurcation in arteries; (2) Identify the components of the brachial plexus; (3) Identify venous name changes; and (4) Identify different fiber types. In some cases, a template with relevant structures and landmarks was provided, so that students could focus on drawing the vessels and nerves (Figs. 1 and 2).

Once complete, each line of the drawing was created individually in PowerPoint (PPT), version 14.5.9 for Mac (Microsoft Corp., Redmond WA), using the curve line shape feature, while also keeping in mind the limitations of this feature, which only allow for up, down, right and left animations of each path. For example, if an artery recurred superiorly, such as the recurrent radial artery, it would be drawn as two lines, one that would animate horizontally or inferiorly, and a second line that would animate superiorly. If the illustration could not fit clearly on one slide, it was continued onto the next slide, however transitions allowed for students to continue drawing on a single piece of paper (Fig. 2). Shapes were sometimes added to indicate landmarks, such as the pectoralis minor muscle as a landmark for the three parts of the axillary artery. In the case of the cranial nerves, functional components, or fiber types (general somatic efferent, general visceral efferent, etc.), were color-coded and drawn within each branch of each nerve. Once the illustration was complete in PPT, identifications for anatomical structures were added using text boxes. The end product was 1–3 slides of static, labeled, simple line illustrations of each topic.

The next step was to animate the static illustration so that the screencast could be narrated in a step-by-step manner for the students. Each line and text item was animated in the order in which the author would typically draw or write them on a piece of paper. For example, when animating arteries of the UL, first the heart would appear as a shape, followed by line representations of the aorta, the brachiocephalic, left common carotid, and left subclavian arteries. The right subclavian and common carotid arteries were then animated, and each branch of the right subclavian artery was animated in the typical order that was presented in textbooks and lecture material. In the case of the cranial nerves, the template of the branching pattern of each nerve and its branches was not animated, and only the fiber types and structure labels were animated. Under the Animation Options menu in PPT, applying the “wipe” animation feature to each line simulated the act of drawing lines. The direction and duration of each “wipe” animation was edited to simulate the direction and duration in which the author would draw the structure on a piece of paper. The “appear” animation feature was used for related landmarks (such as the pectoralis minor muscle) and text. The progression of animation was such that the lines for a structure were animated, the text box to identify this structure appeared immediately afterward, followed by animation of the next artery or nerve and its associated text box, and so on. Once the animation had been

completed, the complete series of animations were played in their entirety in PPT to ensure the proper order of animation of all lines and text. Edits were made to correct any errors that had been made in animation order. Finally, an introduction slide was added to each slideshow.

The final step was to create the narrated screencasts. The PPT presentation was set in presenter mode, and Camtasia®, version 2.10.3 for Mac (TechSmith Corp., Okemos, MI) was opened for screen and voice recording. Camtasia® was utilized for its post-editing capability. The animation was then recorded with narration. Narration included the identification of structures, anatomical relationships, and helpful hints for remembering structures. Comments about common variations were also included. There were no instructions regarding how students should utilize the screencasts, and therefore choosing to draw along with the screencast was entirely up to each student. However, the final images of the drawings were not made available to students, and therefore the only way these could be accessed was through the screencasts. The screencast was then edited to remove any unwanted or unnecessary sections, and to correct any narration errors. The screencasts were then exported as (.mp4) files.

For three screencasts in the Y2 OS1 course (arteries of the UL, the brachial plexus, and arteries of the abdomen), corresponding dissection videos had been created in the previous year, and were included at the end of each screencast. These videos were unique in that they followed arteries and nerves through multiple regions rather than one single region. In the cases of these screencasts, the dissection video was loaded into Camtasia, and relevant images from the drawing tutorials were embedded in a corner of the dissection video, and the structures being pointed out in the video were simultaneously circled on the drawing. Each circle would disappear as the next structure was pointed out.

The mean length of the final version of the drawing component across the 17 screencasts in Y2 was 12 minutes and 35 seconds, and ranged from 3.5 to 21 minutes. The addition of dissection videos to three of the screencasts added an average of 7 minutes and 31 seconds to the final version. However, the longest screencast with or without a dissection video remained at 21 minutes.

Screencasts in (.mp4) format for the first two screencasts (arteries of the UL and the brachial plexus) in Y1 were uploaded directly into BBL, which led to challenges with access and ease of playing the screencasts for students. These were therefore removed from BBL and uploaded, along with all remaining screencasts across both years, into TechSmith Relay® Recorder (TSR), version 5.0.6, (TechSmith Corp., Okemos, MI) and linked to TSR via BBL. TSR is a platform for providing videos in education, and allows for video recording, sharing, and tracking of views. This platform was already in use at MSM to provide videos (primarily lecture recordings) to students, and therefore was a reasonable transition for students. Screencasts were being developed during Y1, and therefore some screencasts were made available later in each course than for the Y2 class, where all except for vasculature of the thorax were available through the entirety of each course. Vasculature of the thorax was developed midcourse, and therefore made available closer to the thorax computer examination in Y2.

Surveys

Students in Y1 received two optional surveys; the first covered screencasts in OS1 and OS2, and the second covered screencasts in OS3. Students in Y2 courses received one survey after each OS course, for a total of three optional surveys. To evaluate screencasts for OS1, data collected from the first Y1 survey and the first Y2 survey were combined. To evaluate screencasts in OS2, data collected from the first Y1 and second Y2 surveys were combined. To evaluate OS3 screencasts, data collected from the second Y1 and third Y2 surveys were combined. Data were downloaded and de-identified using codes so that responses could be matched to course grades and across surveys. Students were asked to provide demographic information, to rank helpfulness of each screencast to their learning on a five-point Likert scale of 1 (least helpful) to 5 (most helpful), and to respond to statements about the efficacy, interface, visual clarity, clarity of narration, level of detail included in the screencasts, and the inclusion of dissection videos (where relevant) also on a five-point Likert scale of 1 (strongly disagree) to 5 (strongly agree). Data were also collected on how students utilized the screencasts, including if they drew along with the screencasts, studied from their own drawing, studied from the final image of the screencast, how many times they typically viewed the screencasts, and when they chose to view the screencasts (before the relevant laboratory, after the relevant laboratory, or at the end of the examination block/before the examination). Students were also invited to provide qualitative responses about the screencasts. These surveys were sent to all first-year medical students enrolled in the OS1, OS2, and OS3 courses (Y1: $n = 84$; Y2: $n = 96$ for OS1, $n = 97$ for OS2 and OS3) via email invitations using the web-based software, LimeSurvey® (LimeSurvey® Project Team, Hamburg, Germany). Completing surveys was optional, and students were allowed to skip questions and exit the survey at any time. Surveys included 12 questions and took approximately 15 minutes to complete.

