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Research report

Measuring Learning Gain: Comparing Anatomy Drawing Screencasts and Paper-Based Resources

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Running title: Learning gain and anatomy resources

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ABSTRACT

The use of technology-enhanced learning (TEL) resources is now a common tool across a variety of healthcare programs. Despite this popular approach to curriculum delivery there remains a paucity in empirical evidence that quantifies the change in learning gain. The aim of the study was to measure the changes in learning gain observed with anatomy drawing screencasts in comparison to a traditional paper-based resource. Learning gain is a widely used term to describe the tangible changes in learning outcomes that have been achieved after a specific intervention. In regard to this study, a cohort of Year 2 medical students voluntarily participated and were randomly assigned to either a screencast or textbook group to compare changes in learning gain across resource type. Using a pre-test/post-test protocol, and a range of statistical analyses, the learning gain was calculated at three test points: immediate post-test, 1-week post-test and 4-week post-test. Results at all test points revealed a significant increase in learning gain and large effect sizes for the screencast group compared to the textbook group. Possible reasons behind the difference in learning gain are explored by comparing the instructional design of both resources. Strengths and weaknesses of the study design are also considered. This work adds to the growing area of research that supports the effective design of TEL resources which are complimentary to the cognitive theory of multimedia learning in order to achieve both an effective and efficient learning resource for anatomical education.

Key words: gross anatomy education, learning gain, technology-enhanced learning, cognitive load, multimedia, computer-based learning

INTRODUCTION

The use of technology in anatomical education is well established with numerous courses utilizing computed-based resources to deliver their curricula (Trelease, 2016). However, despite this rise there remains a paucity in empirical evidence detailing the quantifiable impact on learning gain of such interventions for individual learners. Although numerous evaluation frameworks within the wider medical education literature exist, these are primarily focused at the program and course level rather than a single resource, such as an eBook, application or video series, within a multi-faceted blended learning curriculum (Kirkpatrick and Kirkpatrick, 2006; Frye and Hemmer, 2012; Cook and Ellaway, 2015). Recently, a new evaluation framework has been proposed which focuses on the change in learning gain achieved which can be wholly attributable to an individual learning resource (Pickering and Joynes, 2016). Within this framework it is advised that research should be conducted which seeks to explore the actual change in learning gain, specifically between two points in time. Learning gain across all educational disciplines is a topical theme, however its meaning and method of reporting often varies substantially (McGrath et al., 2015). For example, it may be interpreted as the change in performance by assessing the grades achieved, with this information then used as a predictor for future performance, or alternatively, by asking students to self-report on the perceived benefit after a specific intervention. Within the context of this study learning gain specifically refers to the quantifiable change, and retention, of newly acquired knowledge between two points in time. Research in this area is essential due to the rapid rise in technology-enhanced learning (TEL) resources across anatomy education, and especially as students place considerable authority in learning tools which have been suggested or created by the course tutor. It is essential when suggesting a learning tool that a clear understanding of its efficacy in imparting knowledge compared to other resources is known, and importantly, that it is at least equitable. Furthermore, although an increase in the number of publications on TEL resources integration has not been accompanied by a comparable increase in reports on their evaluation, the development of design strategies for multimedia or TEL resources has been the subject of many scholarly articles. In this context multimedia refers to digitally delivered content such as video, audio, images and text which can be interacted with by the user. The overarching aim in designing effective learning resources is to support the natural cognitive learning process (Sweller and Chandler, 1991, 1994; DiGiacinto, 2007). The development of the cognitive theory of multimedia learning (CTML) provides a framework for designing multimedia resources which is evidence-based and supported by practical examples (Mayer and Moreno, 2003; Mayer, 2009, 2010). The theory provides a number of instructional design recommendations (for review see Mayer and Moreno, 2003 and Mayer, 2009), which are derived from both the cognitive load theory (CLT) (Sweller, 1988; Baddeley, 1997; Plas et al., 2010; Young et al., 2014) and dual code principle (Clark and Paivio, 1991). The CLT is strongly associated with the understanding of the working memory, in that it has a finite capacity which needs to be appropriately managed in order to accommodate the specific learning task. Baddeley (1992) described the working memory as: "…a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning," with Sweller (1988) outlining three types of cognitive load that occupy this system dependent on both the actual task and its instructional design. These are known as: intrinsic load, extraneous load, and germane load. Intrinsic load is the amount of space occupied within the working memory that is directly associated with the complexity of the content that has to be learned; moreover, it occupies a fixed amount that is not modifiable by the instructor (Mayer and Moreno, 2003). The extraneous and germane loads are directly related to the instructional design of the multimedia presentation that is provided to deliver the task's learning objectives. Both of these loads are, therefore, modifiable. Extraneous load relates to the space occupied within the working memory that is not directly related to the task, but contained within the presentation. For example, this is the actual design of the presentation that is used to deliver the task. Germane load is the amount of space occupied to actually learn or understand the task, by selecting, organizing and then integrating the words and images from the resource (Mayer and Moreno, 2003). Due to the limited capacity of the working memory the design of learning tools should, therefore, attempt to balance the germane and extraneous loads, so there is a clear bias towards the former. This approach aims to permit greater (germane) capacity within the working memory for understanding the task by reducing the extraneous load. If resources are designed effectively, the task at hand can then be efficiently organized within the working memory and retained as schema that pass in to the long-term memory (Sweller, 1988; Baddeley, 1997; van Merriënboer and Sweller, 2005).

