

The Development and Assessment of an Online Microscopic Anatomy Laboratory Course

Michele L. Barbeau,¹ Marjorie Johnson,¹ Candace Gibson,² Kem A. Rogers^{1*}

¹Department of Anatomy and Cell Biology, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada

²Department of Pathology, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada

Increasing enrollment in post-secondary institutions across North America, along with an increase in popularity of and demand for distance education is pressuring institutions to offer a greater number and variety of courses online. A fully online laboratory course in microscopic anatomy (histology) which can be taught simultaneously with a face-to-face (F2F) version of the same course has been developed. This full year course was offered in the Fall/Winter (FW) terms in both F2F and online formats. To ensure that the online course was of the same quality as the F2F format, a number of performance indicators were evaluated. The same course, offered exclusively online during the summer with a compressed time frame, was also evaluated. Senior undergraduate students self-selected which version of the course they would enroll in. Course assessment outcomes were compared while incoming grades were used as a predictor for course performance. There were no significant differences between the incoming grades for the F2F FW and Online FW courses; similarly, there were no significant differences between outcomes for these formats. There were significant differences between the incoming grades of the F2F FW and Summer Online students. However, there were no significant differences among any of the outcomes for any of the formats offered. Incoming grades were strong, significant predictors of course performance for both formats. These results indicate that an online laboratory course in microscopic anatomy is an effective format for delivering histology course content, therefore giving students greater options for course selections. *Anat Sci Educ* 00: 000–000. © 2013 American Association of Anatomists.

Key words: microscopic anatomy education; online education; histology; virtual microscopy; incoming grades; student outcomes; virtual classroom

INTRODUCTION

Online Education

Online courses are a popular option for students who are juggling courses and life outside of their studies. Growth in online course enrollment exceeds that of enrollment in higher

education overall. In the United States, there was a 17% increase between 2008 and 2009 in online enrollment compared to a 1.2% increase in the overall enrollment in higher education over the same time period with 25% of all undergraduate students taking at least one online course. Millennial students born between 1982 and 2001 (Strauss and Howe, 1991), who make up the current cohort of undergraduate students, have been shown to embrace technology and are a part of the force driving institutions to increase their online course offerings (Mangold, 2007; DiLullo et al., 2011). This trend is expected to continue for a number of years (Allen and Seaman, 2010) and with growth in this area of education, it is important to ensure that the online courses are of the highest quality and equivalent to the educational experience that students would receive in a traditional face-to-face (F2F) format.

A meta-analysis examining 232 studies published between 1985 and 2002 compared online distance education to F2F

*Correspondence to: Dr. Kem A. Rogers, Department of Anatomy and Cell Biology, Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada, N6A 5C1. E-mail: kem.rogers@schulich.uwo.ca

Received 28 June 2012; Revised 23 November 2012; Accepted 5 December 2012

Published online in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/ase.1347

© 2013 American Association of Anatomists

instruction (Bernard et al., 2004). The overall results indicated a small but significant advantage to distance education, however, the authors noted that there was wide variability among the studies and cautioned against interpreting the results as being equal to, better, or worse than classroom education. A more recent meta-analysis examined 125 studies published between 1990 and 2009 comparing online distance education to F2F instruction in a variety of different subject areas and student levels (Shachar and Neumann, 2010). Their overall findings showed that in 70% of these studies, the outcomes for the online students were better than those for the traditional courses. Additionally, the meta-analysis found that, with increased exposure to the new technology, comfort and familiarity with the format on the part of both instructors and students increased, resulting in increased student performance overall. Less than 70% of the studies published before 2002 reported results favoring online education while in studies published after 2003, 84% of the studies favored online education (Shachar and Neumann, 2010). In summary, steady improvements in student outcomes in online courses have been shown over time (Bernard et al., 2004; Shachar and Neumann, 2010).

Science courses which utilize an online component to support F2F lectures are considered to be “blended” or “hybrid” in nature (Ruiz et al., 2006). A review of internet-based learning in the health professions has shown that, when compared to no intervention, internet-based or online learning lead to an improvement in student outcomes. However, when compared to other non-internet computer aided methods, there was no significant improvement in learning outcomes (Cook et al., 2008). Despite the seeming lack of learning outcome benefit using online resources, there are benefits in other areas, including increased availability of courses to students and savings on laboratory or teaching resources (Sung et al., 2008). Results from studies incorporating online components into F2F courses have shown improved outcomes (Rosenberg et al., 2006; Sung et al., 2008; McNulty et al., 2009) or no change in performance (Bryner et al., 2008; Dantas and Kemm, 2008; Mahnken et al., 2011). A study of a physiotherapy course incorporating a blended learning component showed no improvement in knowledge acquisition; however, skill acquisition was much improved, suggesting that the online component was a beneficial supplement to the F2F component (Arroyo-Morales et al., 2012). Surveys of students using these resources show that students overwhelmingly perceived the online components as helpful (Khogali et al., 2011) including the one study showing no improvement in learning outcomes (Bryner et al., 2008).