Screencast Viewing Data

Overall utilization of the screencasts for each year was evaluated via the analytics feature of TSR. This website provided user data, including total views across all students, which students viewed each screencast, and the total percent length of each screencast viewed by each student. Viewing data were updated by the TSR website in real time. For the Y1 courses, data for the year were recorded at the end of the OS3 course. For Y2 courses, data were recorded weekly and after each examination, and again after the National Board of Medical Examiners® (NBME®) Gross Anatomy and Embryology Subject Examination to determine if screencasts were further utilized to prepare for this examination. Based on the TSR data, the total number of students that pressed play to view each screencast and the number of students that viewed <10%, 10–89%, and 90% of each screencast were recorded. The limitations to these data were that multiple views by individual students were not available. Data were also recorded through the BBL statistical tracking tool during the Y2 courses, which measured “hits,” or the number of times each student clicked an item to be linked to the TSR page. However, it was found that there were significantly more hits/clicks in BBL than actual views in TSR (Greene, 2017), suggesting that some students clicked on an item in BBL to link to the TSR page, but did not actually play the video when they arrived at the TSR page. Therefore, no objective measure of multiple views by

individual students could be collected. However, self-reported average views were collected from students in surveys.

Accurate usage data from arteries of the UL and the brachial plexus could not be evaluated for the Y1 OS1 course due to being temporarily deleted from BBL and then uploaded through TSR midway through OS1. Therefore, 12 screencasts were evaluated for Y1 courses, and 17 screencasts were evaluated for Y2 courses.

Statistical Analyses

Overall survey feedback.—Data were exported to Microsoft® Excel, version 14.5.9 for Mac (Microsoft Corp., Redmond, WA), and statistical analyses were completed using statistical package SPSS Statistics, version 24.0 for Mac (IBM Corp., Armonk, NY). A Cronbach's alpha analysis was completed for Likert scale data regarding efficacy and technical quality of screencasts and for ratings for screencasts on the first survey in Y1 to measure the reliability of the surveys. Only respondents who responded to every item evaluated within each Cronbach's alpha analysis were included.

Overall ratings of efficacy and technical quality of screen-casts were combined across surveys and years to determine mean responses across the 108 respondents. For those who responded to more than one survey, individual responses were averaged across surveys, and then mean responses across all respondents were calculated. Utilization methods (drawing along, studying from one's own drawing, studying from the final image, and timing of viewing screencasts) were collapsed across surveys and years to evaluate the 108 respondents. If individual respondents responded differently across surveys, they were excluded from analyses. Kruskal-Wallis and Mann Whitney-*U* analyses were conducted to determine if there were differences in Likert scale data based on reported screencast utilization methods across surveys, and mean rank (MR) and means are reported for these comparisons.

NVivo software for Mac, version 11.4.0 (QSR International Pty Ltd., Melbourne, Australia) was used for exploratory thematic analysis of qualitative data, which was all completed by the same individual. Thematic analyses were performed once and then repeated in entirety to establish intra-rater reliability. Where there were discrepancies between analyses, each individual response was evaluated a third time to determine if it was appropriate to include within the designated theme. All responses were coded so that individual students who made multiple comments that fell within a particular theme within or across surveys would not be counted more than once when calculating the total responses. This allowed for percent response rates within each theme to be calculated from the 108 total respondents across surveys and years.

Incorporating dissection videos.—Independent *t*-tests were run to determine if there was a significant difference in the length (in seconds) of the screencasts that did ($n = 3$) and did not ($n = 14$) include dissection videos, and also if the number of students who pressed play to begin viewing the screencasts and viewed 90% significantly differed between screencasts that did and did not include dissection videos. Additionally, three questions related to the incorporation of dissection videos were included in the Y2 surveys.

Screencast usage and course performance.—To evaluate usage and course performance, including course examination scores and scores on the NBME Gross Anatomy and Embryology Subject Examination, students within each entire class were classified as watching a screencast (defined as viewing 90% of a screencast) or not watching a screencast (defined as viewing <10% of a screencast). Students that viewed between 10 and 89% of the screencasts were excluded from analyses, given that the actual content they had viewed was quite variable. For computer and practical examination grades, students were identified as scoring below and at or above the 50th percentile, and compared using Pearson Chi-square analyses and *z*-tests. Comparisons of survey data between Y1 and Y2 were completed using Kruskal-Wallis and Mann Whitney-*U* analyses for Likert scale survey data, and Pearson Chi-Square analyses, Fisher's exact analyses, and *z*-tests with Bonferonni correction for screencast utilization methods. Independent *t*-tests were used to directly compare mean examination scores by year. Performance on UL and thorax examinations were only evaluated for Y2, as accurate UL screencast usage data was not available, and thorax screencasts had not yet been created for Y1.

Pearson Chi-Square, Fisher's exact analyses, and *z*-tests with Bonferonni correction were completed to evaluate if significant differences existed in the methods for utilizing screencasts by examination performance, defined as scoring below and at or above the 50th percentile, in those students who responded to surveys. In cases where student-reported drawing versus not drawing along, studying from their own drawing versus studying from the final picture, and timing of viewing screencasts were directly compared, those who indicated more than one response were excluded from analyses. Where usage methods were compared by examination performance, only responses based on the survey relevant to the examination were evaluated.

RESULTS

Overall Student Feedback

For Y1, 36 students (42.9 %) responded to the first survey, and 25 students (29.8%) responded to the second survey. For Y2, 28 (29.2%), 35 (36.1%), and 38 (39.2%) responded to the surveys for OS1, OS2, and OS3, respectively. Therefore 64, 71, and 63 surveys were evaluated for OS1, OS2, and OS3, respectively. Taking into account repeated participation across surveys, a total of 108 students responded to at least one survey across both years (59.7% total response rate). On the first survey administered for Y1, survey items that utilized Likert scales to evaluate efficacy and technical quality of screencasts demonstrated a Cronbach's alpha of 0.89 ($n = 30$), and individual screencast ratings demonstrated a Cronbach's alpha of 0.71 ($n = 27$), indicating high internal consistency. Demographic information for each survey is summarized in Table 1.

There were no significant differences in ratings of individual screencasts; ratings of efficacy, interface, visual clarity, clarity of narration, level of detail, or importance of the incorporation of dissection videos, or in methods for utilizing the screencasts between Y1 and Y2 respondents. Therefore, all comparisons were made across Y1 and Y2, with the exception of comparisons relating to screencasts covering the UL and sympathetics of the thorax, as data were only available for Y2.

