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The Effectiveness of Anatomy Glove Learning System in the Training of Massage Therapy Students

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Published by

The Higher Education Quality Council of Ontario

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Cite this publication in the following format:

Lisk, K., McKee, P., Baskwill, A., & Agur, A. (2013). *The Effectiveness of Anatomy Glove Learning System in the Training of Massage Therapy Students*. Toronto: Higher Education Quality Council of Ontario.

ACKNOWLEDGEMENTS

The authors would like to thank Angela Parsons and Kelsey Deugo for their time and commitment to this research project, as well as the massage therapy students from Humber College for participating in this study.

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Executive Summary

Context

Empirical evidence on the effectiveness of innovative pedagogical tools for teaching and learning anatomy is conflicting and sparse. Although these innovations are designed specifically for anatomical education purposes, assessing their educational effectiveness is critical before their widespread implementation and adoption in classrooms.

Anatomy Glove Learning System (AGLS) is a new pedagogical tool developed for teaching hand anatomy to health students. A comprehensive understanding of hand anatomy and its relationship to function is essential to clinical practice in allied health professions. Anatomy Glove Learning System is comprised of 1) a glove imprinted with anatomically correct bones that is worn on the non-dominant hand of the learner, and 2) video clips showing the anatomy of the hand on dissected cadaveric specimens, followed by a demonstration of how to draw the structures onto the glove using coloured markers.

Research Question

The goal of this study was to evaluate the educational effectiveness of AGLS in the training of massage therapy students at Humber College. It was hypothesized that the tactile experience of drawing the anatomy of the hand onto the glove would provide students with kinesthetic feedback that may enhance their understanding of hand anatomy and their self-perceived confidence in this knowledge. It was also anticipated that drawing onto the glove would serve as an active and engaging learning experience.

Methods

Three evaluation tools were developed to examine the effectiveness of AGLS: 1) an evaluation questionnaire; 2) a measure of self-perceived confidence; and 3) anatomy knowledge tests. The relationship between the use of AGLS and participants' self-perceived confidence and knowledge of hand anatomy was explored using a pre-test post-test control group design. Massage therapy students were allocated into two groups. Each group participated in a short didactic lecture on hand anatomy and drew muscles of the hand onto either: 1) the glove using AGLS instructional videos (3D group); or 2) paper with palmar/dorsal views of hand bones during an instructor-guided activity (2D group). The 2D group represented standard educational practice for teaching hand anatomy and served as the control learning condition in this study. Participants completed a measure of self-confidence and a knowledge test before, immediately after, and one week following the learning conditions. Once the one-week follow-up assessments were completed, participants in the 2D group completed AGLS and those in the 3D group completed the instructor-guided drawing activity. Following these learning activities, participants in both groups evaluated the effectiveness of AGLS by completing an evaluation questionnaire. The questionnaire addressed overall learning value, usability, control, effectiveness and suggestions for improvement.

Summary of Findings

Anatomy Glove Learning System is an innovative tool that enhances students' understanding of hand anatomy and their self-confidence in this knowledge through an interactive, 3D learning experience. Students rated AGLS as a positive learning experience and highly recommended AGLS for future students. Anatomy Glove Learning System and the traditional 2D learning approach had the same effect on students' hand anatomy knowledge and self-perceived confidence; however, students had a strong preference for AGLS. The positive effect that AGLS had on students' knowledge of hand anatomy and on their self-perceived confidence in this knowledge provides support for the use of AGLS in the education curriculum of health profession fields.

Background

The goal of this research is to evaluate the educational effectiveness of Anatomy Glove Learning System (AGLS) in the training of massage therapy students at Humber College. Anatomy Glove Learning System is comprised of 1) a glove imprinted with anatomically correct bones that is worn on the non-dominant hand of the learner, and 2) video clips showing the anatomy of the hand on dissected cadaveric specimens, followed by a demonstration of how to draw the structures onto the glove using coloured markers.

In order to accomplish this goal, we compare the effects of using AGLS to a standard educational approach for teaching and learning hand anatomy on massage therapy students' knowledge of hand anatomy and on their self-perceived confidence in this knowledge. A questionnaire that addressed overall learning value, usability, control, effectiveness and suggestions for improvement is also used to evaluate the effectiveness of AGLS.

Status of Anatomical Education

Knowledge of anatomy is fundamental to health sciences education (Finnerty et al., 2010). Traditionally, teaching anatomy has involved cadaver dissection, which provides students with a three-dimensional (3D) construct of the human body (Dinsmore et al., 1999; Aziz et al., 2002; Granger, 2004; McLachlan et al., 2004; McLachlan & Patten, 2006). However, factors such as a significant reduction in the number of hours dedicated to teaching gross anatomy, fewer trained gross anatomists and the high costs associated with maintaining a cadaver lab have contributed to the declining use of dissection to teach human anatomy in North America (Collins et al., 1994; Mattingly & Barnes, 1994; Jones, 1997; Drake et al., 2009). In Ontario, only one of the 24 publicly funded community colleges presently has a cadaver lab (Humber College, n.d.). As a result, alternative pedagogical approaches have been developed (Sugand et al., 2010).

Research on Pedagogical Tools for Learning Anatomy

Advances in computer technology and medical imaging have allowed for the creation of computer-generated 3D anatomical models based on real anatomical specimens (Garg et al., 1999a). Numerous virtual reality applications using 3D models that can be manipulated into various views have been designed specifically for anatomical education purposes (Nicholson et al., 2006; Sergovich et al., 2010; Venail et al., 2010; Adams & Wilson, 2011; Nguyen et al., 2012). A common belief is that the multiple views presented by 3D computer models simulate reality more accurately and that this enhanced realism improves educational effectiveness (Garg et al., 1999b). However, empirical evidence supporting the effectiveness of these computer-assisted instruction applications on learning anatomy is conflicting and sparse.

