2017. Proceedings of the Indiana Academy of Science 126(1):94–103

MEDICAL STUDENTS SHOW LIMITED USE OF COMPUTER-AIDED INSTRUCTION IN STUDYING GROSS ANATOMY

Allison K. Chatterjee[1]: Marian University College of Osteopathic Medicine, 3200 Cold Spring Road, Indianapolis, IN 46222 USA

James J. Walker: Department of Basic Medical Sciences, Purdue University, 625 Harrison Street, West Lafayette, IN 47907-2026 USA and Indiana University School of Medicine – Lafayette, 715 Clinic Drive, West Lafayette, IN 47907-1671 USA

ABSTRACT. Within the last few decades, there has been increased interest in computer-aided instruction (CAI) as a supplement to, or replacement for, cadaver dissection. With the multitude of resources now available, it is important to collect information regarding students' use of anatomical resources. The purpose of this study was to assess the use of computer-aided instruction (CAI) by gross anatomy students at the Indiana University School of Medicine (IUSM). A survey was developed to assess how frequently students used a variety of resources. The gross anatomy resources were chosen based on their 1) prominence in the field of anatomy; 2) high level of quality; and 3) appropriateness for medical students. Students reported using general computer applications, such as PowerPoint, web browsing, and email most frequently to study gross anatomy. Instructor-made resources were also popular. The three most frequently used commercially available gross anatomy software programs were 1) *The Imaging Atlas of Human Anatomy*; 2) *Netter Interactive CD*; and 3) *The Visible Human Dissector*. However, a majority of students did not use, or were unaware of, the commercially available anatomy software. Students used resources that held the most potential for improving their grades, as was illustrated by the use of instructor-made CD-ROMs/DVD-ROMs at IUSM-Northwest and by the use of *the Visible Human Dissector* and *The Imaging Atlas of Human Anatomy* at IUSM-Lafayette. A number of exam questions came directly from these resources at these campuses. Because students' use of CAI was limited, adding or creating additional resources should be carefully considered.

Keywords: Gross anatomy, computer-aided instruction (CAI), anatomy education, science education

INTRODUCTION

Medical education as a whole, and gross anatomy (GA) specifically, has been undergoing a massive transition towards a prominent electronic presence. The primary means of studying and learning anatomy has been through the use of cadaver dissections, textbooks, and lectures. Within the last few decades, there has been increased interest in alternative methods, including the use of computer-aided instruction (CAI), to supplement or replace cadaver dissection (McNulty et al. 2000; Kesner & Linzey 2005; Kish et al. 2013; Saltarelli et al. 2014). CAI can take many forms including image databases, dissection videos, websites, computer animations, smart phone or tablet applications (apps), and podcasts (Lonn & Teasley 2009; Richardson et al. 2011; Jaffar 2012; Leggate 2012; Baheerathan & Selvaskandan 2014).

The transition towards a technology-centered curriculum has resulted in many research studies aimed at evaluating the effectiveness of different multimedia resources or developing new CAI programs to improve student learning of anatomical structures (McNulty et al. 2000, 2009; Nieder et al. 2000; Van Sint Jan et al. 2003; Elisndo-Omana et al. 2004; Hariri et al. 2004; Hudson 2004; Jastrow & Hollinderbaumer 2004; Lei et al. 2005; Linton et al. 2005; Levinson et al. 2007; Gould et al. 2008; Cook et al. 2010; Rich & Guy 2013). These studies have predominantly involved the evaluation of CAI resources that are instructor-made and course-specific. Results from these studies have been mixed and dependent upon the format of the CAI resource being evaluated.

The development and implementation of any new instructional resource should be driven by well-defined educational objectives that consider

[1] *Corresponding author:* Allison K. Chatterjee, Ph.D., 765-490-4951 (telephone), akford5@gmail.com.

the needs of the students (Jastrow & Hollinderbaumer 2004; Mayfield et al. 2013). Evidence-based instructional design standards and guidelines for creating and implementing CAI are especially important in a medical curriculum (Han et al. 2014). However, in reality, CAI resources tend to be provided as supplemental learning materials for medical students to use at their own discretion. For CAI to realize its full potential, it must be incorporated into the curriculum and assume a more prominent role. Towards this purpose, it is necessary to examine the extent of CAI use and its effectiveness in learning outcomes. Several different terms have been used to describe this process. Educational and instructional designers use the term 'needs assessment' (Bacro et al. 2013), while others refer to it as 'implementation profiling' (Ellaway et al. 2014).

The use and effectiveness of CAI can be most easily evaluated through the collection of computer usage statistics and student surveys. Survey data can provide additional insights into what resources students feel are most useful in their studies (Jastrow & Hollinderbaumer 2004). For example, Mayfield et al. (2013) created a survey to assess students' use of iPads versus traditional dissection atlases "and the nature of [the students'] participation" in the GA laboratory; while Rich & Guy (2013) focused their survey on rating the value of an online teaching module versus lectures and laboratory sessions "as a source of understanding the course and its contents". Surveys may also reveal discrepancies between students' preferences for using electronic resources and students' actual use of electronic resources. Jastrow & Hollinderbaumer (2004) found that students wanted CAI applications in anatomy and stated that they would use them; however, in practice a third of students reported that they accessed the available CAI materials less than once a month.