Mean responses for the helpfulness of each screencast to learning material are presented in Table 2, and mean responses related to efficacy and technical quality of screen-casts are presented in Figure 3. When reporting methods for utilizing the screencasts, respondents were allowed to select multiple answers. Of the 108 total respondents, 52 (48.1%) reported drawing along with the screencasts, while 78 (72.2%) reported watching without drawing along on at least one survey, however 30 of these respondents (27.8%) reported both methods. Twenty-nine respondents (26.9%) reported that they studied from their own pictures that they created using the screencasts, while 51 respondents (47.2%) indicated they studied from the final picture of the screencast on at least one survey, however 16 respondents (14.8%) reported both methods. Eighty-four respondents (77.8%) reported viewing screencasts more than once on at least one survey. For timing of viewing the screencasts, 17 (15.7%), 74 (68.5%), and 64 (59.3%) respondents indicated that they viewed the screencasts before the relevant laboratory, after the relevant laboratory, and prior to the examination, respectively. However, 46 respondents (42.6%) reported more than one answer.

When evaluating methods of drawing versus not drawing along, there were no significant differences in responses to questions regarding the efficacy or technical quality of screen-casts between students who reported drawing along ($n = 22$) versus not drawing along ($n = 48$). There were also no differences in scoring below and at or above the 50th percentile between respondents who reported drawing versus not drawing along for any examination evaluated.

When evaluating reports of studying from one's own drawing versus studying from the final image of the screen-casts, the only significant difference was that respondents who reported studying from their own drawing more strongly agreed that the screencasts were easy to access and watch (Mean = 4.8; MR of 31; $n = 7$) than those who reported studying from the final image (Mean = 4.7; MR of 23; $n = 22$; $P < 0.05$). There were no significant differences in scoring below and at or above the 50th percentile between these groups.

For student-reported number of views of screencasts, there were no significant differences in responses regarding efficacy or technical quality of screencasts between respondents who reported viewing the screencasts once versus more than one time. When evaluating course performance, for the practical examination covering the UL, z -tests revealed that a significantly higher proportion of respondents that fell at or above the 50th percentile reported viewing screencasts more than once (88.2%; $n = 15$) than those who fell below the 50th percentile (54.5%; $n = 60$) on this examination ($n = 28$; $P < 0.05$). Additionally, a Pearson Chi Square analysis revealed an overall significant difference in proportions in the number of reported times screencasts were viewed by performance on the computer examination questions related to the pelvis and perineum ($X^2 [1, n = 71] = 4.9, P < 0.05$), and z -tests revealed that a significantly higher percentage of respondents falling at or above the 50th percentile (89.2%; $n = 33$) reported viewing screencasts more than once than respondents who fell below the 50th percentile (67.6%; $n = 23$; $P < 0.05$).

When student-reported timing of viewing screencasts were evaluated (before the relevant laboratory, after the relevant laboratory, and prior to the relevant examination), a Kruskal-Wallis test revealed an overall significant difference in agreeing with a statement about if the

screencasts helped them to bring concepts together ($X^2 [2, n = 57] = 7.9, P = 0.05$). Follow-up comparisons revealed that those who only reported viewing screencasts before the relevant laboratory less strongly agreed with this statement (Mean = 3.7; MR of 18; $n = 7$) than those who reported viewing screencasts only after the relevant laboratory (Mean = 4.8; MR of 33; $n = 32; P < 0.05$). There was also an overall significant difference in agreeing that the screencasts contained an appropriate level of detail based on reported timing of viewing screencasts ($X^2 [2, n = 57] = 9.3, P = 0.01$), and follow-up comparisons revealed that those who reported viewing the screencasts only after the laboratory (Mean = 4.8; MR of 34; $n = 32$) more strongly agreed with this statement than those who reported viewing the screencasts only prior to the examination (Mean = 4.3; MR of 23; $n = 18; P < 0.05$). Finally, there was an overall significant difference in agreeing that the screencasts were visually clear by reported timing of viewing screencasts ($X^2 [2, n = 57] = 6.5, P < 0.05$), and follow-up comparisons revealed that those who reported viewing the screencasts only after the relevant laboratory more strongly agreed with this statement (Mean = 4.8; MR of 32; $n = 32$) than those who reported viewing the screencasts only before the relevant laboratory (Mean = 3.9; MR of 19; $n = 7; P < 0.05$). When evaluating course performance, a Fisher's Exact analysis revealed an overall significant difference in reported timing of viewing screencasts ($n = 58; P < 0.05$), and follow-up comparisons revealed that a significantly higher proportion of those who reported viewing screencasts prior to the relevant laboratory fell at or above the 50th percentile on the practical examination covering pelvis, perineum, and LL (22.2%; $n = 6$) than those who fell below the 50th percentile (3.2%; $n = 1; P < 0.05$).

Qualitative responses provided further insight into methods for utilization of screencasts, although not all respondents provided qualitative responses to each question. This provided additional information, particularly regarding students that selected more than one answer for drawing or not drawing along with the screencasts. Only two respondents (1.9%) described drawing along with the screencasts during the first viewing. Fourteen respondents (13.0%) indicated that they would first watch without drawing along, and follow this by creating their own drawing with or without a subsequent viewing. Six respondents (5.6%) described methods of utilizing a screenshot of the final image, such as scrolling to the end to print it out and then viewing the screencast, and viewing the screencast first and then printing out a screenshot of the final image at the end. Fifteen respondents (13.9%) provided details on why they chose not to draw along with the screencasts. Themes included personal preference ($n = 10; 66.7\%$), and focusing on the presentation rather than their own drawing ($n = 3; 20\%$).

Students were also asked to provide open comments about what was most helpful about the screencasts, and several themes emerged from their responses (Table 3). Additionally, respondents commented on utilizing user control options (pausing, increasing speed, etc.; $n = 10; 9.3\%$), appreciation of color-coding ($n = 8; 7.4\%$), and that the screencasts were an appropriate pace ($n = 7; 6.5\%$), although two respondents (1.9%) recommended increasing the pace. Students were additionally asked to provide comments on what could be improved in the screencasts. The most common suggestion was to continue to create more screencasts, with some specific suggestions for future screencast topics ($n = 21; 19.4\%$). Additional suggestions were related to improving technical aspects of the videos, such as video speed and full screen viewing ($n = 9; 8.3\%$) and improving the templates ($n = 6; 5.6\%$).