The dual code principle is integrated within the CLT and describes how learners have two sensory channels which specifically receive either auditory or visual information (Clark and Paivio, 1991). When a learner consciously uses a learning resource, higher-order audible and visual information is passed into the brain's working memory from the multilevel neuronal processing networks of the auditory and visual systems of the ear and eye (Clark and Paivio, 1991; van Merriënboer and Ayres, 2005; van Merriënboer and Sweller, 2005). Having entered the working memory through these channels the new information is then interpreted and organized. Therefore, developing TEL resources conscious of the principles that form the CTML attempts to ensure that the information passing into the working memory is directly related to the task and is more efficiently understood and retained. An understanding of this seminal work enables educators to create resources which are both effective and efficient in disseminating the required information to the student (Smith, 2016). An effective resource will support the learning of more information in a specific period of time, while an efficient resource allows the same information to be learned in a shorter period of time. At a time when healthcare courses, such as medicine, are under pressure to deliver more diverse curricula in a shorter time (Heylings, 2002; Trelease, 2002; Turney, 2007; Sugand et al., 2010; Boyce, 2012; Wright, 2012; Attardi et al., 2015; Mathiowetz et al., 2016; Vaccani et al., 2016), understanding, and also implementing, approaches which improve learning efficiency are of clear and obvious importance to anatomy teachers.

Previous studies have highlighted the effective use of CTML principles in improving knowledge acquisition and its retention across a number of disciplines (Mayer, 2009; Starbek et al., 2010), with some specific examples from medical education highlighting the impact after lecture slide re-design (Issa et al., 2011, 2013). Moreover, the author has previously described the utility of anatomy drawing screencasts that are designed based on the most important principles of the CTML, and highlighted how they are closely aligned to the spatial and temporal contiguity, coherence, signaling and redundancy principles (Pickering, 2014, 2015a). The development of anatomy drawing screencasts, which are videos of screen-captured line drawings that illustrate the specific structure and relations of an area, was motivated from a desire to transfer the popular drawing element of didactic lectures into a mobile format to promote flexible learning (Pickering, 2015a). The use of drawing within anatomy education is a common and popular approach to teaching, with several reports highlighting how its integration can have positive outcomes (Clavert et al., 2012; Mavridis, 2013). These include potential knowledge gains after its incorporation into surface anatomy and tutorial sessions (Backhouse et al., 2016), and self-perceived increases in understanding when used as an approach to active learning during didactic lectures (Noorafshan et al., 2014). Within the lecture theatre drawings have been used as introductory and monotony breakers with the use of a traditional blackboard (Nayak and Kodimajalu, 2010), and to support student interaction with PowerPoint slides designed to serve as templates for in-class annotation (Carmichael and Pawlina, 2000). Moreover, within the wider scientific education disciplines drawing is a particularly powerful approach to learning (Dempsey and Betz, 2001; Fiorella and Mayer, 2015), with Ainsworth (2011) commenting on how drawing can deepen understanding compared to written summaries or oral self-explanations, and that visual representations have distinct attributes that match the visual-spatial demands of science learning. These ideas have been formalized into the generative drawing principle which proposes that students can achieve better learning outcomes by creating drawings after reading text (van Meter, 2001; van Meter and Garner, 2005; van Meter et al., 2006; Schwamborn et al., 2010; Leutner and Schmeck, 2014; Fiorella and Mayer, 2015). Importantly though, although this principle is based on empirical evidence, for maximal effect the challenge remains for the instructor to create an environment which limits the development of extraneous load. Creating a supportive environment which includes prompts and instructions to develop the drawing are essential, especially as the accuracy of the drawing is correlated with positive assessment outcomes (van Meter 2001; van Meter 2005).

This study aims to continue investigating the integration of anatomy drawing screencasts into a medical anatomy curriculum by comparing the learning gain achieved to a traditional paper-based resource. Numerous studies have assessed the impact of digitally delivering resources compared to a paper-based equivalent for assessment (Lee and Weerakoon, 2001; Cantillon et al., 2004; Shotwell and Apigian, 2015), case-based teaching (Maleck et al., 2001; Poulton et al., 2014), motivation (Glogger-Frey, 2014) and patient outcomes (Chang et al., 2002) with contrasting results. Although it is appreciated that web-based learning is effective, issues such as information technology (IT) experience, independent study skills and password accessibility need to be addressed prior to implementation (Wilkinson et al., 2004; Cook et al., 2005; cook, 2009). Within anatomy education an obvious comparison can be made between the utility of eBooks and traditional paper-based resources, such as textbooks which are both prevalent and popular amongst students. eBooks have recently emerged as a popular approach to delivering learning objectives within anatomy due to the availability of user-friendly software (Stirling and Birt, 2014; Stewart and Choudhury, 2015; Pickering, 2015b). The transfer from paper to electronic format, however, is not necessarily welcomed by all students. Recent reports have highlighted that students actually prefer paper-based textbooks, which permit a more linear approach compared to eBooks (Berg et al., 2010; McNeish et al., 2012), Moreover, the use of eBooks was found to be not intuitive, lacking in their ability to create a sense of belonging and generally deemed unsatisfactory. Although it is important to understand the effectiveness and efficiency of TEL resources, student enjoyment is also essential and, therefore, all of these characteristics need to be assessed prior to their full integration into curricula (Pickering and Joynes, 2016; Smith, 2016).