Studies looking at exclusively online laboratory courses in higher education have also shown promising results. One such study compared an online laboratory on cell division with a F2F laboratory and found that the online students performed significantly better on the quiz covering that material the following week (Gilman, 2006). The authors point out some shortfalls in their study, including the presence of different instructors for the online versus the F2F laboratories, which could have impacted outcomes and the fact that only one laboratory session was analyzed. Another study compared student perceptions of online laboratories to F2F laboratories in an online biology course (Stuckey-Mickell and Stuckey-Danner, 2007). Results showed that 86.9% of the students agreed or strongly agreed that the F2F laboratories enhanced their understanding of the course content compared to only 60.8% for the online laboratories. For all questions

in their survey, F2F laboratories scored higher compared to the online laboratories. Open ended student comments suggested that the preference for the F2F laboratories was due to the perception that the students can ask questions and receive immediate feedback from the instructor and other students which enhanced their understanding of the course content. They suggested using discussion boards and synchronous online conferencing to increase instructor communication with the students along with the incorporation of collaborative assignments to increase student-to-student interaction. These studies have shown that fully online laboratory courses are effective, however, some limitations may exist which relate to communications.

Virtual Microscopy

Traditionally, microscopic anatomy courses have included viewing glass specimen slides as a component of laboratory exercises. However, innovations in technology have recently allowed for glass slides to be scanned and converted to digital images and viewed on computers with the same visual manipulation as traditional microscopes; effectively replacing the need for microscopes in the laboratory (Lundin et al., 2009; Helle et al., 2011). A recent survey by the American Association of Anatomists indicated that the majority of institutions offering microscopic anatomy courses now use virtual microscopy, either exclusively or in combination with traditional microscopy, confirming that this technology has become commonplace in the histology teaching laboratory (Drake et al., 2009).

Typically, laboratory exercises allow students the opportunity to discover the course material in a “hands-on” way. A histology pre-laboratory talk, using glass or virtual slides to show relevant structures live, has been shown to enhance learning (Higazi, 2011). Students then turn to their own slide collections to find these structures and complete assignments. Histology textbooks and atlases traditionally present exemplars of structures that students are required to locate; but exemplars rarely appear in the eyepiece of a microscope. The students are then forced to use their knowledge to relate the specific structural example before them to the image from the text. This is a valuable learning experience. In the histology laboratory, students are usually asked to examine slides using the microscope and find different cells or tissues. Students learn how to “read” the slide (Cotter, 2001). Often these slides may contain imperfections or artifacts such as folds, debris, or poorly stained areas. Through the laboratory exercises, the students learn how to evaluate the slides and find examples of the structures they are looking for (Bloodgood and Ogilvie, 2006). This evaluation process would be lost if they were only presented with textbook images of the structures being studied. Virtual microscopy retains this valuable learning experience and because only a computer and internet connection are required, virtual microscopy is ideally suited to the online education environment (Sinn et al., 2008; Helle and Säljö, 2012).

There have been many attempts to validate virtual microscopy as an educational tool in comparison to traditional microscopy (Harris et al., 2001; Krippendorf and Lough, 2005; Goldberg and Dintzis, 2007; Scoville and Buskirk, 2007; Braun and Kearns, 2008; Pinder et al., 2008; Husmann et al., 2009). These studies have found student outcomes to be either equivalent to (Scoville and Buskirk, 2007; Braun and Kearns, 2008; Pinder et al., 2008) or better than

(Goldberg and Dintzis, 2007; Husmann et al., 2009) those where traditional microscopy was used. Additionally, several studies have shown that virtual microscopy provides a more efficient method of learning over traditional methods when considering logs of student study hours and overall performance (Krippendorf and Lough, 2005; Braun and Kearns, 2008). In addition to student outcomes, these studies also included survey responses from students. Many students preferred using the virtual microscope, for reasons including ease, accessibility, and the ability to collaborate more easily. For example, Bloodgood (2012) has described an effective group active learning and peer teaching exercise utilizing the collaborative aspects of virtual microscopy. A survey of instructors has echoed these students' comments with the added caution that, with the availability of the virtual microscope outside of class time, students may not be using class time optimally (Collier et al., 2012). For the institution, there are significant advantages to adopting digital microscopy, inclusive of maintaining the availability of high quality slides (specimens) for all of its students and ultimately saving on costs associated with slide and microscope maintenance. It is, however, initially time consuming and costly to digitize the slides but these costs are recouped through decreased maintenance costs. One of the main criticisms of virtual microscopy is that students do not gain microscopy skills; however, the use of the virtual microscope itself is becoming a necessary skill as its use increases in clinical and continuing educational settings as well as competency evaluations (Lundin et al., 2004; Coleman, 2009; Fred, 2009; Lundin et al., 2009; Pratt, 2009; Shaw and Friedman, 2012).