Incorporation of Dissection Videos

Responses to survey questions relevant to including dissection videos are presented in Figure 3. The average length of screencasts that did not include dissection videos ($n = 14$, average length of 13 minutes, 9 seconds) did not significantly differ from that of screencasts that did include dissection videos ($n = 3$, average length of 17 minutes, 34 seconds). For the three screencasts that included dissection videos, an independent t-test revealed that of the students that pressed play to begin viewing these screencasts, the percentage of these students who viewed 90% of the entire screencast (64.9%) was significantly lower than in drawing screencasts without dissection videos (78.3%; $P < 0.05$).

When evaluating qualitative responses, four respondents (3.7%) suggested including dissection videos, however only two of these respondents were from Y2, where dissection videos had already started to be included in three screencasts.

Screencast Usage and Course Performance

Organ systems 1: Back, upper limb, thorax, and abdomen.—Mean scores for the Y2 back and UL practical and computer examinations were 85.1% and 81.7%, respectively. The mean score for Y2 computer examination questions relating to the thorax was 73.3%. Mean scores for computer examination questions relating to the abdomen for Y1 and Y2 were 78.9% and 84.5%, respectively, which were significantly different ($P < 0.001$). Mean scores for the practical examination covering thorax and abdomen for Y1 and Y2 were 84.8% and 86.0%, respectively, which were not significantly different.

When evaluating screencast views and course performance, there were no significant differences in falling below and at or above the 50th percentile on relevant examinations based on viewing or not viewing UL screencasts. A Pearson Chi-Square analysis revealed an overall significant difference in proportions for viewing arteries of the abdomen based on performance on the practical examination covering thorax and abdomen ($\chi^2 [1, n = 153] = 5.2, P < 0.05$), and z-tests revealed that a higher proportion of those who fell at or above the 50th percentile (55.3%, $n = 47$) than below the 50th percentile (36.8%; $n = 25$) had viewed this screencast ($P < 0.05$).

For screencast ratings, those who fell at or above the 50th percentile on computer examination questions relating to the abdomen rated arteries of the abdomen significantly higher (Mean = 5.0; MR of 32; $n = 33$) than those who fell below the 50th percentile (Mean = 4.9; MR of 28; $n = 26$). For responding to statements about efficacy and technical aspects of the screencasts, a Mann-Whitney U analysis revealed that respondents who scored at or above the 50th percentile on computer examination questions relating to the abdomen more strongly agreed that the screencasts helped them to understand versus memorize material (Mean = 4.9; MR of 16; $n = 19$), than respondents who scored below the 50th percentile (Mean = 4.4; MR of 9; $n = 8$; $P < 0.05$), and also more strongly agreed that the screencasts were visually clear (Mean = 4.9; MR of 32; $n = 33$) than respondents who scored below the 50th percentile (Mean = 4.7; MR of 26; $n = 25$; $P < 0.05$).

Organ systems 2: Posterior abdominal wall, pelvis and lower limb.—The mean computer examination scores for Y1 and Y2 for questions relating to the LL were 82.8% and 76.0%, respectively, which were significantly different ($P < 0.01$). Mean computer examination scores for Y1 and Y2 questions relating to the pelvis and perineum were 69.3% and 70.0%, which were not significantly different. Mean practical examination scores for material covering the posterior abdominal wall, pelvis, and LL for Y1 and Y2 were 79.8% and 78.0%, which were not significantly different. There were no significant differences in falling above or below the 50th percentile on the relevant examinations based on viewing or not viewing any of the OS2 screencasts.

There were no significant differences in ratings of screen-casts based on scoring below and at or above the 50th percentile on the relevant examination for OS2. For responding to statements about efficacy and technical aspects of the screencasts, respondents who scored below the 50th percentile on computer examination questions related to the pelvis and perineum more strongly agreed that screencasts helped them to bring concepts together (Mean = 4.8; MR of 38; $n = 30$) than those who scored at or above the 50th percentile (Mean = 4.5; MR of 30; $n = 36$; $P < 0.05$), more strongly agreed that the screencasts helped them to understand anatomical relationships (Mean = 4.9; MR of 37; $n = 29$) than those who scored at or above the 50th percentile (Mean = 4.7; MR of 30; $n = 36$); and more strongly agreed that the screencasts covered the correct level of detail (Mean = 4.9; MR of 37; $n = 29$) than those who scored at or above the 50th percentile (Mean = 4.6; MR of 30; $n = 36$; $P < 0.05$).

Organ systems 3: Head and neck.—The mean computer examination scores for Y1 and Y2 for questions relating to the head and neck anatomy were 74.9% and 76.1%, respectively, which were not significantly different. Mean practical examination scores for material covering the head and neck for Y1 and Y2 were 86.9% and 80.9%, respectively, which were significantly different ($P < 0.001$).

For the practical examination, there was an overall significant difference in proportions for viewing CN VII based on examination performance ($X^2 [1, n = 165] = 4.5, P < 0.05$), and a z-test revealed that a significantly higher proportion of those who fell at or above the 50th percentile (39.8%; $n = 39$) than below the 50th percentile (23.9%; $n = 16$) had viewed this screencast ($P < 0.05$). For the computer examination questions relating to head and neck anatomy, there were several significant differences based on viewing or not viewing screencasts and examination performance. For CN V2, there was an overall significant difference in proportions ($X^2 [1, n = 158] = 8.4, P < 0.01$), and a z-test revealed that a significantly higher proportion of students who fell at or above the 50th percentile (56.8%; $n = 46$) than below the 50th percentile (33.8%; $n = 26$) had viewed this screencast ($P < 0.05$). For CN V3, there was an overall significant difference in proportions ($X^2 [1, n = 161] = 7.1, P < 0.01$), and a z-test revealed that a significantly higher proportion of students who fell at or above the 50th percentile (47.5%; $n = 38$) than below the 50th percentile (27.2%; $n = 22$) had viewed this screencast ($P < 0.05$). For CN VII, there was an overall significant difference in proportions ($X^2 [1, n = 162] = 9.2, P < 0.01$), and a z-test revealed that a significantly higher proportion of students who fell at or above the 50th percentile (44.7%; $n = 38$) than below the 50th percentile (22.1%; $n = 17$) had viewed this screencast ($P < 0.05$). For CN IX, there was an overall significant difference in proportions ($X^2 [1, n = 169] = 13.1$,

$P < 0.001$), and a z-test revealed that a significantly higher proportion of students who fell at or above the 50th percentile (43.5%; $n = 37$) than below the 50th percentile (17.9%; $n = 15$) had viewed this screencast ($P < 0.05$). For CN X, there was an overall significant difference in proportions ($\chi^2 [1, n = 165] = 9.8, P < 0.001$), and a z-test revealed that a significantly higher proportion of students who fell at or above the 50th percentile (54.1%; $n = 46$) than below the 50th percentile (30.0%; $n = 24$) had viewed this screencast ($P < 0.05$).