In order to compare the impact on learning gain across resources between two-points in time, several approaches have been documented within the literature that are dependent on study context and the methodology used to achieve statistical significance and effect size. Similar studies within the medical education literature have assessed the increase in knowledge and its retention using mean data to compare results across the respective control and test groups (Issa et al., 2011, 2013). However, an alternative approach has been developed within the physics education community (Hake, 1998; Fagen et al., 2002; Hake, 2002; Meltzer, 2002), and now utilized elsewhere (Knight and Wood, 2005; Epstein, 2006, Prather et al., 2009; Epstein, 2009). This approach calculates the absolute and normalized gains from this mean data, with the latter intended to remove the influence of the pre-test scores. Only one instance of normalized gains as a determinant of learning gain was identified in the medical education literature (Colt et al., 2011). Due to the current lack of consensus on how best to measure learning gain with pre-test/post-test study designs (Bonate, 2000), all three approaches are employed.

Aims and Research Questions

The aims of the study were to assess the impact on learning gain of contrasting learning resources which are utilized within a medical anatomy course, and also to provide a comprehensive analysis of learning gain using a range of approaches. In order to achieve this the following research questions were developed:

(1) Do anatomy drawing screencasts increase learning gain compared to traditional paper-based resources?

(2) Is any increase in learning gain between the resources retained for an extended period of time?

MATERIALS AND METHODS

Participants and Study Design

The study recruited 49 (11 male; 38 female) second year medical student volunteers who were enrolled at the University of Leeds medical school during the 2014/15 academic session. All students were studying medicine as their first degree. Ethical approval for the study was granted from the Research Ethics Committee of the University of Leeds School of Medicine (protocol MREC 15-095). The group was selected due to their existing understanding of anatomical terminology to ensure the suitability of the test instrument, however, importantly, all participants confirmed they had not previously studied the specific area of anatomy which the TEL resource addressed. This was possible as the Leeds MBChB (Bachelor of Medicine and Surgery program) anatomy curriculum is delivered during the first two years of the course. Year one is focused on the main systems of the body in relation to the trunk (e.g., respiratory cardiovascular, digestive, urinary and reproductive). Year 2 considers the musculoskeletal system, the nervous system, and the head and neck region. Learning objectives are delivered via a combination of didactic lectures, dissection- and prosection-based practical classes, living anatomy and radiology small group classes, and clinical case tutorials. Alongside these teacher-led sessions there are also a range of additional student-led resources, such as formative self-assessment questions, eLectures, dissection instruction videos, paper-based workbooks, and anatomy drawing screencasts, which are available via the respective teaching unit's virtual learning environment. Participants were randomly assigned to either the textbook or screencast group, and a pre-test/post-test protocol was used with resource type (textbook vs. screencast) as the between group factor and time of test (pre-test, post-test, 1-week post-test and 4-week post-test) as the within group factor. Only students who completed all 4 tests were included in the analysis, resulting in a final total of 43. Of these students all had successfully completed the first year of their medical education and based on the anatomy assessments in that year, no significant difference in attainment was observed between groups, $t(38) = 0.053$, $P = 0.958$ (N.B., data from 3 students was missing as they entered the course at the beginning of year 2 as part of a widening access scheme).

Asynchronous Teaching Session and Learning Resource Development

The asynchronous learning session covered the muscular anatomy of the gluteal region. This region was chosen as the students had not yet covered the lower limb, but had already completed sufficient anatomy in Year 1 to understand important concepts, such as muscle attachments, and anatomical terminology. The session lasted for 45 minutes and covered the following learning objectives: (1) describe the location of the muscles within the gluteal region; (2) appreciate the origin and insertion of: gluteus maximus, gluteus medius, gluteus minimus, piriformis, superior and inferior gemelli, obturator internus and quadratus femoris; (3) describe the movements of the hip joint associated with these muscles. Each student was provided with a learning resource: either a 10-minute anatomy drawing screencast (screencast group; n = 24) or relevant pages from a course suggested textbook (textbook group; n = 19). The textbook group were provided with colored photocopies of the relevant pages of a popular textbook from the course's reading list. The creation of anatomy drawing screencasts and how they conform to the CTML has been detailed elsewhere (Pickering, 2015a). Briefly, the anatomy drawing screencast used for this study starts with the posterior aspect of the hip joint detailed, and then the numerous muscles of the region (gluteus maximus, gluteus medius, gluteus minimus, piriformis, superior and inferior gemelli, obturator internus and quadratus femoris) drawn onto the screen. Anatomical position, relations to other structures, and movements of each muscle were described with narration. The drawing was created using illustration software (Illustrator, Adobe CS6, version 16.0.4, Adobe Systems Software Ireland Ltd., Dublin, Ireland), on a Wacom Cintiq 24HD professional interactive pen tablet (Wacom Technology Corp., Vancouver, WA) that was connected to an Apple Mac-Book Pro, 2.3 GHz Intel Core i7 (Apple Inc., Cupertino, CA) with the audio-visual digital output recorded via screen-capture software (Camtasia 2, version 2.6.0, Tech-Smith Corp., Okemos, MI). The narration audio was recorded using a DC1 dynamic cardioid broadcast microphone (RoXdon, London, UK) connected to a Scarlett 2i2 recording interface preamp (Focusrite Audio Engineering Ltd., High Wycombe, Buckinghamshire, UK). The screencast was then edited with a title sequence added, rendered to a video (.mp4) file and made available via a personal or institutional electronic device. The content of the screencast was matched by the author to include the same content of that detailed in the section of the textbook that was provided. Although it would be impossible to replicate the exact content of the textbook into the screencast, detailed notes were taken from the textbook and converted into a narration which accompanied the drawing of the relevant structure Students were allowed to use the resources for the duration of the session and could interact with them as they wished. All resources were returned after the teaching session.