A study by Garg and colleagues (1999a) that looked at the effectiveness of different types of instruction to teach the spatial anatomy of carpal bones using a 3D computer model found that providing students with multiple views was not advantageous compared to providing only standardized key views of the anatomical object. The standard key views were similar to viewpoints presented in a two-dimensional (2D) anatomy textbook. To the contrary, when students' spatial ability was controlled, it was found that providing students with low spatial ability and only key views was advantageous to learning the spatial anatomy of the carpals (Garg et al., 1999b). The results from these studies support the computational theories of object recognition, which contend that 3D images are stored as certain key 2D images in the brain (Bulthoff et al., 1995). In a more recent study, Nicholson and colleagues (2006) found that students performed better on an evaluation that measured their understanding of 3D relationships of the components of the inner ear when they completed a web-based tutorial that included an interactive 3D model of the ear than did students who completed the same web-based tutorial without the 3D model. The positive effect on learning observed in this study was attributed to the greater level of interactivity of the anatomical model (Nicholson et al., 2006). In another study, Hariri et al. (2004) found that there was no difference in medical students' ability to transfer knowledge of shoulder joint anatomy to a clinical setting whether they studied the material using 2D textbook images or a virtual reality 3D simulator. At first glance, it seems intuitive that learning anatomy using computer-generated 3D models would promote better learning than standard 2D static images. However, evidence of this is not consistent in the literature. Each of these studies demonstrates the importance of assessing the educational effectiveness of innovative pedagogical tools for teaching and learning anatomy before their widespread implementation and adoption in classrooms.

Standard educational practice for teaching the anatomy of the hand to massage therapy students at Humber College includes using a didactic lecture and an instructor-guided drawing activity. The didactic lecture introduces the compartments of the hand, nerve distributions and hand joint movements. The drawing activity uses paper showing the palmar and dorsal views of the hand bones and distal forearm bones. This standard educational practice will serve as our control learning condition in this study.

Description of the Anatomy Glove Learning System

Anatomy Glove Learning System is an innovative pedagogical tool that has been developed to teach hand anatomy to health students. A comprehensive understanding of hand anatomy and its relationship to function is essential to clinical practice in allied health professions due to the hand's central role in daily activities and the prevalence of hand conditions (Barr et al., 2004; IWH, 2009). However, the anatomical complexity of the hand makes it a particularly challenging region for students to learn. Anatomy Glove Learning System was created by two professors at the University to Toronto to address this challenge by enabling students to learn the relationship between hand structure and function through the direct experience of wearing a glove. Anatomy Glove Learning System includes 1) a glove imprinted with anatomically correct bones that is worn on the non-dominant hand of the learner, and 2) video clips showing the anatomy of the hand on dissected cadaveric specimens followed by a demonstration of how to draw the structures of the hand onto the glove using coloured markers. The video clips provide a description of the bones and joints of the hand, attachments for the superficial muscles in the thenar and hypothenar compartments of the hand, distal tendon attachments for anterior and posterior forearm muscles, and general nerve distributions. The information in the video clips is organized by muscle group (e.g., wrist flexors, thumb extensors, etc.) and builds up the layers of the hand from deep to superficial. Anatomy Glove Learning System is designed so that the learner can control the pace of the videos by starting and stopping them at any point and choosing the order in which they are presented.

The development of AGLS was guided using experiential learning theory (ELT), which defines learning as a "process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 41). Experiential learning theorists see learning as rooted in constructivism, and its core condition is participation (Yardley et al., 2012). Kolb's ELT proposes that learners develop knowledge as they progress through a four-stage cycle that consists of: concrete experience, reflective observation, abstract conceptualization and active experimentation (Kolb, 1984). The learning of hand anatomy using AGLS can be understood using Kolb's theoretical model. In this view, learners extract knowledge from their direct experience of drawing the structures of the hand onto the glove. Once the glove drawing is complete, learners can visually observe the structures and assimilate their observations into their existing knowledge base. For example, if learners have drawn a muscle over a particular joint, they intuitively understand that the muscle could theoretically produce movement at that joint. Finally, through active experimentation, learners can confirm their predictions by manipulating their own hand in 3D space while wearing the glove. Active experimentation with the glove can become very useful for understanding the complex mechanisms of certain intrinsic hand muscles. Given the theoretical nature of Kolb's ELT model, however, we acknowledge that all learners may not progress from one stage to the next as described in this learning theory.

Research Question and Hypothesis

The purpose of this study was to evaluate the effectiveness of AGLS as a learning tool using a questionnaire that addressed overall learning value, usability, control, effectiveness and suggestions for improvement. The relationship between the use of AGLS and participants' knowledge of hand anatomy and their confidence in this knowledge before, immediately after and one week after use were also explored using a pre-test post-test control group design. It was hypothesized that learner control of and drawing onto the glove would constitute a more active and engaging learning activity than the traditional method of teaching and would improve students' self-perceived confidence of hand anatomy. Furthermore, it was anticipated that the tactile experience of drawing the anatomy of the hand onto the glove would provide students with kinesthetic feedback that would enhance their understanding of spatial perspectives on and knowledge of the hand.

Method

Participants

All first-year students (n=77) enrolled in Humber College's massage therapy program were eligible to participate. This group of students has minimal, if any, prior exposure to the clinical anatomy of the hand. To encourage participation, all participants were given a $25 gift card to the bookstore for completing all aspects of the study. Ethics approval for this study was provided by the research ethics board at Humber College and informed consent was obtained from all participants.

Learning Material

The learning material for the control learning condition (2D group) consisted of a didactic lecture and an instructor-guided drawing activity that taught the structures and functions of the hand. The didactic lecture introduced the compartments of the hand, general nerve distributions, and reviewed joint movements permitted by hand joints. The drawing activity used a paper showing the palmar and dorsal views of the hand and distal forearm bones (see Figure 1). This learning condition represented the standard educational practice for teaching hand anatomy to allied health students. The learning material for the intervention condition (3D group) used the same didactic lecture as in the 2D group. In the 3D group, the structures and functions of the hand were taught by drawing the anatomy of the hand onto a glove using the instructional AGLS videos (Figure 2A-B). Participants worked at their own pace and in pairs to complete this learning activity (Figure 2C). One instructor and two research assistants were present during both learning conditions to assist at any point if needed. Both groups had 75 minutes to complete their learning condition.