There were no significant differences in ratings efficacy, interface, visual clarity, clarity of narration, or level of detail by examination performance for the OS3 survey.

National board of medical examiners (NBME) gross anatomy and embryology subject examination.—The NBME Gross Anatomy and Embryology Subject Examination was administered three days after the final OS3 examination covering head and neck anatomy for the Y2 class. NBME gross anatomy (excluding embryology) scores were evaluated only for the Y2 class. There were no significant differences in examination performance based on viewing screencasts. However, there was an increase in views for multiple OS1 and OS2 screencasts from the time of the relevant course examination to the NBME Gross Anatomy and Embryology Subject Examination. The screencasts with the most new views were the brachial plexus (51 new views), arteries of the UL (38 new views), arteries of the pelvis (25 new views), and arteries of the abdomen (21 new views).

DISCUSSION

In this study, the use and effectiveness of pre-recorded, progressive drawings for teaching the structure of arteries, veins, and nerves across several regions of the body was evaluated. The overall positive responses by students were consistent with that of a previous study on utilizing screencasts for teaching pelvic anatomy (Pickering, 2015).

There were several advantages to this methodology, despite the lengthy process of creating and animating the lines and text in PPT. This technique allowed for control over the drawing, reduction of errors during recording, and reduced time during recording as compared to the author's experience with free drawing. Editing the duration of each line animation to replicate the process of drawing allowed for the narration pace to be maintained as it would during free drawing. Color-coding the lines in PPT also allowed for a smooth transition for color changes, with no delay or distraction in stopping to change pen color. The animation in PPT combined with the post-editing capabilities of Camtasia® allowed the author to back up ("undo") and renarrate a section if necessary, without having to start again from the beginning. The unwanted section could then be deleted when creating the final screencast. When recording with narration, the author knew exactly where structures would appear on the screen and how the drawing would fit on the slide, as well as at which point the drawing would be continued onto the next slide. Although data were not recorded to contrast the methods used for posting the screen-casts, the use of TSR recorder reduced the technical issues that were noted when screencasts were posted directly to BBL.

Perceived Helpfulness of Screencasts for Student Learning

The first hypothesis in this study was that students would find these drawings helpful in their learning of anatomy. Each of the animated drawing screencasts received very high ratings for helpfulness in learning material. Questions about how students utilized the drawings revealed that a majority of survey respondents watched the screencasts more than once, suggesting that providing recorded screencasts that can be viewed multiple times might be of more benefit to students than a single drawing in the classroom. Additionally, across the OS courses, nearly half of respondents reported drawing along with the screencasts; while a larger majority reported that they found watching without drawing along most helpful to their learning. It is important to note, however, that nearly 30% of respondents reported multiple methods of both drawing and not drawing along with screencasts across the OS courses. Students that selected both answers were of particular interest, and their open comments helped to clarify that in many instances students would watch without drawing, and then watch again while drawing along or generate the image on their own without watching. The latter supports a recent study that reported the significance of incorporating drawing into a cyclical learning process of observing, reflecting, drawing, editing, and repeating (termed ORDER) (Backhouse et al., 2017). The spontaneous production of a drawing after viewing the screencast could also provide students the ability to gain awareness of their knowledge, supporting its importance to their metacognitive processes, as was also described in a study by Naug and colleagues (Naug et al., 2011). This was indicated in one of the qualitative responses: “I would watch the videos twice. The first time I would [watch] and then attempt to draw out what I watched from memory. After that, I would watch it again to see what gaps I was missing and then try to fill those in. I would then sometimes go to the end of the video to just get a feel for what I was missing.” This is somewhat in line with other work (Noorafshan et al., 2014) where it was found that 60% of students reported that drawing along with their instructor was helpful in learning concepts. Interestingly, in the current study, there were no significant differences in agreement with statements about the efficacy and technical quality of screencasts, and no significant differences in scoring below and at or above the 50th percentile for any examination between respondents who did and did not report drawing along. Because some students reported that they created their own drawing after viewing the screencasts, students who reported studying from their own drawing, regardless of it was created during or after viewing the screencast, were compared to those who only reported studying from the final image of a screencast. Here, the only significant difference in ratings for quality and efficacy of screencasts was that those who created their own drawing felt more strongly that the screencasts were easy to access and watch. For these comparisons, there remained no significant differences in scoring below and at or above the 50th percentile on an examination between groups. Together, these results suggest that the process of watching a progressive drawing may be helpful to learning, regardless of whether or not a student chooses to create their own drawing.

In terms of timing of viewing the screencasts, across the OS courses, a majority of respondents found that it was most helpful to view the screencasts after the relevant laboratory/lecture, and the next most likely time that respondents reported viewing the screencasts was before the examination. The least number of respondents reported viewing

the screen-casts prior to the relevant laboratory/lecture. Only the first view of each student could be accurately recorded in TSR, however the reported views appeared to be consistent with the trends of first views across all students that were observed in the TSR data. Multiple students selected more than one answer, most of which reported watching the screencasts more than once, suggesting that they may have watched them at multiple points throughout the course, and not necessarily multiple times in a row. A small number of students selected multiple answers and reported viewing the screencasts only one time, suggesting they may have found it helpful to watch different screencasts at different points in each course. Reasons for multiple answers may have also included that students watched a screencast and returned to watch it later to fill or search for knowledge gaps in preparation for examinations, which was indicated in the qualitative comments, and has been reported in the literature (Green et al., 2012). Regardless, when evaluating those who indicated only one preferred time for viewing screencasts, there were significant differences in agreement with statements about if the screencasts helped to bring concepts together, contained the appropriate level of detail, and were visually clear, which together suggest that the optimal time for viewing the screencasts is likely after the relevant laboratory, as opposed to prior to the relevant laboratory or examination.