To assess knowledge retention a 10-item (multiple choice questions; single best answer from 4 options) assessment instrument was developed consistent with all of the session's learning objectives and administered to the students prior to receiving the learning resource (pre-test). They were allowed 10 minutes to complete the assessment. Immediately after the 45 minute teaching session the same test was re-administered and the students given another 10 minutes to complete the assessment (post-test). To assess the retention of knowledge over time the same test was re-administered during designated periods of self-directed study at one-week and four-week intervals. Each student had 1 hour to complete the same test with each student confirming they had not conducted any additional study on the specific region. Students were not provided with answers until the final post-test (week-4 post-test) answers had been received. No additional study time was dedicated to the gluteal region between test points and the students did not know the same test was going to be re-administered. Completed tests were collected and double marked with the scores collated so learning gain could be calculated and appropriate statistical analysis performed.

Calculation of Learning Gain

The use of pre-test/post-test design studies is a particularly common methodology to assess learning gain, with two measurements recorded from a single subject either side of an intervention. In this case the intervention is a specific learning tool (screencast or textbook), with the overall test scores compared to assess the impact on changes to both the acquired (post-test), and retained (post-tests 1-week and 4-week) knowledge. To calculate the absolute gain from the pre-test and post-test scores a simple bivariate to univariate data transformation is performed according to Equation (Eq.) 1, revealing the difference in retention at two points in time. However, due to the maximum score of a test instrument being 100% a strong negative correlation is observed between students' absolute gain (Eq. 1) and their pre-test scores (i.e., a higher pre-test score results in reduced absolute gains). In order to reduce the influence of pre-test scores the normalized learning gain is calculated by dividing the absolute gain by the maximum possible gain (Eq. 2). Normalization, therefore, allows for the actual realized change in learning gain to be recorded independent of pre-test scores and permits comparisons between groups to be made. With a diverse range of students yielding a wide range of pre-test scores the normalized gain values should be equal, and with all other conditions being controlled, any observed changes in gain can be attributed to the intervention. This is supported from other studies which reveal that the mean normalized gain values are uncorrelated with the mean pre-test scores (Hake, 1998, 2002).

Eq. 1 Learning gain (absolute) = % post-test – % pre-test

Eq. 2 Normalized learning gain = g_i = (% post-test – %pre-test) / (100% – %pre-test)

In order to calculate the group mean normalized gain either Eq. 3 or Eq. 4 can be employed. The advantages of calculating the normalized gain of averages (Eq. 3) have been discussed elsewhere (Hake, 1998). However, for this study the average of the individual normalized learning gain (Eq. 4) has been used as it generates standard deviations which allow for the respective effect sizes to be calculated.

Eq. 3 Normalized gain of average = ⟨g⟩ = (%⟨post-test⟩ – %⟨pre-test⟩) / (100% – % ⟨pre-test⟩)

Eq. 4 Average of normalized learning gain = g_{ave} = [$\sum_{\text{from 1 to n}}$ (g_i)] / n

Statistical Analysis

All tests were scored out of 10 and then converted to a percentage. All pre-test and post-test results were analyzed with the descriptive statistics including the mean and ± standard deviation (±SD) calculated. Comparisons in scores between groups were assessed by an independent t-test for all four tests points. To take into account the pre-test score as a confounding factor in determining the post-tests score an analysis of covariance (ANCOVA) was used with the pre-tests scores used as the covariant.

Comparison in scores within groups over time were assessed by a repeated-measures ANOVA, with post-hoc comparisons using the Bonferroni correction for pairwise comparisons between test points. A Cronbach's alpha of 0.67 and 0.73 was calculated for the instrument after the pre-test and post-test, respectively. The effect size for pairwise comparisons throughout was calculated using Cohen's d (Becker, 2000) and for the repeated-measures ANOVA the Partial Eta Squared (η^2) was used. An alpha of < 0.05 was used for all statistical tests. Preliminary data sorting was performed using Microsoft Excel 2015, version 15.14 (Microsoft Corp., Redmond, WA) with statistical analysis performed in Statistical Package for Social Sciences, version 22 (IBM Corp., Armonk, NY).