When considering the inclusion or development of CAI resources for teaching GA, one of the first steps should be to determine which resources students are actively using. However, there is a noticeable lack of information about what learning resources students actually use under normal circumstances. Ellaway et al. (2014) conducted a similar study to explore how students made use of mobile devices. Although their experiment focused on the use of hardware, they did find that student use was heavily dependent upon context. With the variety of available resources, it is more important to make a concerted effort to collect information regarding students' use of anatomical resources on a regular basis. The purpose of this study was to assess the use of computer-aided instructional (CAI) resources used to study gross anatomy by first-year medical students at Indiana University School of Medicine (IUSM).

MATERIALS AND METHODS

This study was conducted at IUSM. IUSM is one of the largest medical schools in the United States. It consists of a central campus in Indianapolis, Indiana and eight regional centers across the state of Indiana. Four of the nine campuses granted permission to conduct this research project. The campuses that participated were the main campus in Indianapolis, IUSM-Northwest (Gary), IUSM-Lafayette, and IUSM-Terre Haute.

At the time of this study, the curriculum at IUSM was equivalent across the campuses, but not identical. Teaching pedagogies at each campus varied. However, there was a common core curriculum, statewide discipline exams, and common assessment of competencies for standardization across the nine campuses. The main Indianapolis campus and IUSM-Lafayette had discipline-based curricula with multiple courses in each semester. At both campuses GA was a stand-alone course in the fall semester and was taught through didactic lectures and full cadaver dissection. IUSM-Northwest (Gary) had an integrated, problem-based learning (PBL) block schedule. GA was integrated with cell biology, histology, embryology, and radiology and was taught through prosected cadavers. IUSM-Terre Haute had an integrated discipline-based curriculum with multiple courses in each semester. GA was taught through a combination of team-based learning (TBL), lecture, and full cadaver dissection during the fall semester. CAI was used as a supplement to dissection laboratory sessions.

A pencil-and-paper questionnaire assessing the use of multimedia, specifically computer-aided instruction, in gross anatomy courses was developed to evaluate how frequently students used a variety of resources ranging from instructor-made to commercially available anatomy software. Several previously published surveys evaluating medical students' use of CAI and their computer literacy were used as a guideline for the questionnaire in the current study (Magid et al. 1988; Lang

Table 1.—Response rate from participating IUSM Campuses.

Campus	%	N
IUSM-Northwest	87.5	21
IUSM-Indianapolis	71.0	98
IUSM-Lafayette	100.0	16
IUSM-Terre Haute	95.8	23

1995; Lynch et al. 2000; Dørup 2004; Jastrow & Hollinderbaumer 2004; Link & Marz 2006; Forman & Pomerantz 2006). The questionnaire contained items designed to 1) assess general computer-usage; 2) determine the frequency and usefulness of various resources, including the ones made by course instructors; and 3) gauge the use of commercially available software packages designed specifically for anatomy. The GA resources included in this survey were chosen based on the following factors: 1) their prominence in the field of anatomy; 2) their high level of quality; and 3) their appropriateness for first-year medical students. The questionnaire was pilot tested on a sample of fourteen second-year medical students at IUSM-Lafayette in order to obtain feedback regarding the clarity of the instructions and appropriateness of the questions. A cover letter attached to each survey explained the purpose of the study and addressed concerns regarding anonymity and informed consent. This anonymous survey study was deemed exempt by the Institutional Review Board (Protocol #: 081007481).

Descriptive statistical analyses were conducted using SAS 9.1. Percentages were calculated based on the total number of respondents who answered each item. Chi-Square Goodness of Fit Tests and Chi-Square Tests of Association were conducted using SPSS version 24.

Table 2.—Demographic information for first-year medical students at IUSM.

Age	
Mean	24
Range	20–44
Gender	
Male	56%
Female	44%
Ethnicity	
Caucasian	68%
Asian/Pacific Islander	18%
African American	5%
Hispanic	3%

Table 3.—Basic computer usage of first-year medical students at IUSM.

	%	N
Use or Own PC	63.3	105
Use or Own Mac	33.1	55
Cable Broadband Internet	57.3	90
DSL Internet	28.0	44
Use Wireless Internet	95.4	147
Access Email Daily	96.8	152
Browse Internet Daily	90.6	144

RESULTS

The overall response rate for participating IUSM campuses was 78% (n=158). The response rates at the four participating campuses are reported in Table 1. Demographic information for all surveyed students is provided in Table 2. Data on basic computer usage, provided in Table 3, were used as a base-line comparison to the data obtained regarding CAI used to study GA.