It has been suggested that showing and/or telling a story is an effective method for creating an educational video (Thomson et al., 2014). This was eloquently outlined by one survey respondent, suggesting that presenting information in a way that tells a story is indeed helpful to students: "I feel like I am being taken on a journey throughout the particular organ system I am currently studying. Having a professor walkthrough the subject matter from start to finish while making relevant associations really helps to solidify the information." Additionally, a majority of students agreed or strongly agreed that utilizing the drawings assisted in feeling more confident about concepts and anatomical relationships, which is consistent with a previous study of progressive drawing on the blackboard (Nayak and Kodimajalu, 2010). This was also supported by the number of views that some of the screencasts received between the time of the relevant course examination and the NBME Gross Anatomy and Embryology Subject Examination, particularly the brachial plexus and arteries of the upper limb screencasts, which received the most additional views. The results of the current study therefore support that making screencasts of drawings available as online learning screencasts allows each student to utilize them based on their level of knowledge and preferences, as well as throughout the first-year curriculum, as opposed to a single drawing in the classroom setting.

Finally, the dynamic nature of screencasts was also of importance to students. Two students commented about watching the screencasts while performing activities such as cooking or exercising, suggesting that the online format provides students the ability to learn in multiple environments. The importance of student control was also mentioned by several students, with five students commenting on the importance of being able to pause the screencast during viewing. This suggests that the online format of the drawings, where the instructor is narrating but not present for questions, may not detract from the usefulness of the exercise of progressive drawing.

Technical Quality of Screencasts

The second hypothesis of this study was that students would not have issues with technical quality of the screencasts. One challenge in producing computer generated drawing screencasts was finding the correct level of detail where students could easily follow and replicate the drawing without the necessity for artistic ability, yet ensuring that the necessary material was included, so that they were of value to student learning. It has been reported that the level of detail, ranging from line drawings to actual images, and from black and white to the incorporation of color, play a role in the effectiveness of educational tools (Dwyer, 1968). These screencasts were created as simple, color-coded, progressive line drawings. A majority of respondents agreed or strongly agreed that screencasts were at the correct level of detail, were visually clear, were presented in a clear and concise manner, looked professional, and were of an appropriate length. There were no comments regarding difficulty with reading text, suggesting that the use of text rather than handwriting may have addressed the issue of illegible handwriting previously reported in screencasts of progressive drawing (Pickering, 2015). There were also no negative qualitative responses related to color-coding of structures, and in fact eight students commented positively on the use of color-coding.

Incorporation of Dissection Videos

Three of the 17 screencasts in Y2 included companion dissection videos, where the drawing was followed by a dissection video with the drawing inset into a corner of the screen, and structures were pointed out simultaneously in the drawing and dissection images. A majority of students agreed or strongly agreed that simultaneously viewing the drawing and dissection made them feel more confident in identifying structures, and that this improved their understanding of anatomical relationships. The three screencasts with the highest mean ratings for helpfulness in learning material were the brachial plexus, arteries of the UL, and arteries of the abdomen, all of which included dissection videos. However, significantly fewer students who started to play these screencasts viewed 90% of their total length than those that did not include dissection videos, suggesting that some may not have viewed the dissection portion. It is possible that although the difference in length of these versus screencasts without dissection videos did not reach significance, screencasts with dissection videos were approximately 4 minutes longer, and may have therefore been longer than the optimal length for student viewing. It has been suggested that fewer viewers watch the entire length of longer videos (Fishman, 2016). The acceptable duration for watching a video on a mobile device and computer screen are approximately five and ten minutes, respectively (Cann, 2007), and engagement tends to drop after two minutes, and again at twelve minutes (Fishman, 2016). Therefore the average length of screencasts without dissection videos was closer to the optimal length for viewers. Additionally, the screencast with the largest total number of views (arteries of the pelvis) did not include a companion dissection video. Of note, only two students suggested including more dissection videos at the end of the drawings across the Y2 surveys. These results suggest that students are likely accessing the screencasts for the purpose of learning from the drawings, and while including dissection videos is appreciated and perceived to be important by a majority of students, it is unknown how this affects learning or to what extent students actually view the dissection portion of the screencast. To date, there are no known reports on the effect of drawing screencasts that

include companion dissection videos that provide simultaneous viewing and interaction of media in learning in the anatomical sciences, and therefore further research is warranted on this topic.

Screencast Viewing and Course Performance

The final hypothesis in this study was that screencast usage would have an effect on course performance. A recent study indicated that when compared to learning from textbooks, students learning topics in anatomy from drawing screencasts demonstrated increased learner gain between pre- and postassessments (Pickering, 2017), suggesting students that utilize anatomical drawing screencasts might perform higher than students that don't utilize screencasts on course examinations. In this study, there were several instances where a higher percentage of students who viewed the screencasts fell at or above the 50th percentile on examinations than those that did not view the screencasts. However there were also instances where there were no differences, making it difficult to draw conclusions. However, in the case of the OS3 course that covered head and neck content, there was clearer evidence to support the value of these screencasts in student learning, where a higher percentage of students who viewed several relevant screencasts fell at or above the 50th percentile on examinations than those that did not view screencasts, though these results appeared to be primarily driven by the Y1 data. It is possible that the Y1 influence on the results may have been related to the significant difference in performance on the practical examination between Y1 and Y2, where the Y1 mean was significantly higher than that of Y2. The significant differences observed in the OS3 course are consistent with previous studies related to drawing (Balemans et al., 2016; Alsaid and Bertrand, 2016), and the instances across the first year where there were no significant differences are consistent with a recent study that found no significant change in course grades after drawing screencasts were implemented (Pickering, 2014). Although a negative effect of drawing due to cognitive load has been reported (Leutner et al., 2009), those results were based on learner-generated drawings from text rather than instructor-guided drawings such as those utilized in the current study, and therefore it is unknown if this could have been a contributing factor to these results. Instances where there were no significant differences in the current study could be explained by the nature of the examination questions, as the literature suggests that learner-generated drawing tends to demonstrate differences in deep versus factual knowledge (Van Meter and Garner, 2005; Van Meter et al., 2006). It is possible that the identification of structures on a practical examination may not reach a deep enough level of knowledge to demonstrate a difference, but that questions requiring students to problem solve might demonstrate a difference. Data were not collected on why some students chose not to watch the screencasts; however a previous study might provide insight to this. Green and colleagues (2012) found that the most frequently reported reason for students choosing not to utilize screencasts was that they did not feel they needed additional assistance, and that this was generally a correct assumption based on their course performance. This reasoning could also potentially account for instances where there were not consistent differences in course performance between students that did and did not utilize screencasts in this study, as students might have selected their study strategy based on perceived studying needs to achieve a passing grade. However, overall and contrary to previous studies that have found higher achieving students tend to view screencasts less frequently than lower

achieving students (Owston et al., 2011; Green et al., 2012), the current study found that both high and low achieving students utilized the screencasts, with no clear preference by one group across the first year of the curriculum. This is also supported by responses to certain statements in this study, where in OS1, respondents falling at or above the 50th percentile more strongly agreed that the screencasts helped them to understand versus memorize material, while in OS2, respondents who fell below the 50th percentile more strongly agreed that the screencasts helped them to bring together and anatomical relationships, suggesting that the screencasts catered to all levels of knowledge.