RESULTS

Learning Gain Determination Using Overall Scores

The overall scores obtained from the pre-test, post-test, 1-week post-test and 4-week post-test for both groups are detailed in figure 1, with the statistical significance and effect size provided in table 1. The screencast and textbook groups did not differ significantly after the pre-test, $t (41) = 0.953$, $P = 0.347$, $d = 0.28$. However, in all the subsequent post-tests the screencast group scored significantly higher: post-test, $t (41) = 2.71$, $P = 0.011$, $d = 0.85$; 1-week post-test, $t (41) = 4.783$, $P < 0.001$, $d = 1.50$; 4-week post-test, $t (41) = 3.259$, $P = 0.002$, $d = 1.04$. An ANCOVA was deployed using the pre-test scores as a covariant and produced comparable results with the screencast group once again yielding significantly higher test scores after the: post-test, $F (1, 40) = 9.054$, $P = 0.005$; 1-week post-test, $F (1, 40) = 24.762$, $P < 0.001$; 4-week post-test, $F (1, 40) = 10.302$, $P = 0.003$.

Retention of knowledge at each of the test points was observed to be greater with the screencasts (Fig. 1 and Table 1); however, within each group there were significantly higher test scores recorded for each of the post-tests compared to the pre-test, although the level of increase reduced with time. Comparisons over time indicated there was a significant time effect on test scores for the screencast group, and a large effect size: $F(3, 69) = 47.39$, $P < 0.001$, $\eta^2 = 0.673$. Follow up pairwise comparisons of the screencast group indicated a significant difference between all test points (table 2), except between 1-week post-test and 4-week post-test ($P > 0.05$; $d = -0.46$). Similarly, statistical analysis of the textbook group indicated a significant negative time effect on test scores, with relatively smaller effect sizes. As Mauchly's test indicated that the assumption of sphericity had been violated (χ^2 [5] = 19.04, $P = 0.002$), the Greenhouse-Geisser correction was used yielding, $F(1.82, 32.75) = 27.49$, $P < 0.001$, $\eta^2 = 0.604$. Similarly, pairwise comparisons of the textbook group indicated a significant difference between all test points (table 2), except between 1-week post-test and 4-week post-test ($P > 0.05$; $d = -0.29$), with the mean data indicating a decline that leveled off (Fig. 1).

Learning Gain Determination Using Absolute and Normalized Gain

The results when an alternative measure of learning gain was deployed is provided in Table 3 with the absolute gain (Eq. 1) and normalized gain (Eq. 4) calculated using the same overall scores. Despite this alternative data transformation a similar pattern emerged with the screencast group achieving a significantly greater level of learning gain when the absolute gain was calculated: post-test, $t(41) = 3.043$, $P = 0.004$, $d = 0.92$; 1-week post-test, $t(41) = 4.594$, $P < 0.001$, $d = 1.44$; 4-week post-test, $t(41) = 3.077$, $P = 0.002$, $d = 0.98$; and when the normalized gain was calculated: post-test, t

(41) = 3.236, P = 0.002, d = 0.98; 1-week post-test, t (41) = 5.094, P < 0.001, d = 1.57; 4-week post-test, t(41) = 3.047, P = 0.004, d = 0.89.

DISCUSSION

This study adds to the growing body of empirical evidence that suggests multimedia learning resources that are designed based on the principles of the CTML provide greater retention of knowledge compared to more traditional paper-based learning resources (Mayer, 2009, 2010; Issa et al., 2011, 2013). The further reinforcement that instructional design recommendations can have an enhanced impact on learning gain is of paramount importance as TEL resources become ubiquitous across both anatomical, and medical education. Specifically, the current study has shown that both the screencast and textbook groups showed retention of significant knowledge gains for the duration of the project, although the screencast group exhibited a much greater effect. This was consistent irrespective of which statistical approach was used to determine learning gain with remarkably similar effect sizes being observed. Furthermore, it appears that towards the end of the study period the actual learning gain achieved by the textbook group declined and then leveled off, although it was still higher than the pre-test, indicating a considerable impact on learning. However, the screencasts appeared to have a more enhanced impact on retention with a similar leveling-off effect not being observed within the same time period. Although the difference between the 1-week post-test and the 4-week post-test did not reach significance, the change in effect size was greater, indicating that the screencast group maintained an increase in learning gain. These results indicate that screencasts designed with the recommendations put forward by the CTML appear to enhance learning gain to a greater extent than a traditional textbook resource, and support the proposal that learning resources need to be effective and efficient (Smith, 2016). This is particularly noteworthy as students could potentially cover a broader area of their curriculum in the time available knowing that specific learning resources can support the retention of knowledge for longer periods of time. This means they would have more time to focus on other areas of the curriculum which they find difficult.