Figure 1: Two-Dimensional Group Learning Activity

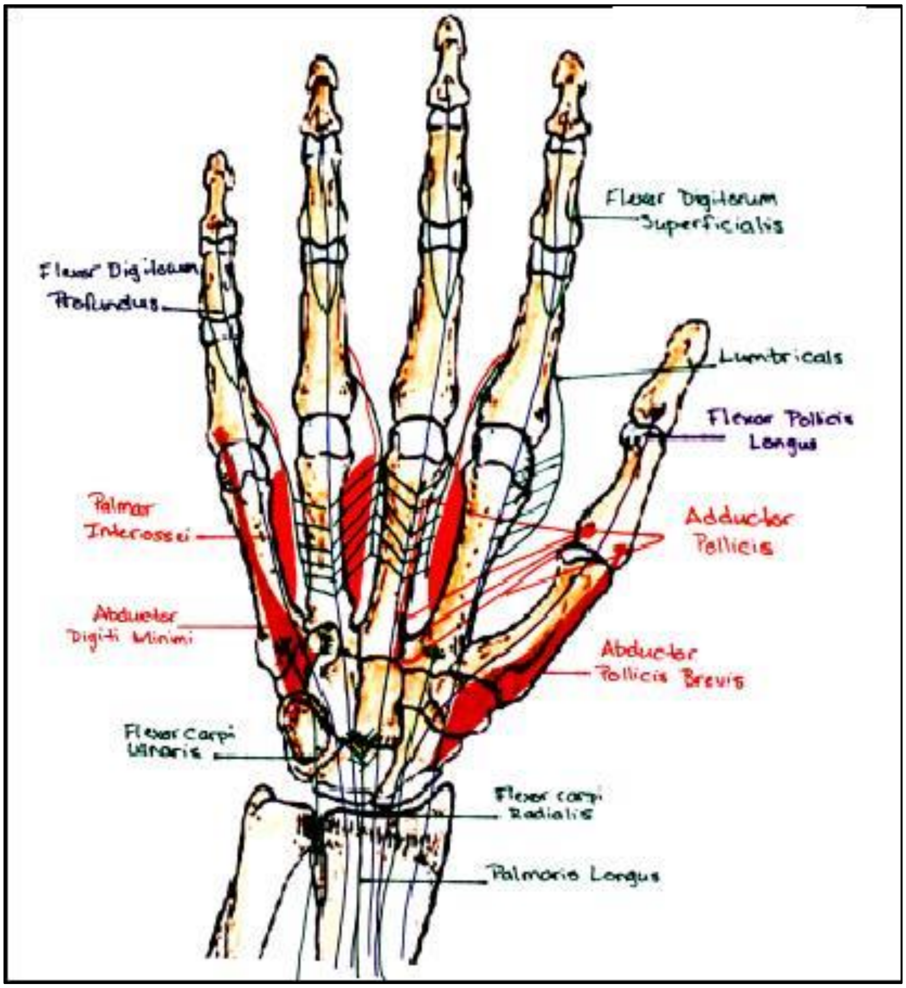
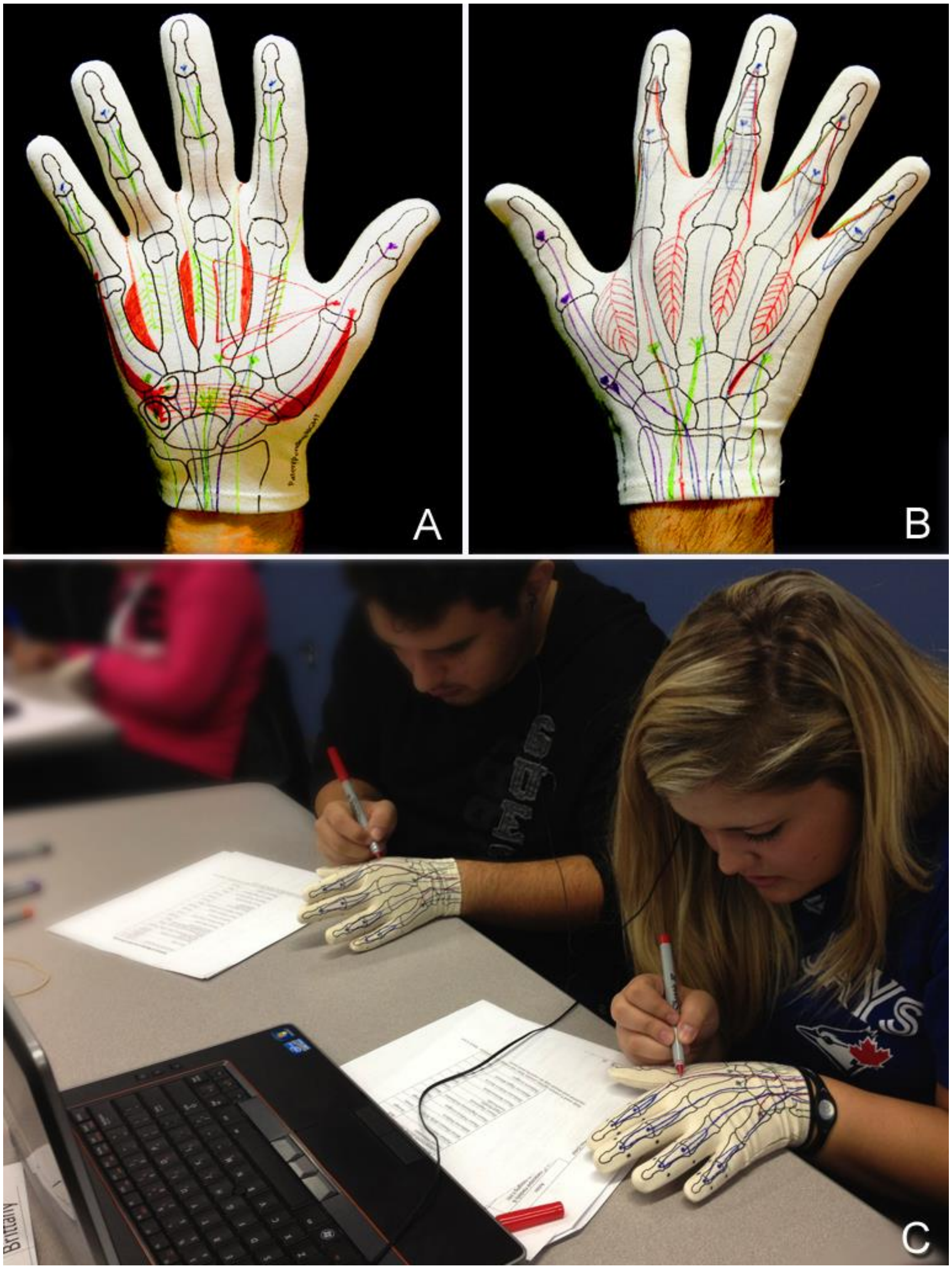