Overall, students reported using Internet browsing (44.6%), PowerPoint presentation software (47.1%), and email (37.6%) on a daily basis to study GA (Table 4). There was a statistically significant difference ($p < 0.001$) in the proportion of students reporting daily use of the following computer applications to study GA: Internet browsing, word processing, spreadsheets, CD-ROMs/ DVD-ROMs, presentation software, and email. Word processing, spreadsheets, and CD-ROMs/ DVD-ROMs were used less frequently, with spreadsheets being the least used resource. Not surprisingly, instructor-made resources were quite popular with the students. There was a statistically significant difference ($p < 0.001$) in the proportion of students reporting the use of different types of instructor-made resources. Instructor-made handouts and PowerPoint presentations were used by a majority of students across all four participating campuses. In a typical didactic lecture, PowerPoint presentations are the predominant method of delivering anatomy content. GA course packets, consisting of detailed notes or outlines for each lecture, are typically provided to students at several of the IUSM campuses. Additional handouts could have been in the form of print-outs of the PowerPoint lectures. The use of CAI at one particular campus, IUSM-Northwest, stood out from the others. Here 81% of surveyed students reported using instructor-made CD-ROMs or DVD-ROMs to study GA. This campus utilized a problem-based

Table 4.—Frequency of use of resources to study gross anatomy. * = There was a statistically significant difference ($p < 0.001$) in the proportion of students reporting daily use of the following computer applications: internet browsing, word processing, spreadsheets, CD/DVD-ROMs, presentation software, and email.

Resource	Daily* %	Several times a week %	Several times a month %	Several times a year %	Less often %	Never %
Internet Browsing	44.6	35.0	14.0	1.3	1.3	3.8
Word Processing (Word, Wordperfect)	15.9	26.1	23.6	6.4	10.2	17.8
Spreadsheets (Excel)	5.1	16.4	19.0	3.8	19.6	36.1
CD-ROMs/ DVD-ROMs	1.3	8.4	13.0	4.6	13.6	59.1
Presentation Software (Powerpoint, Corel)	47.1	26.8	10.2	1.9	3.8	10.2
Email	37.6	29.9	10.8	0.6	9.6	11.5

learning (PBL) curriculum in a block schedule. Instructor made CD-ROMs and DVD-ROMs may have been used to provide students with electronic versions of handouts, PowerPoint lectures, or provide additional anatomy content to students as they work through PBL cases.

Not only was it beneficial to determine how often students used CAI resources, it was also important to discover whether or not the students found them useful. A majority of students reported that course websites, learning management systems (such as Blackboard), and PowerPoint presentation software were useful to study GA (by 80.9%, 89.2%, 89.7% of student, respectively). Email and reference websites (such as Wikipedia) were also reported as useful (by 75.8% and 69.8% of students, respectively). Although the overall use of CD-ROMs/DVD-ROMs was rather infrequent, they were seen as useful by 20.7% of participating students. There was a statistically significant difference ($p < 0.001$) in the proportion of students reporting that they found the following computer applications useful to study GA: Internet browsing, word processing, spreadsheets, CD-ROMs/DVD-ROMs, presentation software, and email.

The surveys indicated that the overall use of CD-ROMs/DVD-ROMs was dependent upon location (Table 5). Students at the IUSM-Northwest campus used CD-ROMs/DVD-ROMs more frequently (1/3 of students using them several times a week) than at the other reporting campuses. The sample size was too low to calculate the statistical significance of the proportion of students reporting frequent use (daily or several times a week) of CD-ROMs/DVD-ROMs to study GA by campus at the four IUSM campuses. However, there was a statistically significant difference ($p < 0.001$) in the proportion of students reporting that they never used CD-ROMs/ DVD-ROMs to study GA. A majority of students at both the IUSM-Indianapolis and the IUSM-Terre Haute campuses reported never using any CD-ROMs/DVD-ROMs to study GA.

The perceived usefulness of CD-ROMs/DVD-ROMs in general was also variable across the campuses (Table 6), which is most likely due to the differences in how often students at each campus

Table 5.—Frequency of use of CD-ROMs and DVD-ROMs to study gross anatomy at each IUSM Campus. * = There was a statistically significant difference ($p < 0.001$) in the proportion of students reporting that they never used CD-ROMs/ DVD-ROMs to study GA.

Campus	Daily %	Several times a week %	Several times a month %	Several times a year %	Less often %	Never* %
IUSM – Northwest	0	33.3	38.1	9.5	14.3	4.8
IUSM – Indianapolis	1.1	4.2	4.2	3.2	12.8	74.5
IUSM – Lafayette	6.3	6.3	37.5	6.3	12.5	31.2
IUSM –Terre Haute	0	4.4	8.7	4.4	17.4	65.2

Table 6.—Frequency of reported usefulness of CD-ROMs and DVD-ROMs to study gross anatomy at each IUSM Campus.

Campus	Useful %	Undecided %	Not useful %	N/A – Did Not Use %
IUSM-Northwest	61.9	23.8	14.3	0
IUSM-Indianapolis	10.5	27.4	3.2	58.9
IUSM-Lafayette	31.2	37.5	18.8	12.5
IUSM-Terre Haute	17.4	17.4	4.3	60.9

used them. At IUSM-Northwest, 61.9% of surveyed students found CD-ROMs/DVD-ROMs useful to study GA compared with only 31.3% of students at IUSM-Lafayette. However, there was no statistically significant difference ($p = 0.08$) in the proportion of students reporting that they found CD-ROMs/ DVD-ROMs useful for studying GA by campus.