Recent work by the author has provided a detailed account of how anatomy drawing screencasts match the principles set out within the CTML (Pickering, 2015a). This is can be summarized mostly succinctly by understanding the modality principle that aims to manage the essential processing that is required for knowledge acquisition (Mayer, 2009). This principle states that multimedia presentations should use pictures and spoken words rather than pictures and printed words to present the information (Mayer and Anderson, 1992; Mayer, 2009). This instructional design approach is closely aligned to the anatomy drawing screencast that presents all words in audio form rather than text; the only exception being, in this case, the naming of the gluteal muscles adjacent to the drawn structure. Moreover, the complex anatomical image is not presented all at once, but gradually developed over time as the drawing progresses. This approach supports the working memory as the relevant structure is selected by the instructor and presented at the same time as the corresponding words are narrated. With only the relevant images presented, it could be suggested that the working memory can more efficiently organize and integrate this information into schema which are subsequently passed into the long-term memory. Furthermore, due to the way students interact with the anatomy drawing screencasts as a learning resources, links to the generative drawing principle can be made. Previous research has suggested how a carefully considered multimedia resource which has suitable supporting characteristics can promote increases in knowledge outcomes (van Meter 2001; van Meter 2005;

Leutner and Schmeck, 2014). Due to the design of the screencasts which provide a clear framework for students to follow, mirror, and anticipate, these resources provide additional empirical evidence to support this principle. Moreover, with the students behaviorally, with use of their hands, and cognitively, by anticipating the next structure to be drawn, engaging, the learner is able to create their own self-explanation which is an important process for embedding knowledge deeply (Mayer et al., 2003; Wylie and Chi, 2014).

These finding are particularly important due to the wide spread use of drawing within anatomical education, albeit with limited empirical evidence to support its effectiveness (Nayak and Kodimajalu, 2010; Clavert et al., 2012; Mavridis, 2013; Noorafshan et al., 2014; Pickering, 2015a; Backhouse et al., 2016). Furthermore, this awareness that drawing can have a tangible impact on learning gain is of particular importance for resources that are primarily intended for use in a self-directed manner when the learner is effectively learning in isolation. Although similar gains have been observed in classroom-based teaching where lecture slides are designed with the same instructional design principles taken into consideration (Issa et al., 2011, 2013), during a face-to-face teaching session it is possible for the teacher to adjust their delivery in real time as the session progresses. It could be postulated, therefore, that it is more important multimedia presentations intended for consolidation and revision of material away from the teacher-led session are designed to ensure learning is efficient and effective.

With various studies exploring differences in paper- and computer-based resources (Lee and Weerakoon, 2001; Maleck et al., 2001; Chang et al., 2002; Cantillon et al., 2004; Glogger-Frey, 2014; Poulton et al., 2014; Shotwell and Apigian, 2015), and student perceptions not necessarily being overwhelmingly positive (Berg et al., 2010;

McNeish et al., 2012), it is important to understand how the design of multimedia resources can support the learner (Wilson, 2015). By comparing the anatomy drawing screencast to the textbook in relation to the principles of the CTML, it could be postulated that the differences in learning gain are due to this instructional design approach with obvious differences being drawn. The principles of the CTML contain five principles that specifically aim to limit extraneous information within the presentation and include: spatial contiguity (i.e., position text adjacent to corresponding image), temporal contiguity (i.e., position narration and animation at the same time), coherence (i.e., remove extraneous words, picture or sounds), signaling (i.e., only present essential information), and redundancy (i.e., do not use text with a narrated presentation) (Mayer, 2009, 2010). In comparison to the textbook the screencast closely aligned with the spatial contiguity principle as only essential material is presented and this information is progressively added as the presentation continues. This is in contrast to the textbook which presents the full annotated picture and accompanying text at the same time, with this being evident every time the page is turned. Similarly, the temporal contiguity principle is also applied with the corresponding narration occurring at the same time as the relevant structure is drawn allowing the two to be linked together seamlessly. For a textbook reader the text needs to be understood and then applied to the diagram, which in some circumstances can be particularly difficult. The coherence principle advocates the removal of extraneous information; with only the essential structures drawn, irrelevant text removed and a guided narration, the screencasts closely match this recommendation. The screencasts conform to the signaling principle with no additional prepositions being used and only the anatomical structure or movement term being added. This is obviously in stark contrast to the textbook which has extensive, and often highly detailed, sections of text to explain the relevant anatomy. The redundancy principle suggests that no text is added to a narrated presentation. Although the author appreciates the logic behind this recommendation, having an anatomical structure or movement term added does not appear to be overly distracting and allows the resources to serve as a useful revision aid.

Although the data presented has highlighted an enhanced impact on learning gain with the use of a TEL resources, the author is not advocating the withdrawal of textbooks from anatomy curricula. Many students of anatomy have, and will continue to, successfully utilize these resources as part of their own learning. However, taking into consideration the results presented in this study and the principles of the CTML, multimedia presentations do have a positive role in anatomical education which are evidenced based.