There have been attempts to teach histology online with promising results (Schoenfeld-Tacher et al., 2001). The laboratory component of the course studied involved having the students view micrographs taken at various magnifications. Although not stated, it is assumed that the F2F students used a microscope to complete their assignments, as the micrographs were supplied at various magnifications "to simulate the process of moving a microscope objective" (Schoenfeld-Tacher et al., 2001). In this example, online students would lose the opportunity to evaluate the whole slide (Cotter, 2001). Despite the differences in the laboratory exercises for each format, the online student out-performed the F2F students on the assessments. A study where the laboratory exercises are more similar to each other, with only the format of delivery differing, would be a preferable way to evaluate the laboratory component of such a course.

In 2011, Western University in London, Ontario, Canada, like many other North American universities, welcomed its largest first year class in history (Snyder and Dillow, 2011; Travis, 2011). This trend of increased university enrollment is expected to continue for at least the next decade (Hango and de Broucker, 2007). As universities face increasing pressure to accept and train greater numbers of students with limited space and budgets, creative solutions must be developed to accommodate them. In this article, the development and evaluation of a fully online undergraduate science laboratory course in microscopic anatomy (histology) which offered the same content as our traditional F2F histology laboratory course has been described. Both the lecture and laboratory material were delivered using the online format. In order to ensure that the online students received an experience equivalent to that of the F2F format, for both the lecture and laboratory component, this study has been designed to address the following objectives:

1. To assess student outcomes for the various assessments used in the course.
2. To assess the predictability of students' incoming grades on course outcomes in either format.

Hypothesis: Using synchronous videoconferencing software to create a virtual classroom accompanied by virtual microscopy technology, it is possible to offer an effective microscopic anatomy laboratory course to students online.

MATERIALS AND METHODS

Approval to conduct this study was given by Western University's Office of Research Ethics (protocol no. 17426E).

Virtual Slidebox

The virtual slidebox was created using the Aperio ScanScope CS (Aperio®, Vista, CA) digital slide scanner. The slide collection used for the laboratory component of the F2F course (140 slides) was scanned at $\times 40$ and images were stored on a dedicated server. They were arranged into groups according to the topics covered in the laboratory outline and placed on a web page. Students in both the F2F and online sections of the course had access to the virtual slidebox.

Course Design

Both formats of the histology course use the WebCT platform (Blackboard Inc., Washington, DC) to organize course materials such as syllabus, notes, virtual slidebox, and laboratory manual. The online version of the course has an additional icon linking to the virtual classroom, provided by Wimba Classroom, version 6.1.5 (Wimba Inc., New York, NY). A histology textbook and atlas were required for both groups of students (Ross and Pawlina, 2011). The virtual classroom allows students to participate either synchronously, by joining the lecture in real time or asynchronously by watching archives of the live lectures. Students participating in the live lecture can respond to questions posed by the instructor or ask questions themselves. Due to the large size of the F2F class, a teaching assistant is placed in the audience to monitor the online students and present their questions to the professor as required.

The F2F and online lectures were given simultaneously and recorded using the virtual classroom. The equipment required was portable, available from any electronics store, and fit into a backpack. The equipment could be set up quickly and taken down in the time between lectures. The contents of the virtual classroom backpack included: (1) an high definition video camera (Canon M30 HD, Canon Canada Inc., Mississauga, ON) and tripod used to capture the instructor and any supplementary equipment; (2) The Pinnacle Dazzle Video Creator Plus HD (Pinnacle Systems Inc., Mountain View, CA) to convert the video signal to a digital signal; (3) A wireless microphone used for audio for both the F2F and online classes; (4) A laptop computer to connect to the virtual classroom via the internet and the classroom projector. All of the above components were connected using the appropriate cables (F2F internet, video, audio, and projector). The total additional cost for the equipment to provide the lectures both F2F and online was approximately \$1,200 USD.