We were particularly interested in determining if students used commercially available software for learning GA. Examples included *ADAM Interactive*, *Netter's Interactive Atlas*, *The Imaging Atlas of Human Anatomy*, *Primal 3D*, *The Dynamic Human*, CD-ROMs/DVD-ROMs accompanying textbooks of anatomy, *Thieme Image Collection*, *Acland's DVD Atlas*, and *The Visible Human Dissector* (Fig. 1). There was a statistically significant difference ($p < 0.001$) in the proportion of students reporting frequent use (daily or several times a week) of these commercially-available CAI resources. The three most used commercially available software programs were: 1) *The Imaging Atlas of Human Anatomy* (27.3%); 2) *Netter Interactive CD* (23.2%); and 3) *The Visible Human Dissector* (16.2%). However, they were not used frequently by many students. Instead, a majority of students did not use or were unaware of these commercially available anatomy instructional software packages (Table 7). Of the three most used programs mentioned above, *The Imaging Atlas of Human Anatomy* was used the most frequently, with 13.6% of students reporting usage daily or several times a week (Table 7).

To further investigate the use of these three resources, the usage frequencies were determined for each campus. Of the four participating campuses, IUSM-Lafayette was the only campus that showed a distinct pattern of use for these commercially available anatomy software programs. At IUSM-Lafayette, *The Visible Human Dissector* was the most frequently used software program. In fact, just over 75% of the students

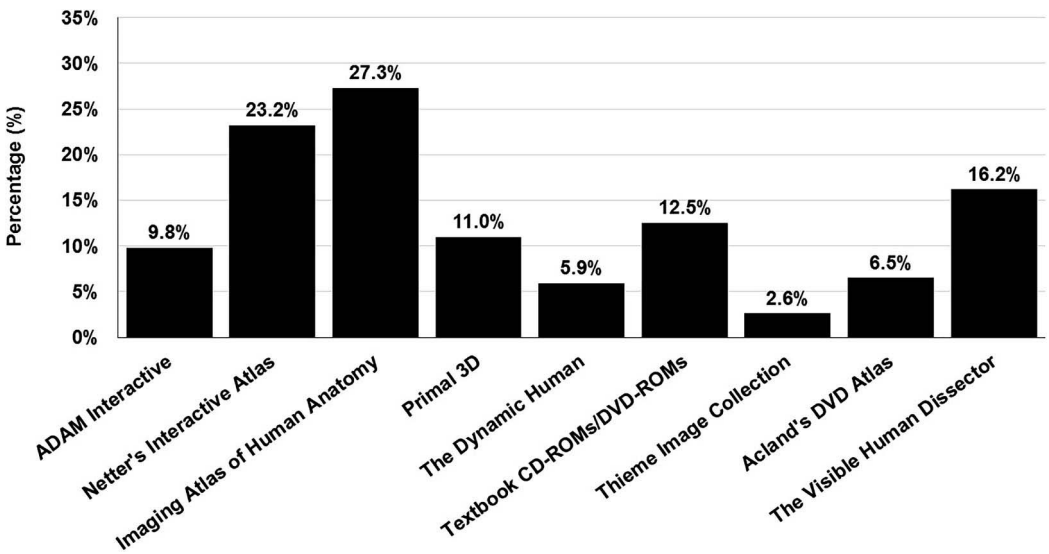

Figure 1.—Percentage of students at IUSM reporting use of commercially available anatomy software to study gross anatomy.

Table 7.—Frequency of use of commercially available anatomy software to study gross anatomy at each IUSM Campus.

Resource	Daily %	Several times a week %	Several times a month %	Several times a year %	Less often %	Never %	Have not Heard Of %
Netter's Interactive Atlas CD-ROM	0.7	5.8	7.1	1.9	7.7	65.8	11.0
Imaging Atlas of Human Anatomy	6.5	7.1	10.4	0.7	2.6	45.4	27.3
The Visible Human Dissector	0.7	6.5	3.2	4.5	1.3	42.9	40.9

used *The Visible Human Dissector* between several times a week and several times a month (Fig. 2).

In addition to using *The Visible Human Dissector*, over half (56.3%) of the students at IUSM-Lafayette made use of *The Imaging Atlas of Human Anatomy*, with 12.5% indicating daily use of this program (Fig. 3). These two resources were made available to students at IUSM-Lafayette in CD-ROM/DVD-ROM format; and a number of written exam questions came directly from the content of these resources. From the data obtained from this study, it is unclear whether the other IUSM campuses made use of these, or similar, resources.

From these observations it can be concluded that students at IUSM-Northwest use instructor-made CD-ROMs/DVD-ROMs frequently to study GA, and they generally found them useful. Data also suggest that students at IUSM-Lafayette used commercially available anatomy CD-ROMs/DVD-ROMs, and generally found them useful as well.