Figure 2: Three-Dimensional Group Learning Activity. A. Palmar View of AGLS Glove. B. Dorsal View of AGLS Glove. C. Students Working in Pairs Completing AGLS



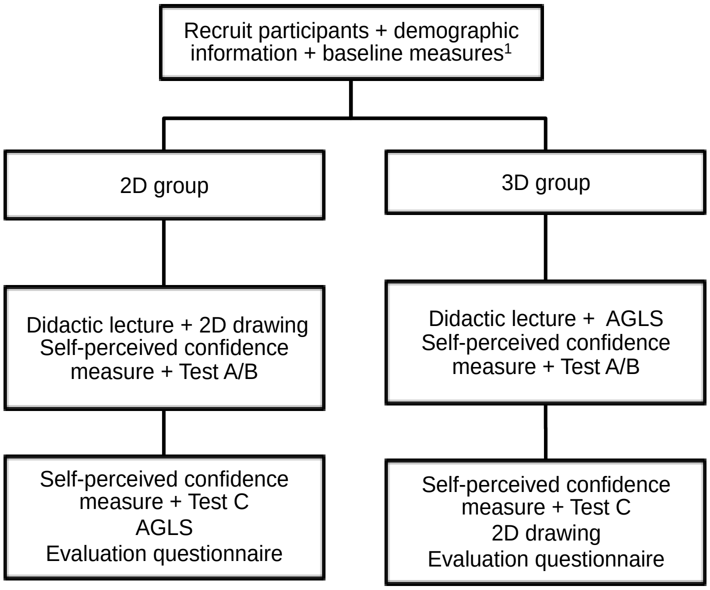
Evaluation and Assessment Material

An evaluation questionnaire, self-perceived confidence measure and anatomy knowledge test were used to determine the effectiveness of AGLS. The evaluation questionnaire consisted of closed and open-ended questions that addressed issues such as the overall learning value of AGLS, usability, control, effectiveness and suggestions for improvement (Appendix A). Closed-ended questions used a 10-point Likert scale, where 1 represented “strongly disagree” and 10 represented “strongly agree”. The self-perceived confidence measure asked students to rank their level of confidence in their knowledge of hand anatomy on a 10-point Likert scale, where 1 represented “low self-confidence of hand anatomy” and 10 represented “high self-confidence of hand anatomy”. Finally, the anatomy knowledge tests consisted of four multiple-choice questions and 19 short answer questions that assessed recall and hand anatomy knowledge. Examples of the types of questions used are provided in Appendix B. For counterbalancing purposes, three different anatomy knowledge tests (A, B, C), matched for difficulty, were developed collaboratively by an anatomist, a hand therapist and a massage therapist. Tests A and B were piloted by second- and third-year student massage therapists (n=15) and registered massage therapists (n=8) and changes were made accordingly. The course instructor did not participate in the development of the tests and was blinded to their content.

Study Protocol

All aspects of this study took place in a classroom setting and the timing of this study was aligned with the massage therapy anatomy curriculum. Although all students in the class participated in the learning activities, no data were collected from those who did not provide consent. As outlined in Figure 3, at baseline, participants provided demographic information and completed the self-perceived confidence measure and an anatomy knowledge test (Tests A and B). Participants were allocated into the 2D and 3D learning conditions based on their assigned anatomy section. A coin was flipped one day before the learning conditions to determine which section would be the 3D group. Seven weeks after baseline, participants completed either the 2D or 3D learning condition. Immediately following learning, participants completed the self-perceived confidence measure and an anatomy knowledge test. Those who had initially completed Test A completed Test B and vice versa. Participants in both learning conditions were not allowed to take home their completed learning tool until after the study was complete. One week following initial learning, participants in both groups completed an anatomy knowledge test (Test C) and the self-perceived confidence measure. Participants in both groups were given 15 minutes to review the anatomy of the hand using their completed learning tool (paper or glove). After the assessments were completed, participants in the 2D group completed AGLS and those in the 3D group completed the instructor-guided drawing activity. Following these learning activities, participants in both groups evaluated the effectiveness of AGLS by completing the evaluation questionnaire.

Figure 3: Study Protocol



Note:[1]Baseline measures included the self-perceived confidence measure + Test A/B

Data Analysis

The mean and standard deviation values were calculated for student responses to the closed-ended questions on the evaluation questionnaire. Overall internal consistency (Cronbach's alpha) was calculated to measure reliability. Open-ended responses were analyzed using a line-by-line open coding method with NVivo software (QSR International Pty Ltd. Version 10, 2012). The coding scheme was based on knowledge of the topic and familiarity with the data. Summary reports of the themes were generated to illustrate the findings.

For each participant, the number of correct responses on the anatomy knowledge tests was calculated. Anatomy knowledge and self-perceived confidence for all participants were analyzed separately using a 2x3 repeated measures ANOVA with the learning group (2D vs. 3D) as the between-subject factor and time (before, immediately after, one week later) as the within-subject factor. Quantitative data were analyzed using SPSS statistical software package, version 20 (SPSS Inc., Chicago, IL).

Results

The participation rate for this study was 95%. Of the 73 participants who consented, 64 (88%) completed all aspects of this study. Table 1 contains the demographic characteristics of participants.