Study Limitations

One limitation to this study was that survey data were collected on only a small group of students due to a low response rate. A higher number of students utilized the screencasts than the number that responded to the surveys, with as many as 73 students utilizing one of the screencasts in one class. It is unknown why there was a low response rate to these surveys, though it could have been due to the method of invitation (which was one class announcement and follow-up email invitations), or the timing of the surveys in the first year curriculum. In terms of screencast usage, the TSR usage data did not provide information on multiple views by students, and therefore multiple use data is based on student reporting. Also, if multiple students were viewing the screencasts as a group, only one student would have been recorded as viewing the screencast. Timing of views was difficult to interpret based on TSR data, as only the timing of the first view could be confirmed, and not if and when students returned to view screencasts at a later point, unless they returned and viewed a higher total percent length of the screencast. User data from Y1 were recorded at the end of the OS3 course for all screencasts. It is unknown if additional views occurred after the conclusion of each course, which might have influenced results of analyses for course performance based on screencast usage for the Y1 OS1 and OS2 courses. The length of time between when most students utilized the screencasts and when the surveys were administered (1–9 weeks) may have also had an effect on responses. Additionally, because these screencasts were provided as optional supplemental material, there was not a control group for comparison that reviewed similar material at the same level of detail and within the same period of time using another method, and therefore comparisons could only be made between those that did and did not view the screencasts. There were also instances where there were particularly small sample sizes, and therefore these data are difficult to generalize to a larger population. Finally, no data were collected on why some students chose not to utilize the drawing screen-casts. It is possible that students self-selected their studying tools based on their own learning preferences, or, as previously mentioned, their perceived need for the utilization of additional learning materials.

CONCLUSIONS

Overall, data suggest that students felt positive toward these drawing screencasts, and a majority of students felt that they contributed to their learning. Usage of the screencasts based on total views and the number of students that viewed the screencasts supported that students found the screencasts to be useful. However, data based on usage and course performance did not provide clear evidence that usage improved nor impeded the learning

process. While this method of progressive drawing appeared to resolve previously reported issues with visual clarity in reading text, data come from a small group of students and continued studies are needed to continue to improve and evaluate these drawing screencasts, and to evaluate their effect on learning. As new screencasts continue to be developed, the effectiveness of these tools in learning material within the anatomical sciences curriculum will be evaluated.

ACKNOWLEDGMENTS

The author wishes to thank Dr. Anne Gaglioti, Dr. Fengxia Yan, and Dr. Lawrence Wineski for providing guidance and support.

Grant sponsor: National Institutes of Health; contract grant number: P03-1B040107

Grant sponsor: National Institutes of Health; contract grant number: G12-MD00762

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Figure 1.

Example of animated drawing (arteries of the abdomen). (A) Example of template provided to students that they could use to draw along with the screencast; (B) Example of completed drawing. This screencast also included a description of common variations in these arteries, and was approximately 10 minutes long, followed by a corresponding 8.5 minute long dissection video.

Figure 2.

Example of an animated drawing (arteries of the upper limb) that was created across slides (A, B, and C each represent one slide), but developed so students could continue on one piece of paper.

Figure 3.
Mean and standard deviation for responses to a series of statements where students were provided a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Data were combined across years and surveys. For students that responded to multiple surveys, responses were averaged across surveys.

Table 1.

Demographic Data for Each Survey

			Gender N (%)	
Class	Total N	Age in years Mean (±SD)	Female	Male
Organ System (OS) 1 Survey				
2015–2016a	36	24.3 (±2.7)	24 (66.7)	12 (33.3)
2016–2017	28	23.9 (±2.5)	18 (64.3)	10 (35.7)
Combined	64	24.1 (± 2.6)	42 (65.6)	22 (34.4)
Organ System (OS) 2 Survey				
2015–2016a	36	24.3 (±2.7)	24 (66.7)	12 (33.3)
2016–2017	35	24.5 (±2.6)	18 (51.4)	17 (48.6)
Combined	71	24.4 (±2.6)	42 (59.2)	29 (40.8)
Organ System (OS) 3 Survey				
2015–2016	25	25.9 (±4.2)	15 (60.0)	10 (40.0)
2016–2017	38	25.1 (±3.8)	23 (60.5)	15 (39.5)
Combined	63	25.4 (±3.9)	38 (60.3)	25 (39.7)

^aNote that only one survey was provided to students in the 2015–2016 class, which covered both OS1 and OS2 screencasts, therefore data is included under both surveys.

Table 2.

Screencast Usage and Rating Data

Screencast	Total views/N of students who pressed play, (% of class) ^a		Total N of students who viewed greater than 90% of screencast length (% of class) ^b		Mean total % length viewed across all students who played each screencast (±SD) ^c		Combined Y1 and Y2 mean rating (±SD) for helpfulness in learning material/N of students ^d	Y2 mean rating (±SD) for helpfulness in preparing for NBME® Gross Anatomy/N of students ^e
	Y1	Y2	Y1	Y2	Y1	Y2		
Organ Systems (OS) 1 Screencasts								
Arteries of the upper limb	ND	186/58 (60.4)	ND	34 (35.4)	ND	78.4 (±28.6)	4.95 (±0.23)/55	4.4 (±1.4)/15
The brachial plexus	ND	186/55 (57.3)	ND	33 (34.4)	ND	82.0 (±24.3)	4.95 (±0.23)/55	4.90 (±0.28)/13
Sympathetics of the thorax	ND	154/56 (58.3)	ND	45 (46.9)	ND	87.2 (±29.3)	4.80 (±0.51)/24 (Y2 only)	4.70(±0.68)/10
Vasculature of the thorax	ND	82/34 (35.4)	ND	22 (22.9)	ND	78.0 (±35.1)	4.91 (±0.30)/21 (Y2 only)	4.78 (±0.44)/9
Arteries of the abdomen	65/34 (40.5)	168/55 (57.3)	27 (32.1)	38 (39.6)	81.2 (±37.4)	82.4 (±28.4)	4.93 (±0.32)/58	4.90 (±0.30)/11
The portal system	60/31 (36.9)	118/46 (47.9)	25 (29.8)	38 (39.6)	84.6 (±33.0)	90.0 (±24.0)	4.86 (±0.41)/55	4.90 (±0.32)/10
Autonomics of the abdomen	ND	129/52 (54.2)	ND	44 (45.8)	ND	91.0 (±22.7)	4.70 (±0.64)/23 (Y2 only)	4.67 (±0.71)/9
Organ Systems (OS) 2 Screencasts								
Arteries of the posterior abdominal wall	70/43 (44.8)	136/61 (62.9)	38 (39.6)	55 (56.7)	89.9 (±28.6)	91.3 (±25.9)	4.89 (±0.40)/71	4.67 (±0.71)/9
Arteries of the pelvis and perineum	119/57 (67.9)	229/72 (74.2)	51 (53.1)	66 (68.0)	94.1 (±19.8)	97.4 (±10.2)	4.91 (±0.29)/67	4.80 (±0.42)/10
Arteries of the lower limb	81/44 (52.4)	157/60 (61.6)	38 (39.6)	52 (53.6)	88.9 (±29.1)	92.2 (±22.0)	4.91 (±0.29)/66	4.89 (±0.33)/9
Organ Systems (OS) 3 Screencasts								
Arteries of the head and neck	136/59 (72.2)	264/73 (75.3)	51 (60.7)	60 (61.9)	89.7 (±25.7)	86.4 (±31.2)	4.78 (±0.62)/59	4.78 (±0.67)/9