Limitations

This study has added to the growing body of empirical evidence on how multimedia resources can enhance and prolong knowledge outcomes. However, despite these positive findings it is important to note there are some key limitations of the study which should be considered when generalizing the findings for wider interpretation. The study was based on a single teaching session, at a single institution on a narrow area of anatomy. Although the volunteers confirmed they had no prior knowledge of the specific topic, all had a similar academic record, and with the group randomization to limit any confounding variables, this student profile still needs to be noted. It is also acknowledged that the resources used in this study are not intrinsically comparable. A more appropriate design would have been to compare two screencasts with one being designed in relation to the principles of the CTML and the other without. However, this study took a pragmatic approach and wanted to assess the impact of two resources that are both available within the institution's anatomy curriculum. Moreover, students in actual courses have to continuously make resource choice decisions to support their learning. Having a greater understanding of the difference in learning gain between these two contrasting types was essential, especially as previous work has noted how heavily the screencasts are used (Pickering, 2014, 2015a).

A well observed drawback of pre-test/post-test design is that once an intervention has been completed, individuals are able to have their knowledge influenced by uncontrollable factors which can alter the post-test scores and lead to misleading conclusions being formed (Bonate, 2000). In this study the pre-test/post-test protocol was voluntary and not synchronized with the current M.B.Ch.B. anatomy curriculum. It could be considered, therefore, to represent an unbiased view of the learning resources as the drive to remain engaged was reduced, thereby limiting opportunities to have their acquired knowledge altered. However, conversely, with the resource not providing information relevant to the current stage of their curriculum the volunteers could disengage to such a level that the results are not a true representation.

Future directions

Future research will endeavor to remedy some of the limitations documented, and concentrate on how TEL resources can be used effectively within learning situations to promote learning gain. This will include three potential streams. Firstly, a number of project design modifications will be attempted. This will include creating and using screencasts that address a broader range of anatomical areas based on the perceived degree of difficulty. For example, the anatomy of the perineal pouches, infratemporal fossa or long sensory and motor pathways could be used, to gain a greater understanding of how this type of resource impacts on learning gain when difficulty of subject area is taken into consideration. Furthermore, work on types of question can also be assessed with factors such as difficulty, relevance and application being included. Additional studies will also attempt to increase the sample size and delay post-tests beyond 4-weeks in attempt to understand further the suggestion that screencasts support increased retention of knowledge. This is particularly pertinent for anatomy education which continues to explore approaches that can support the retention of knowledge beyond the period of study. Secondly, work will explore how the teacher can have a more focused role in guiding students through online resource that serves to support student learning and whether structured interventions, such as short periods of use followed by periods of note taking or drawing compared to non-supportive sessions, have an impact. As students use these resource in effective isolation understanding how they are best used is an important endeavor. Finally, how the level of individual student's spatial awareness impacts on their learning gain with more interactive resources, including the anatomy drawing screencasts and more complex 3D anatomy applications, which are becoming an increasingly popular teaching resource both formally within curricula and as a student-led tool.

CONCLUSIONS

This study has highlighted how multimedia resources that are designed with the recommendations of the CTML taken into consideration can enhance learning gain beyond traditional paper-based resources. In an era where increasing portions of anatomy curricula are delivered online within multifaceted blended learning courses, it is essential that members of faculty are aware of the benefits these resources can have on learning gain in comparison to existing resources. This information should not only be disseminated to teachers of anatomy to support the greater integration of TEL resources into curricula with confidence, but also with students who can then make informed decisions as to which resources to utilize with increased confidence.

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TABLES

Table 1

Overall scores	**Pre-test**	**Post-test**	**Post-test (1-week)**	**Post-test (4-week)**
	Mean (± SD)	Mean (± SD)	Mean (± SD)	Mean (± SD)
Screencasts* (n = 24)	36.67 (±14.93)	84.17 (±11.00)	72.08 (±14.74)	64.58 (±17.44)
Textbooks* (n = 19)	40.00 (±7.45)	71.58 (±17.72)	53.16 (±10.03)	50.53 (±7.80)
Between groups significance (independent t-test P-value)	0.347	0.011	< 0.001	0.002
Between groups significance controlling for pre-test (ANCOVA P-value)	-	0.005	< 0.001	0.003
Between groups effect size (Cohen's d)	0.28	0.85	1.50	1.04

* Scores presented as percentages; SD, standard deviation; ANCOVA, analysis of covariance

Table 2

Resources	Post-test	Post-test (1-week)	Post-test (4-week)
Screencasts (n = 24)			
Pre-test	$P < 0.001$ $d = 3.62$	$P < 0.001$ $d = 2.38$	$P < 0.001$ $d = 1.71$
Post-test	-	$P = 0.007$ $d = -0.92$	$P = 0.001$ $d = -1.34$
Post-test (1-week)	-	-	$P > 0.05$ $d = -0.46$
Textbooks (n = 19)			
Pre-test	$P < 0.001$ $d = 2.32$	$P = 0.001$ $d = 1.48$	$P = 0.001$ $d = 1.30$
Post-test	-	$P = 0.003$ $d = -1.27$	$P = 0.001$ $d = -1.57$
Post-test (1-week)	-	-	$P > 0.05$ $d = -0.29$

Significance (P) is calculated via repeated measures analysis of variance (ANOVA); d, Cohen's effect size.