DISCUSSION

Overall, students reported using general computer applications, such as PowerPoint, web browsing, and email, most frequently to study GA. Email as a study method was an interesting and surprising finding. New technologies are changing the learning environment for professional students and studying is no longer limited to reading the textbook, attending class, and taking notes. Email as a study method could include submitting questions to the course instructor, or sharing notes, references, and websites with other classmates. Several studies have used email as an integral part of instructional

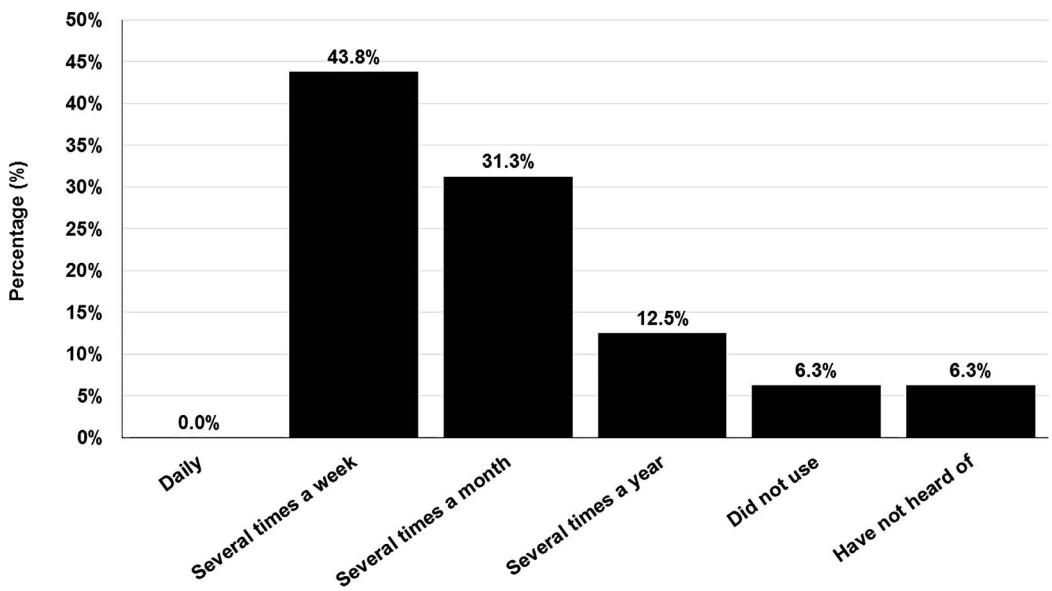

Figure 2.—Frequency of use of *The Visible Human Dissector* to study gross anatomy at the IUSM-Lafayette Campus.

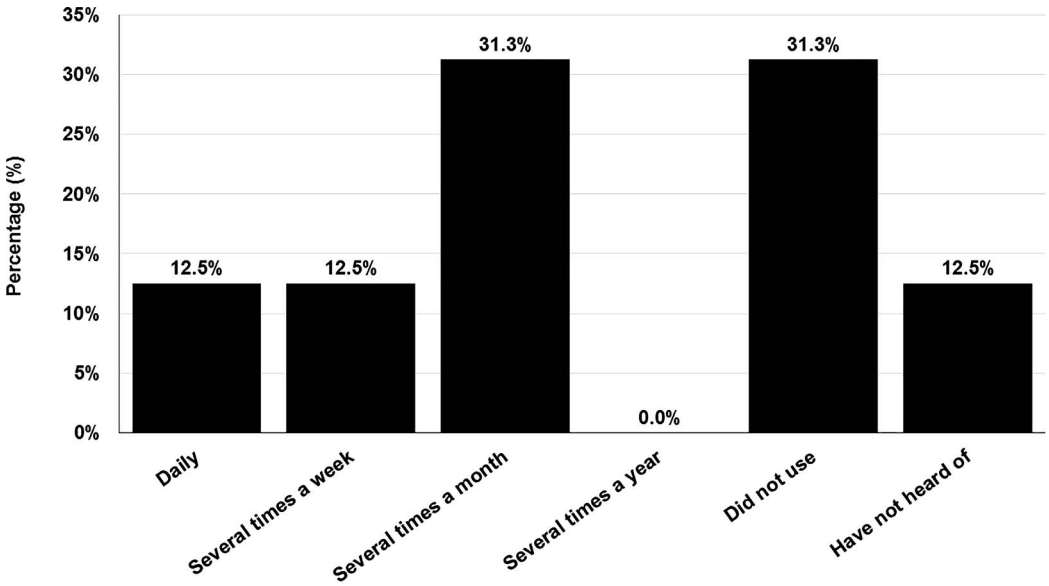

Figure 3.—Frequency of use of *The Imaging Atlas of Human Anatomy* to study gross anatomy at the IUSM-Lafayette Campus.

intervention activities (Kerfoot et al. 2012; Bow et al. 2013).