Table 1: Demographic Characteristics of Participants in Percentage[1]

		2D group	3D group
Gender	Female	62	67
	Male	38	33
Handedness	Right	85	97
	Left	15	3
Previous exposure to hand anatomy at the college or university level	Yes	26	27
	No	74	73

Note: [1]Number of participants n=64

Quantitative Findings of Evaluation Questionnaire

The mean and standard deviation for each of the closed-ended questions are summarized in Table 2. The overall internal consistency of the questionnaire was 0.87. Participants perceived the learning value of the AGLS to be strongly positive, with an overall impression mean score of 8.1 out of 10. The videos of the AGLS provided straightforward instructions on how to draw the anatomy of the hand onto the glove and were reported to be very helpful in improving participants' understanding of hand anatomy (mean = 8.3). Similarly, participants also found that the exercise of drawing the extrinsic tendons and intrinsic muscles of the hand onto the glove very helpful in improving their understanding of the structures and function of the hand (mean = 8.1). 85% of participants reported a strong preference (≥ 8 out of 10) for using AGLS to learn hand anatomy over the instructor-guided drawing activity, and 86% of participants reported that they intended to use the glove and/or the videos to prepare for upcoming examinations. The responses to the questions that assessed user friendliness and learner control of AGLS were also high, with mean scores of 8.8 and 9.1, respectively. Participants also highly recommended (mean = 9.0) the AGLS as a learning tool for future massage therapy students.

Table 2: Participants' Ratings of AGLS as a Learning Tool Using a 10-Point Likert Scale with 1 = Strongly Disagree and 10 = Strongly Agree[1]

	Mean	±SD
Please rate your overall impression of AGLS.	8.1	1.6
AGLS was user friendly.	8.8	1.3
I could easily control the pace of the videos.	9.1	1.5
I intend to use the glove and/or videos of AGLS to study hand anatomy.	8.7	1.7
Overall, how helpful were the videos in helping you to understand the anatomy of the hand and to draw the anatomy of the hand?	8.3	2
Overall, how helpful was drawing the muscles/tendons on the glove in helping you to understand the anatomy of the hand?	8.1	1.8
I preferred drawing the muscles and tendons of the hand on the glove versus drawing the structures on paper.	8.6	2.2
I would recommend AGLS to future massage therapy students.	9	1.7

Note: [1]Number of participants n=64

Qualitative Findings of Evaluation Questionnaire

The open-ended questions on the evaluation questionnaire were designed to collect participants' perceptions of the effectiveness of AGLS as a learning tool and suggestions on how it could be improved. Responses to these questions were analyzed and the following five themes emerged: anatomical content, learner preference, interactivity, useful learning tool and enjoyable learning experience. Examples of student responses for each theme are provided below in italics.

Theme 1: Anatomical content

66% (n=42) of participants commented that the anatomy glove drawing experience improved their understanding of hand anatomy. These participants reported that the act of drawing the structures onto the worn glove helped them identify the exact location and attachment sites of the tendons and muscles in the hand. Many of these participants also mentioned that manipulating the glove on their own hand was useful in visualizing and understanding muscle function.

> *I was more able to grasp the concept that the tendons wrap around from the palmar to the dorsal side of the hand.*
>
> *It helped me identify where all the muscles, nerves, and tendons were on my hand making it more realistic than a labelled 2D diagram.*
>
> *It gave my learning a more visual 3D experience and a better understanding of where certain muscle are located.*
>
> *Demonstrate the movements that the muscles do.*

Theme 2: Learning preference

22% (n=14) of participants stated a preference for learning using visual learning materials and hands-on activities. These participants commented that being able to draw the structures onto their own hand and thus visualize the location of the muscles deep to their skin allowed for a better understanding of the specific location and function of the muscles in the hand.

> *I am a visual learner, so being able to draw them and picture exactly where they are in respect to the actual hand was very helpful and easier to understand*
>
> *Doing it step by step at my own pace gave time to really locate/understand each structure.*
>
> *I enjoyed that it was a hands on activity, which I understand better and* prefer.

Theme 3: Interactivity

31% (n=20) of participants indicated that the AGLS experience was interactive and hands-on. Nine of these participants indicated that the glove improved their understanding of muscle function because they were able to manipulate the glove on their own hand while simultaneously watching the muscles produce movement at the hand joints.

> *The experience enhanced my understanding of hand anatomy by making things more 3D as well as 'real life' so I could locate on my hand.*
>
> *The fact that you can see what each muscle does when using the glove.*

Theme 4: Useful learning tool

47% (n=30) of participants indicated that once all of the structures were drawn onto the glove, it became a very useful tool to use to visualize or palpate the exact location of muscles. Six participants also indicated that the anatomy glove drawing provided them with an opportunity to create a useful study tool.

I ended up with a complete glove to study with.

It helped me visualize where those muscles actually go and what they can do.

The chance to scale out each muscle/tendon on our fingers/hand.

Theme 5: Enjoyable learning experience

Overall, 28% (n=18) of participants specifically indicated that they enjoyed the AGLS learning experience. Many of these participants reported that the anatomy glove drawing activity was a different, fun and cool way to learn hand anatomy. Two participants indicated that it was not only a creative way to learn, but also an easier way to learn the structures compared to using 2D pictures from a textbook.

I enjoyed viewing the video and drawing on the glove with a partner.

It was a nice change from lectures.

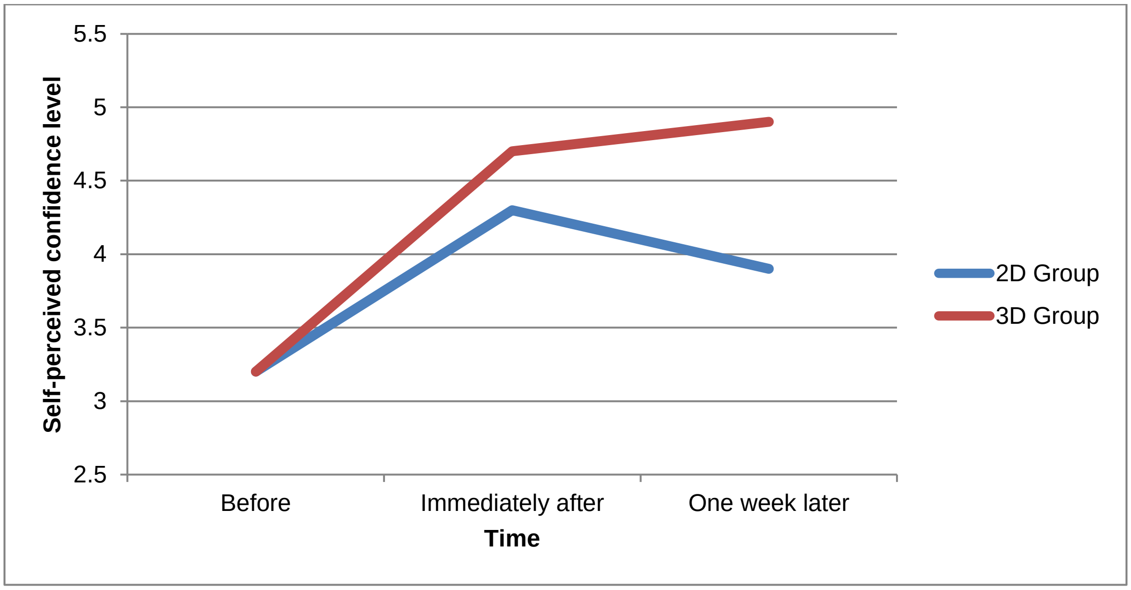
It's a fun way to learn.