Table 3

Learning Gain	**Pre-test**	**Post-test**	**Post-test (1-week)**	**Post-test (4-week)**
	Mean (± SD)	Mean (± SD)	Mean (± SD)	Mean (± SD)
Absolute gain				
Screencasts (n=24)	-	47.50 (± 15.67)	35.42 (± 17.93)	27.92 (±23.03)
Textbooks (n=19)	-	31.58 (± 18.64)	13.16 (± 12.50)	10.52 (± 9.70)
Between groups significance (independent t-test P-value)	-	0.004	< 0.001	0.002
Between groups effect size (Cohen's d)	-	0.92	1.44	0.98
Normalized gain (g_{ave})				
Screencasts (n=24)	-	0.75 (± 0.16)	0.55 (± 0.24)	0.41 (± 0.35)
Textbooks (n=19)	-	0.52 (± 0.29)	0.21 (± 0.19)	0.17 (± 0.15)
Between groups significance (independent t-test P-value)	-	0.002	< 0.001	0.002
Between groups effect size (Cohen's d)	-	0.98	1.57	0.89

SD, standard deviation; g_{ave}, normalized gain.

TABLE TITLES

Table 1

Pre-test and post-test results for the screencast and textbook groups with between group significance and effect size using mean percentage data.

Table 2

Pre-test and post-test within-group significance and effect size for screencast and textbook groups.

Table 3

Post-test results for the screencast and textbook groups with between group significance and effect size using absolute and normalized gain data as a percentage.

FIGURE LEGEND

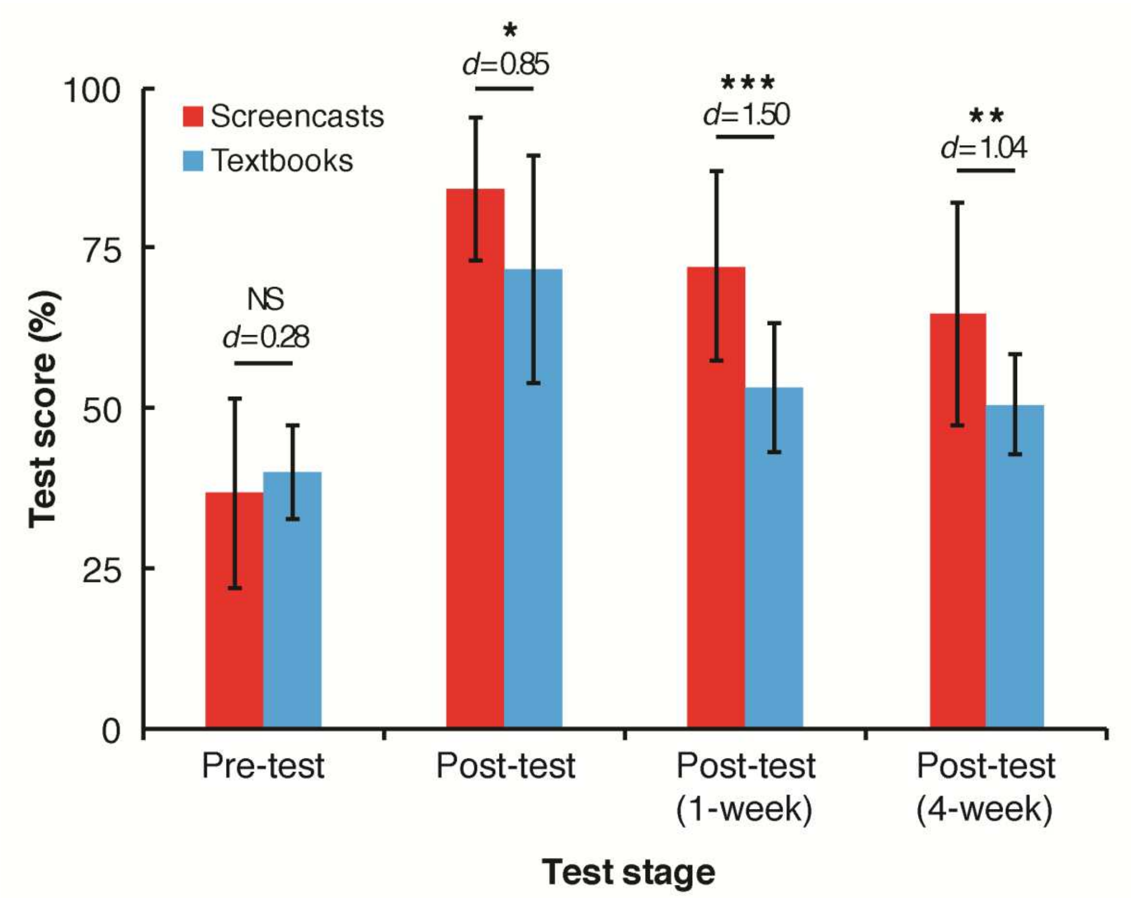

Figure 1 Bar chart displays the percentage of correct answers for the pre-test, post-test, 1-week post-test and 4-week post-test for the screencast and textbook groups. Error bars indicate standard deviation. Horizontal bars indicate between group significance and effect size (NS, not significant; * P > 0.05, * P < 0.05, ** P < 0.01, *** P < 0.001; d, Cohen's effect size.