Screencast	Total views/N of students who pressed play, (% of class) ^a			Total N of students who viewed greater than 90% of screencast length (% of class) ^b		Mean total % length viewed across all students who played each screencast (±SD) ^c		Combined Y1 and Y2 mean rating (±SD) for helpfulness in learning material/N of students ^d	Y2 mean rating (±SD) for helpfulness in preparing for NBME® Gross Anatomy/N of students ^e
	Y1	Y2		Y1	Y2	Y1	Y2		
Cranial nerve V1	153/65 (77.4)	193/60 (61.9)		56 (66.7)	48 (49.5)	89.1 (±28.9)	89.9 (±23.4)	4.81 (±0.58)/57	4.44 (±0.88)/9
Cranial nerve V2	106/58 (69.1)	140/52 (53.6)		46 (54.8)	33 (34.0)	84.5 (±31.5)	76.1 (±35.6)	4.81 (±0.58)/57	4.56 (±0.73)/9
Cranial nerve V3	80/54 (64.3)	106/42 (43.3)		37 (44.0)	29 (29.9)	80.1 (±35.3)	75.9 (±40.0)	4.82 (±0.53)/55	4.63 (±0.74)/8
Cranial nerve VII	97/43 (51.2)	130/48 (49.5)		28 (33.3)	31 (32)	68.5 (±43.7)	76.5 (±36.4)	4.80 (±0.53)/54	4.57 (±0.79)/7
Cranial nerve IX	74/42 (50)	102/36 (37.1)		32 (38.1)	27 (27.8)	82.3 (±35.5)	82.2 (±33.3)	4.77 (±0.55)/52	4.50 (±0.76)/8
Cranial nerve X	81/48 (57.1)	134/49 (50.5)		32 (38.1)	39 (40.2)	83.5 (±34.4)	88.8 (±26.5)	4.84 (±0.42)/55	4.67 (±0.71)/9

Usage statistics from TechSmith Relay® website at end of each year and ratings from student surveys for each screencast at end of each course. ND, No Data; Y1, Year 1; Y2, Year 2. ND was either due to data not being accurately collected due to removal and/or reposting of screencast, or the screencast not being available in Y1.

^aColumn contains the total number of times the video was played

^bColumn contains the total number of students that pressed play to view any length of each screencast

^cColumn contains the mean % length (in seconds) viewed for each screencast across all students who pressed play to view any length of each screencast (TechSmith Relay reports of <1% were recorded as 0.5% to indicate that the student pressed play)

^dColumn contains mean responses to the statement "Please rate the following drawing screencasts regarding how helpful they were to you in learning the material (1 = least helpful; 5 = most helpful)"

^eColumn contains mean responses to the question: "On a scale of 1–5 (1 = least helpful; 5 = most helpful), how helpful were the each of the drawing screencasts in preparing for the NBME® Gross Anatomy Miniboard?"

Table 3.

Qualitative Responses

Themes	Students' comments	Respondents N (%)
Importance of audio and visual components of screencasts	<ul style="list-style-type: none"> • "Seeing the structures in lab is not always helpful if you don't know where the structures and connections are supposed to be so I found that being able to see a general 'map' of where everything should be was very helpful in helping me identify structures on the cadavers." • "[The narrator] clearly goes through AS she draws it in. I can understand exactly what she is saying, and seeing the picture as she says it helps solidify the image in my mind." • "The color coordination is most helpful in my opinion." 	29 (26.9)
Improved understanding of anatomical relationships	<ul style="list-style-type: none"> • "What I especially like from the video is that she gives landmarks so we can know where each structure is relative to other structures..." • "It was a great way for me to really understand nerves and vasculature and make important connections that I did not pick up on in class." • "A clear, stepwise method that visually connects all of the relevant structures & highlights important anatomical relationships without being overwhelming (i.e. Having all structures in one image)." 	23 (21.3)
Clarity of information being presented in screencasts	<ul style="list-style-type: none"> • "Provided clarity on exactly what structures we were expected to know, and they were presented in a clear manner without 'mental interruption' of other topics, questions from students, other distractions of live teaching." • "They are clear and concise, and perfectly within the scope of our curriculum." 	21 (19.4)
Pulling together material presented (seeing the "big picture")	<ul style="list-style-type: none"> • "They put everything together rather. Learning individual aspects of anatomy gets confusing without the big picture. The videos provide the big picture as well as the small details." • "They bring a lot of concepts together in a simple manner." • "It's nice to have all the information talked about on hundreds of different slides in one place." 	21 (19.4)
Stepwise/progressive method for presenting and breaking down material	<ul style="list-style-type: none"> • "I get to see everything step by step rather than as one massive compilation of structures." • "I also like that they're done in a step-wise manner from simplest (i.e. the aorta) to the more complicated (i.e. branches off anterior division of the internal iliac) because that makes it easier for me to learn and memorize." • "They break everything down from branching and origins to destination/insertions. This is all broken down in a way that includes pathways and overall function, making the overall video comprehensive." 	19 (17.6)
Simplicity of presentation of material	<ul style="list-style-type: none"> • "The screencasts are extremely easy to follow, simplifies the concepts in a way that allows students to learn most effectively." • "They provide a simple way to learn the structures and layout, which you can then apply in the gross anatomy lab." 	16 (14.8)