Participants also provided valuable feedback on how AGLS could be improved. 33% (n=21) of participants indicated that they either felt rushed to complete the glove drawing activity in class or suggested that more time would have been beneficial. Some students (n=8) also suggested that it would have been helpful if the videos included instructions on how to label all of the structures once they had been drawn onto the glove. 22% (n=14) of participants also suggested that the voice used in the videos should be a louder and use more inflection.

Self-Perceived Confidence and Knowledge of Anatomy Findings

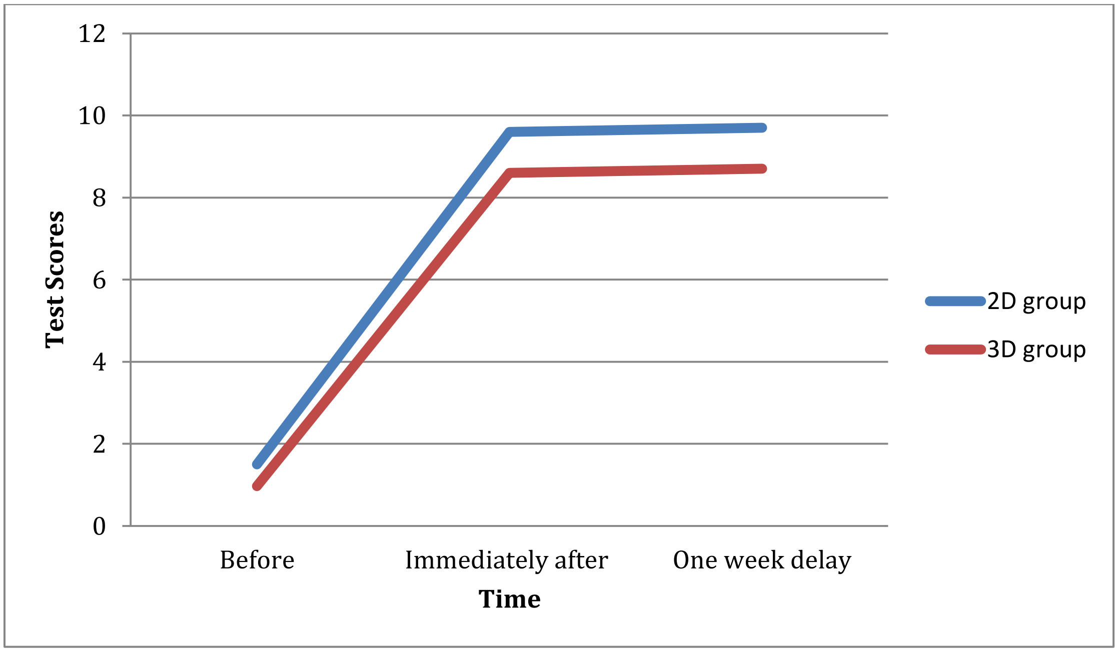
Participants completed a measure of self-perceived confidence and a knowledge test before, immediately after and one week following the learning conditions. Participants' self-perceived confidence in their knowledge of hand anatomy increased gradually in the 3D group (3.3/10, 4.7/10, 4.8/10), whereas self-perceived confidence in the 2D group began to decline one week following initial learning (3.1/10, 4.3/10, 3.9/10) (Figure 4). Self-perceived confidence improved for both groups after the 2D and 3D learning conditions ($F_{(1, 63)}$, $p < 0.05$). A main effect for time was found to be significant ($p < 0.05$) and post hoc t-tests confirmed that self-perceived confidence improved significantly immediately after learning. There was no difference observed for self-perceived confidence between the 3D and 2D groups.

Figure 4: Participants' Self-Perceived Confidence of Hand Anatomy Knowledge before, immediately after and One Week after Learning. Self-perceived confidence improved for both groups immediately after the 2D and 3D learning conditions ($F (1, 63)_{,}$ $p < 0.05$).



The results of the knowledge tests are shown in Figure 5 and demonstrate that both groups had almost no clinical anatomy knowledge prior to starting the study. At baseline, the 2D and 3D group mean scores were 1.5 and 0.97 out of 23, respectively. The knowledge test scores for both the groups after learning were also low. The results on the knowledge test for the 2D group immediately after learning and one week later were 9.6 and 9.7, respectively, while the results for the 3D group immediately after learning and one week later were 8.6 and 8.7 out of 23, respectively. Hand anatomy knowledge improved in both groups after the learning conditions, $F (1, 63)_{,}$ $p < 0.05$. A main effect of time was found to be significant ($p < 0.05$) and post hoc t-tests confirmed that knowledge improved significantly immediately after the learning conditions. There was no difference observed for knowledge between the 3D and 2D groups. Although the gains in knowledge for both groups appear to be relatively small, it is important to note that the questions on the test primarily assessed hand anatomy knowledge and not recall of facts. In addition, in many instances students had part of a short answer correct but not enough to be awarded a mark, such as, for example, a student may have answered "digitorum superficialis" when the correct answer was "flexor digitorum superficialis". Had more multiple choice-style questions been used, knowledge test results after learning may have been higher.

Figure 5: Participants' Hand Anatomy Knowledge before, immediately after and One Week after Learning. Hand anatomy knowledge improved in both groups immediately after the learning conditions ($F(1, 63)$, $p < 0.05$).