The distinction between technology as an educational tool versus technology as an integral part of instruction is blurring. Technologically-savvy students may have different perceptions of what qualifies as 'studying'. For example, Han et al. (2014) found that students perceived Google Docs, wikis, podcasts, YouTube, Google Calendar, Skype, and Learning Management Software (LMS) useful for learning. The addition of technology such as iPad apps, *Second Life, Twitter™,* and *Facebook* to the domain of instructional methods has further changed the way people study and learn (Lonn & Teasley 2009; Richardson et al. 2011; Richardson-Hatcher et al. 2013, 2014; Jaffar 2014; Lee & Gould 2014). Most of these computer applications do not explicitly fall within the category of CAI. A major drawback to these applications is that they may not provide relevant, correct, and up-to-date information. Raikos & Waidyasekara (2014) evaluated YouTube videos of the human heart and discovered that most were of poor quality and were not of sufficient detail for medical students. Vilensky & Steenberg (2015) had similar findings from their investigation of anatomy pages on Wikipedia. Lewis et al. (2014) performed a systematic search for iPad apps relating to anatomy. With no guidelines or standards for the content of apps, the concerns remain not just on the availability of recent and up-to-date information on the content in these learning apps, but also on the validity and appropriateness of the content.

The current study indicated that the use of CAI to study GA was limited. Students used instructor-made resources, but most students either did not use, or were unaware of, the commercially available anatomy software programs. Possible reasons for this are: 1) the programs were not available for the students; 2) the programs were available but the students were not explicitly informed about them; or 3) the students were informed that programs were available as supplemental study material, but the programs were not incorporated directly into the course. The availability of commercially prepared CAI programs for students may be challenging to address, requiring financial investment on the part of universities and/or students. However, textbooks like Moore's *Clinically Oriented Anatomy,* Netter's *Atlas of Anatomy*, and Gilroy's *Atlas of Anatomy* are now available in eBook format, making access to enhanced online study tools even easier. There are also many anatomy applications (apps) available for download onto tablets or smartphones.

This highly technology-driven generation of students with access to educational resources

literally at their fingertips may be expected to find useful online resources for their studies on their own. However, the time-intensive demands of medical school education along with the compressed design of anatomy taught in an integrated curriculum may prevent students from seeking out and identifying the best and most appropriate resources to aid their studies. In fact, Johnson et al. (2013) found that students expect the faculty to be able to direct them to appropriate resources. As experts in the field, anatomy faculty could advise students on the best CAI resources available.

Students tend to use resources that hold the most potential for directly improving their grades, as was illustrated by the frequency of use of instructor-made CD-ROMs/DVD-ROMs at IUSM- Northwest and by the frequency of use of *the Visible Human Dissector* and *The Imaging Atlas of Human Anatomy* at IUSM-Lafayette. The information from these programs was included as part of the GA exams at these campuses. Jastrow & Hollinderbaumer (2004), in their study of web-based resources and CD-ROMs in GA, found that students' "focus of interest was on material with relevance to current courses and examinations", while Jaffar (2012) found that "students preferred resources based on the expected benefits in examinations". Both of these results support the findings from the current study.

CAI is most effective when it is fully incorporated into a course rather than solely used as an optional resource (Jastrow & Hollinderbaumer 2004; Vivekananda-Schmidt et al. 2004; Kish et al. 2013). When CAI is provided as supplementary resources for GA courses, students' use of these resources is often inconsistent (McNulty et al. 2009). When asked why they did not use the CAI resources, students' common responses included: "1) technical difficulties with their computers; 2) lack of sufficient time; 3) other resources were more useful to their study; and 4) specific CAI did not fit their learning style" (McNulty et al. 2009). In light of the results of McNulty et al. (2009), the findings from the current study may not be unique to IUSM, and may have broader implications for developing and incorporating CAI into GA courses at medical schools across the country.

If, as in this study, students' use of CAI is limited mostly to instructor-made resources and materials directly incorporated into exams, the purpose of adding or creating additional resources should be carefully considered. Prior to spending countless hours creating and testing new CAI resources, instructors might consider tailoring one of the many programs already in existences to fit their course design, course objectives, and needs of the students (Doubleday et al. 2011; Robin et al. 2011). Along these similar lines, Attardi & Rogers (2015) critically evaluated ten commercial software programs prior to choosing Netter's 3D Interactive Anatomy as the program that would fit their needs best (Netter 2012). CAI can be a great tool to aid teaching and enhance the learning experience when used appropriately and in conjunction with other teaching tools. The focus of educators should be how CAI could address specific learning objectives within the anatomy curriculum (Tworek et al. 2013).

Although this study took place during a transitional period in CAI from CD-ROM/DVD-ROMs to Internet-based resources, the impact of the findings remains relevant. There is now a plethora of available resources online that are accessible via any mobile device (laptop, tablet, smart phone, ebook reader, etc.). Smart phone applications and YouTube videos can be created by just about anyone. So it is important to evaluate these resources critically, both for consistency with specified learning objectives and for potential use among students. CAI may enhance and maximize student learning when these resources are matched to course and curricular learning objectives. One of the most important findings from this study was that students were largely unaware of the commercially available GA resources. We are still in the midst of a technology revolution in medical education, so instructors should stay abreast of new technologies and actively evaluate how students choose to use these technologies as they study anatomy.