This course was taken by students in their third or fourth year of an undergraduate medical sciences baccalaureate program. It was offered three times over the course of this evaluation; once as a full year course over the fall/winter terms (FW; 25 weeks), and over two sequential summer terms (12 weeks each). The FW course consisted of two lecture hours and three laboratory hours per week (50 lecture hours, 75 laboratory hours, 125 total hours), while the condensed summer course consisted of four lecture hours and six laboratory hours per week (44 lecture hours, 69 laboratory hours, 113 total hours). The FW course was offered in either fully F2F ($N = 116$) or fully online formats ($N = 47$) while the summer courses were offered exclusively in the online format ($N = 73$). During the FW terms students self-selected which format they preferred to take. Students in the F2F course did not have access to the virtual classroom or the archived lectures but were able to access the virtual slidebox.

The F2F laboratory consisted of a pre-laboratory talk where the instructor highlighted the tissues covered in that day's topic. Following the pre-laboratory talk, the students used their microscopes with glass slides and/or the virtual slidebox to complete assignments consisting of drawings of important structures and applied questions. Students submitted their assignments by the end of the laboratory session. The online laboratory was delivered and completed entirely online. There was a pre-laboratory talk given by the instructor within Wimba Classroom to highlight the tissues of the laboratory period. The pre-laboratory talk was recorded and archived for online students not present during the live talk for access within 24 h. The F2F students did not have access to the archives. The online assignment consisted of locating important structures using the virtual slidebox, annotating, and saving images as well as answering applied questions. These assignments were submitted within 24 h of the pre-laboratory talk.

Course Performance

Course outcomes were measured using the following grading system: 50% of the final grade was obtained from the laboratory component and 50% from the lecture component. The laboratory components consisted of weekly laboratory assignments, six practical quizzes, and two practical examinations. The F2F students completed the laboratory assessments during the laboratory period. Laboratory quizzes and examinations were taken in a proctored environment for the F2F students, while the online students completed all laboratory components online in a non-proctored environment. The quizzes and examinations had time restrictions for both groups. Both online and F2F students received feedback on their weekly assignments and other assessment measures the week following their completion. The lecture component was assessed using two multiple choice examinations, one at the end of each term, based on the lecture material only. Both sections completed the same multiple choice examinations at the same time in proctored examination rooms.

Previous Grades

The majority of students taking the histology course were enrolled in the undergraduate Bachelor of Medical Sciences (BMSc) or biology programs (see Table 1 “ n ” values). Administrators for the BMSc program provided grades for

Table 1.

Foundation Course Average (FCA) for Students Enrolled in Each Course Offering

Students	N^a	n^b	FCA (mean \pm SD)
F2F—Fall/Winter (2010/2011)	116	113	75.1 \pm 10.0
Online—Fall/Winter (2010/2011)	47	43	71.6 \pm 8.3
Combined online summers (2010/2011)	73	66	69.2 \pm 9.0 ^c

^aTotal number of students enrolled in the course.

^bNumber of students whose foundation course average (FCA) data were included in the study.

^cIndicates a significant difference between Fall/Winter F2F and Online Summer courses ($P < 0.05$).

the second year “foundation courses” in the form of Foundation Course Averages (FCA). These courses are common to all BMSc students and include: cell biology, genetics, biochemistry, organic chemistry, and statistics. Those students not enrolled in the BMSc program were not included in this portion of the study. These grades were used to determine whether there is a predictive correlation between previous grades and course performance. Students were grouped according to their FCA, and each group compared among the course formats to determine whether there were differences at the various grade level groupings for the final course grade as well as the total laboratory grade (Table 2).

Course Evaluations

Institution instructor and course evaluations were collected for all course sections. F2F students completed these evaluations in person during the laboratory time while FW and Summer Online students were emailed institutional evaluations.

Statistical Analysis

Differences between course assessment outcomes were compared using a one-way ANOVA ($P \leq 0.05$) and a Bonferroni correction to determine significant differences among the course sections. Significant correlations between previous grades and final histology course grades were determined using Pearson's correlations ($P \leq 0.05$). Significant differences among overall course evaluation scores were determined using a student's t test ($P \leq 0.05$). The IBM SPSS statistical package, version 19 (IBM Corp., Armonk, NY) was used for the analysis.

RESULTS

The Virtual Classroom

The simultaneous delivery of the F2F and online lectures during the FW term was facilitated through the use of the virtual classroom software Wimba Classroom. Contents of the virtual classroom backpack were used to capture the live lecture for simultaneous transmission to online students and for

Table 2.