Discussion

Summary of Findings

Students rated AGLS as a positive learning experience and highly recommended it for future students. The results of this study suggest that AGLS is an effective and engaging learning tool. While both AGLS and the traditional 2D learning approach had the same effect on students' hand anatomy knowledge and self-perceived confidence, students voiced a strong preference for AGLS. These results are consistent with other studies that have compared 3D and 2D anatomy learning tools. Keedy and colleagues (2011) reported that a 3D multimedia module on hepatobiliary anatomy neither enhanced nor inhibited medical students' learning; however, medical students were more satisfied with the 3D multimedia module than with a module that utilized textbook images. Likewise, no difference was observed in medical students' ability to learn shoulder joint anatomy using a virtual reality 3D simulator or images from a textbook. However, those who used the 3D simulator rated it as being significantly more effective and were more likely to claim that they would use it as a learning tool if it were available to them (Hariri et al., 2004). It should be noted that in both of these studies, the 3D learning tools were presented on a 2D computer screen.

Two recent studies demonstrate that students had significantly better anatomy knowledge after learning using a physical, plastic 3D model compared to using a virtual reality 3D model or textbook images (Khot et al., 2013; Preece et al., 2013). Both of these studies suggest that using 3D virtual models and 2D textbook images requires extraneous cognitive load and as a result limits learning in comparison to the use of a physical 3D model. In the current study, it is plausible that both extraneous and intrinsic cognitive load was a factor that resulted in no difference in anatomy knowledge being observed. Cognitive load is defined as the multidimensional construct representing the load that performing a task imposes on a learner's cognitive system (Paas et al., 2003). Intrinsic cognitive load is the inherent level of difficulty associated with the learning materials and extraneous cognitive load is additional load generated by the manner in which information is presented to learner (Paas et al., 2003). Both the 3D and 2D groups may have been exposed to too much complex information during the learning conditions and this may have affected students' ability to pay attention to specific details and subsequently process information into long-term memory.

Although AGLS and the traditional 2D learning approach were equally as effective at promoting learning, the qualitative results distinguish AGLS as a more favorable learning tool. Students strongly believed that the AGLS videos (mean = 8.3 out of 10) and drawing activity (mean = 8.1 out of 10) improved their understanding of hand anatomy. The majority of students (85%) also preferred AGLS as a learning tool in comparison to the 2D drawing activity. Experiential learning theorists would suggest that this preference is the result of students being able to experiment actively with the learning tool (Kolb, 1984). While both the 3D and 2D learning conditions involved active participation, the direct manipulation of the glove on the learner's own hand allowed for active experimentation and may have resulted in a better appreciation of hand structure and function. The literature on deliberate practice and repeated exposure (Ericsson, 2004) suggests that if students had been given more time to interact with the glove, they may have performed better on the knowledge test.

The results also revealed that the majority of students intended to use the glove and/or the videos to prepare for upcoming examinations. A recent study of first-year medical students found that participation, such as optional study assignments outside of class, was positively associated with academic performance (Stegers-Jager et al., 2012). Thus, it is plausible that if students had the opportunity to use their completed learning tool beyond the confined learning condition, students in the 3D group may have scored higher on the delayed knowledge test. In addition, since students indicated that they intended to use AGLS to prepare for future examinations, it is possible that this increased engagement and effort during self-study could lead to better learning.

Implications

An ongoing trend in anatomical education is the development of technology-based educational tools to replace or compliment traditional experiences in a cadaver lab (Collins et al., 1994; Sugand et al., 2010). Although these new educational tools are designed specifically for anatomical education purposes, empirical evidence of their effectiveness on learning anatomy is often conflicting and sparse. This study provides empirical evidence demonstrating that AGLS is an effective and preferred pedagogical approach for learning hand anatomy. For the growing number of programs that have limited access to a cadaver lab, AGLS also provides an opportunity for students to view cadaveric hand prosections. The positive effect on students' knowledge and self-perceived confidence provides support for the use of AGLS in the education curricula of health professions.

Limitations

This study has limitations that should be noted. The generalizability of our findings is potentially limited by the fact that only massage therapy students took part in this study. The results found may not reflect the AGLS' effect on the general population of health students.

In addition, all aspects of this study took place in a classroom setting within the time allowed by the curriculum, so factors such as participant interaction and time on task could not be controlled. Participants in both groups had to complete their assigned learning activity and evaluations within a defined period of time (90 minutes). Many students in the 3D group reported that they felt rushed to complete the glove activity and many did not have time to review thoroughly the structures using the glove prior to writing the test. Other colleges and universities should consider replicating this research within the constraints of their own curriculum to support the generalizability of the study's findings.

Furthermore, since this study took place in an uncontrolled classroom setting, some participants were not focused on reviewing the anatomy of hand once they had completed the learning activity. To prevent contamination between groups, neither group was allowed to review hand anatomy with their learning tool beyond the time permitted in the initial learning activity. It is plausible that students in both groups would have benefitted from additional exposure and experimentation with their assigned learning tool.

Future Research

In a follow-up study, an evaluation questionnaire will also be administered to gather feedback on the 2D drawing activity. Based on previous findings that have shown a relationship between the use of 3D computer models and spatial ability (Garg et al., 1999a; 1999b; Levinson et al., 2007; Stull et al., 2009; Nguyen et al., 2012), future research will also explore the relationship between students' spatial ability and the use of AGLS. Further investigation will also aim to determine the efficacy of the different components (glove vs. video) of AGLS.

Conclusions

Our research supports the use of AGLS as an effective and preferred learning tool for allied health students learning hand anatomy. Students strongly preferred AGLS as a learning tool in comparison to the traditional learning experience. Anatomy Glove Learning System is an innovative pedagogical approach with the potential to enhance students' understanding through an interactive, 3D learning experience.

References

Adams, C. M., & Wilson, T. D. (2011). Virtual cerebral ventricular system: An MR-based three-dimensional computer model. *Anatomical Sciences Education*, *4*(6), 340-347.

Aziz, M. A., McKenzie, J. C., Wilson, J. S., Cowie, R. J., Ayeni, S. A., & Dunn, B. K. (2002). The human cadaver in the age of biomedical informatics. *The Anatomical Record*, *269*(1), 20-32.