ACKNOWLEDGMENTS

We would like to thank our participants at Indiana University School of Medicine at the Northwest, Indianapolis, Lafayette, and Terre Haute regional campuses for their voluntary participation in this study. We would also like to thank the individuals who helped to distribute and administer the survey at each of these campuses.

LITERATURE CITED

Attardi, S.M. & K.A. Rogers. 2015. Design and implementation of an online systemic human

anatomy course with laboratory. Anatomical Sciences Education 8:53–62.

Bacro, T.R.H., M. Gebregziabher & J. Ariail. 2013. Lecture recording system in anatomy: possible benefit to auditory learners. Anatomical Sciences Education 6:376–384.

Baheerathan, A. & H. Selvaskandan. 2014. Smartphones and medical education. The Clinical Teacher 11:485–486.

Bow, H.C., J.R. Dattilo, A.M. Jonas & C.U. Lehmann. 2013. A crowdsourcing model for creating preclinical medical education study tools. Academic Medicine 88:766–770.

Cook, D.A., A.J. Levinson, S. Garside, D.M. Dupras, P.J. Erwin & V.M. Montori. 2010. Instructional design variations in internet-based learning for health professions education: a systematic review and meta-analysis. Academic Medicine 85:909–922.

Dørup, J. 2004. Experience and attitudes towards information technology among first-year medical students in Denmark: longitudinal questionnaire survey. Journal of Medical Internet Research 6:e10. doi:10.2196/jmir.6.1.e10.

Doubleday, E.G., V.D. O'Loughlin & A.F. Doubleday. 2011. The virtual anatomy laboratory: usability testing to improve an online learning resource for anatomy education. Anatomical Sciences Education 4:318–326.

Elisndo-Omana, R.E., J.A. Morales-Gomez, S.L. Guzman, I.L. Hernandez, R.P. Ibarra & F.C. Vilchez. 2004. Traditional teaching supported by computer-assisted learning for macroscopic anatomy. Anatomical Record Part B, New Anatomist 278B:18–22.

Ellaway, R.H., M. Pusic, S. Yavner & A.L. Kalet. 2014. Context matters: emergent variability in an effectiveness trial of online teaching modules. Medical Education 48:386–369.

Forman, L.J. & S.C. Pomerantz. 2006. Computer-assisted instruction: a survey on the attitudes of osteopathic medical students. Journal of the American Osteopathic Association 106:571–578.

Gould, D.J., M.A. Terrell & J. Fleming. 2008. A usability study of users' perceptions toward a multimedia computer-assisted learning tool for neuroanatomy. Anatomical Sciences Education 1:175–183.

Han, H., E. Nelson & N. Wetter. 2014. Medical students' online learning technology needs. The Clinical Teacher 11:15–19. doi:10.1111/tct.12092.

Hariri, S., C. Rawn, S. Srivastava, P. Youngblood & A. Ladd. 2004. Evaluation of a surgical simulator for learning clinical anatomy. Medical Education 38:896–902.

Hudson, J.N. 2004. Computer-aided learning in the real world of medical education: does the quality of interaction with the computer affect student learning? Medical Education 38:887–895.

Jaffar, A.A. 2012. YouTube: an emerging tool in anatomy education. Anatomical Sciences Education 5:158–164.

Jaffar, A.A. 2014. Exploring the use of a Facebook page in anatomy education. Anatomical Sciences Education 7:199-208. doi:10.1002/ase.1404

Jastrow, H. & A. Hollinderbaumer. 2004. On the use and value of new media and how medical students assess their effectiveness in learning anatomy. Anatomical Record Part B, New Anatomist 280B:20–29.

Johnson, I.P., E. Palmer, J. Burton & M. Brockhouse. 2013. Online learning resources in anatomy: what do students think? Clinical Anatomy 26:556–563.

Kerfoot, B.P., H. Baker, L. Pangaro, K. Agarwal, G. Taffet, A.J. Mechaber & E.G. Armstrong. 2012. An online spaced-education game to teach and assess medical students: a multi-institutional prospective trial. Academic Medicine 87:1443–1449.

Kesner, M.H. & A.V. Linzey. 2005. Can computer-based visual-spatial aids lead to increased student performance in anatomy & physiology? The American Biology Teacher 67:206–212.

Kish, G., S.A. Cook & G.T. Kis. 2013. Computer-assisted learning in anatomy at the international medical school in Debrecen, Hungary: a preliminary report. Anatomical Sciences Education 6:42–47.

Lang, W.P. 1995. Trends in students' knowledge, opinions, and experience regarding dental informatics and computer applications. JAMIA 2:374–382.

Lee, L.M.J. & D.J. Gould. 2014. Educational implications of a social networking application, Twitter™, for anatomical sciences. Medical Science Educator 24:273–278.

Leggate, M. 2012. Online resources for basic sciences. The Clinical Teacher 9:125–126.

Lei, L., W. Winn, C. Scott & A. Farr. 2005. Evaluation of computer-assisted instruction in histology: effect of interaction on learning outcome. Anatomical Record Part B, New Anatomist 284B:28–34.

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

Lewis, T.L., B. Burnett, R.G. Tunstall & P.H. Abrahams. 2014. Complementing anatomy education using three-dimensional anatomy mobile software applications on tablet computers. Clinical Anatomy 27:313–320. doi:10.1002/ca.22256.

Link, T.M. & R. Marz. 2006. Computer literacy and attitudes towards e-learning among first year medical students. BMC Medical Education 6:34. At: http://www.biomedcentral.com/1472-6920/6/34.

Linton, A., R. Schoenfeld-Tacher & L.R. Whalen. 2005. Developing and implementing an assessment method to evaluate a virtual canine anatomy program. Journal of Veterinary Medical Education 32:249–254.

Lonn, S. & S.D. Teasley. 2009. Podcasting in higher education: what are the implications for teaching and learning? Internet and Higher Education 12:88–92.

Lynch, D.C., T.W. Whitley, D.A. Emmerling & J.E. Brinn. 2000. Variables that may enhance medical students' perceived preparedness for computer-based testing. Journal of American Medical Informatics Association 7:469–474.

Magid, A.D., M. Miller & J. Levine. 1988. Computer literacy in a first year medical school class. Proceedings: The Twelfth Annual Symposium on Computer Applications in Medical Care: 888–892. At: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2245243/.

Mayfield, C.H., P.T. Ohara & P.S. O'Sullivan. 2013. Perceptions of a mobile technology on learning strategies in the anatomy laboratory. Anatomical Sciences Education 6:81–89.

McNulty, J.A., J. Halam, M.F. Dauzvardis & B. Espiritus. 2000. Evaluation of web-based computer-aided instruction in a basic science course. Academic Medicine 75:59–65.

McNulty, J.A., B. Sonntag & J.M. Sinacore. 2009. Evaluation of computer-aided instruction in a gross anatomy course: a six-year study. Anatomical Sciences Education 2:2–8.

Netter, F.H. 2012. Netter's 3D Interactive Anatomy. At: http://netter3danatomy.com/ (Accessed 31 March 2017).

Nieder, G.L., J.N. Scott & M.D. Anderson. 2000. Using QuickTime virtual reality objects in computer-assisted instruction of gross anatomy: Yorick - the VR skull. Clinical Anatomy 13:287–293.

Raikos, A. & P. Waidyasekara. 2014. How useful is YouTube in learning heart anatomy? Anatomical Sciences Education 7:12–18. doi:10.1002/ase.1361

Rich, P. & R. Guy. 2013. A "Do-It-Yourself" interactive bone structure module: development and evaluation of an online teaching resource. Anatomical Sciences Education 6:107–113.

Richardson, A., M. Hazzard, S.D. Challman, A.M. Morgenstein & J.K. Brueckner. 2011. A "Second Life" for gross anatomy: applications for multi-user virtual environments in teaching the anatomical sciences. Anatomical Sciences Education 4:39–43.

Richardson-Hatcher, A., M. Hazzard & J. Brueckner-Collins. 2013. Using a three-dimensional virtual platform to teach the pterygopalatine fossa. Medical Science Educator 23:308–312.

Richardson-Hatcher, A., M. Hazzard, C. Bentley, C. Gazave, T. Greenlee & J. Brueckner-Collins. 2014. Team-based learning in a 3D online environment. Medical Science Educator 24:11–14.

Robin, B.R., S.G. McNeil, D.A. Cook, K.L. Agarwal & G.R. Singhal. 2011. Preparing for the changing role of instructional technologies in medical education. Academic Medicine 86:435–439.

Saltarelli, A.J., C.J. Roseth & W.A. Saltarelli. 2014. Human cadavers vs. multimedia simulation: a study of student learning in anatomy. Anatomical Sciences Education 7:331–339. doi:10.1002/ase.1429.

Tworek, J.K., H.A. Jamniczky, C. Jacob, B. Hallgrímsson & B. Wright. 2013. The LINDSAY virtual human project: an immersive approach to anatomy and physiology. Anatomical Sciences Education 6:19–28.

Van Sint Jan, S., M. Crudele, J. Gashegu, V. Feipel, P. Poulet, P. Salvia, I. Hilal, V. Sholukha, S. Louryan & M. Rooze. 2003. Development of multimedia learning modules for teaching human anatomy: application to osteology and functional anatomy. Anatomical Record Part B, New Anatomist 272B:98–106.

Vilensky, J.A. & J. Steenberg. 2015. Anatomy and Wikipedia. Clinical Anatomy 28:565–567.

Vivekananda-Schmidt, P., A.B. Hassell & M. McLean. 2004. The evaluation of multimedia learning packages in the education of health professionals: experience of a musculoskeletal examination package. Nurse Researcher 11:43–55.

Manuscript received 16 January 2017, revised 7 April 2017.