Barr, A. E., Barbe, M. F., & Clark, B. D. (2004). Work-related musculoskeletal disorders of the hand and wrist: Epidemiology, pathophysiology, and sensorimotor changes. *Journal of Orthopaedic and Sports Physical Therapy, 34*(10), 610-627.

Bulthoff, H. H., Edelman, S. Y., & Tarr, M. J. (1995). How are three-dimensional objects represented in the brain? *Cerebral Cortex*, *5*(3), 247-260.

Collins, T. J., Given, R. L., Hulsebosch, C. E., & Miller, B. T. (1994). Status of gross anatomy in the U.S. and Canada: Dilemma for the 21st century. *Clinical Anatomy*, *7*(5), 275-296.

Dinsmore, C. E., Daugherty, S., & Zeitz, H. J. (1999). Teaching and learning gross anatomy: Dissection, prosection or both of the above? *Clinical Anatomy*, *12*(2), 110-114.

Drake, R. L., McBride, J. M., Lachman, N., & Pawlina, W. (2009). Medical education in the anatomical sciences: The winds of change continue to blow. *Anatomical Sciences Education*, *2*(6), 253-259.

Ericsson, K. A. (2004). Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Academic Medicine*, *79*(10), S70-S81.

Finnerty, E. P., Chauvin, S., Bonaminio, G., Andrews, M., Carroll, R. G., & Pangaro, L. N. (2010). Flexner revisited: The role and value of the basic sciences in medical education. *Academic Medicine*, *85*(2), 349-355.

Garg, A., Norman, G., Spero, L., & Taylor, I. (1999a). Learning anatomy: Do new computer models improve spatial understanding? *Medical Teacher*, *21*(5), 519-522.

Garg, A., Norman, G. R., Spero, L., & Maheshwari, P. (1999b). Do virtual computer models hinder anatomy learning? *Academic Medicine, 74*(10), S87-S89.

Granger, N. A. (2004). Dissection laboratory is vital to medical gross anatomy education. *The Anatomical Record (New Anat), 281*(1), 6-8.

Hariri, S., Rawn, C., Srivastava, S., Youngblood, P., & Ladd, A. (2004). Evaluation of a surgical simulator for learning clinical anatomy. *Medical Education*, *38*(8), 896-902.

Humber College. (n.d.). School of Health Sciences: Biosciences Lab. Retrieved from http://healthsciences.humber.ca/resources/living-and-simulated-learning-environments/biosciences-lab.html

IBM SPSS Statistics for Windows. IBM Corp. Version 20.0, 2011.

Institute for Work and Health. (2009). Do workplace programs protect upper extremity musculoskeletal health? Retrieved from http://www.iwh.on.ca/system/files/documents/best_evidence_upper_extremity_2009.pdf

Jones, D. G. (1997). Reassessing the importance of dissection: A critique and elaboration. *Clinical Anatomy*, *10*(2), 123-127.

Keedy, A. W., Durack, J. C., Sandhu, P., Chen, E. M., O'Sullivan, P. S., & Breiman, R. S. (2011). Comparison of traditional methods with 3D computer models in the instruction of hepatobiliary anatomy. *Anatomical Sciences Education*, *4*(2), 84-91.

Kolb, D. A. (1984). *Experiential learning: experiences as the source of learning and development.* First edition. Upper Saddle River, NJ: Prentice Hall.

Khot, Z., Quinlan, K., Norman, G. R., & Wainman, B. (2013). The relative effectiveness of computer-based and traditional resources for education in anatomy. *Anatomical Sciences Education*, *6*(4), 211-215.

Levinson, A. J., Weaver, B., Garside, S., McGinn, H., & Norman, G. R. (2007). Virtual reality and brain anatomy: A randomized trial of e-learning instructional designs. *Medical Education*, *41*(5), 495-501.

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. M. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychology, 38*(1), 63-71.

Preece, D., Williams, S. B., Lam, R., & Weller, R. (2013). “Let’s get physical”: Advantages of a physical model over 3D computer models and textbooks in learning imaging anatomy. *Anatomical Sciences Education*, *6*(4), 216-224.

Mattingly, C. E., & Barnes, G. E. (1994). Teaching human anatomy in physical therapy education in the United States: A survey. *Physical Therapy*, *74*(8), 720-727.

McLachlan, J. C., Bligh, J., Bradley, P., & Searle, J. (2004). Teaching anatomy without cadavers. *Medical Education*, *38*(4), 418-424.

McLachlan, J. C., & Patten, D. (2006). Anatomy teaching: Ghosts of the past, present and future. *Medical Education*, *40*(3), 243-253.

Nguyen, N., & Wilson, T. D. (2009). A head in virtual reality: Development of a dynamic head and neck model. *Anatomical Sciences Education*, *2*(6), 294-301.

Nicholson, D. T., Chalk, C., Funnell, W. R., & Daniel, S. J. (2006). Can virtual reality improve anatomy education? A randomised controlled study of a computer generated three-dimensional anatomical ear model. *Medical Education*, *40*(11), 1081-1087.

NVivo qualitative data analysis software. QSR International Pty Ltd. Version 10, 2012.

Sergovich, A., Johnson, M., & Wilson, T. D. (2010). Explorable three-dimensional digital model of the female pelvis, pelvic contents, and perineum for anatomical education. *Anatomical Sciences Education*, *3*(3), 127-133.

Stegers-Jager, K. M., Cohen-Schotanus, J., & Themmen, A. P. (2012). Motivation, learning strategies, participation and medical school performance. *Medical Education*, *46*(7), 678-688.

Stull, A. T., Hegarty, M., & Mayer, R. E. (2009). Getting a handle on learning anatomy with interactive three-dimensional graphics. *Journal of Educational Psychology*, *101*(4), 803-816.

Sugand, K., Abrahams, P., & Khurana, A. (2010). The anatomy of anatomy: A review for its modernization. *Anatomical Sciences Education*, *3*(2), 83-93.

Venail, F., Deveze, A., Lallemant, B., Guevara, N., & Mondain, M. (2010). Enhancement of temporal bone anatomy learning with computer 3D rendered imaging software. *Medical Teacher*, *32*(7), e282-e288.

Yardley, S., Teunissen, P. W., & Dornan, T. (2012). Experiential learning: AMEE guide No. 63. *Medical Teacher*, *34*(2), e102-e115.

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