Comparison of Ranked Incoming Grades (FCA) vs Final Course Grade and Laboratory Grade

FCA	Fall/Winter F2F		Fall/Winter Online		Summer Online				
	N	Final (mean% ± SD)	Laboratory (mean% ± SD)	N	Final (mean% ± SD)	Laboratory (mean% ± SD)	N	Final (mean% ± SD)	Laboratory (mean% ± SD)
<69	33	62.5 ± 4.7	63.2 ± 17.5	16	62.8 ± 4.1	70.0 ± 19.0	38	62.8 ± 5.1	72.9 ± 10.0
70–74	18	72.7 ± 1.5	70.5 ± 13.8	12	71.9 ± 1.4	74.0 ± 14.4	5	71.4 ± 1.0	75.4 ± 10.2
75–79	26	77.5 ± 1.3	79.7 ± 9.0	7	77.6 ± 1.3	85.5 ± 8.9	17	77.0 ± 1.2	79.9 ± 13.9
80–89	30	85.0 ± 2.7	84.7 ± 7.0	8	83.6 ± 1.3	87.3 ± 6.3	5	84.6 ± 3.1	92.3 ± 3.4
>90	6	92.2 ± 0.7	89.8 ± 5.3	0			1	96.5	99.0

Note that there were no significant differences within each ranking among the course formats ($P > 0.05$); FCA, foundation course average; F2F, face-to-face.

archival purposes. Within the virtual classroom, the video camera provided a live image of the instructor and any supplementary props that were in use, while the main screen of virtual classroom displayed the lecture slide and any annotations made by the instructor (Fig. 1). Audio, video, and the slide presentation including annotations were captured in the archived file. In addition, the Wimba Classroom interface used for the virtual classroom lists the online students in attendance at the bottom of the screen, as well as areas where students can “raise their hands” to participate verbally and a chat area for them to communicate with the instructor or each other using text (Huijser et al., 2008) (Fig. 1). The online students who participated in the synchronous (live streaming) lecture could ask questions in real time using these areas. Either method allows the instructor and or the teaching assistant in the classroom to respond immediately (Tagge, 2009). In addition, the instructor is able to incorporate polling questions into the lecture where students can enter their answer and the survey results can be immediately displayed. This gives an overall picture of the class responses in much the same way that “clickers” or personal response systems are incorporated into F2F lectures to enhance learning (Mayer et al., 2009).

The weekly F2F laboratories consisted of a pre-laboratory talk where ideal photographs of the tissues being examined were briefly projected and reviewed by the instructor. The students had a laboratory outline to guide their study, their own microscope, and a complete glass slide collection as well as access to the digitized version of these slides through the virtual slidebox. During the laboratory time, the instructor and teaching assistants circulated throughout the room, answering questions and discussing slides with the students. At the completion of the laboratory, each student submitted an assignment consisting of drawings of relevant structures or tissues and answers to applied questions (Fig. 2A).

The laboratory experience for the online students was similar to that of the F2F students, insofar as there was a pre-laboratory talk using the virtual classroom. However, online students were shown relevant images using slides from the virtual slidebox. This talk would be archived for those students who were not attending synchronously. The students would then use the laboratory outline and the virtual slidebox to complete an assignment similar to the F2F students.

Instead of drawing the structures, students would have to find areas on the virtual slides, annotate, and save them for submission as part of the assignment (Fig. 2B). During the online laboratory time, the instructor remained in the virtual classroom to answer any questions or discuss slides with the students. Application sharing, a tool available in the virtual classroom, permitted the students to share their desktop with the instructor who could respond to common histology laboratory queries including “what am I looking at?” or “where can I find that feature?” mimicking the experiences of students in a F2F laboratory (Huijser et al., 2008). Those students who did not attend the synchronous laboratory session had the opportunity to ask questions through email. Analysis of student logins to the virtual classroom shows that, over the time period of the course, students took advantage of both live and archived lecture and laboratory sessions.

Pre-course Data Analysis and Student Demographics

Course enrollment numbers and mean FCAs are listed in Table 1. There were no significant differences between student FCA for the FW F2F and FW Online courses, which were offered concurrently. There was a significant difference between the FW F2F and Summer Online FCA. Although normally distributed, the grades for the Summer Online students showed a tendency for either higher achieving or weaker students in comparison to the FW Online group which showed a more even distribution (Table 2).

Results for each assessed outcome are given in Figure 3. There were no significant differences between the course outcome means for the FW F2F or FW Online formats, which were offered simultaneously. Also, despite having a significantly lower FCA for the Summer Online students, there were no significant differences among the course outcome means for any of the course sections.

Course Evaluations

Institutional course evaluations for online and F2F courses varied in the questions asked, however, both asked questions pertaining to student’s overall satisfaction with the course.

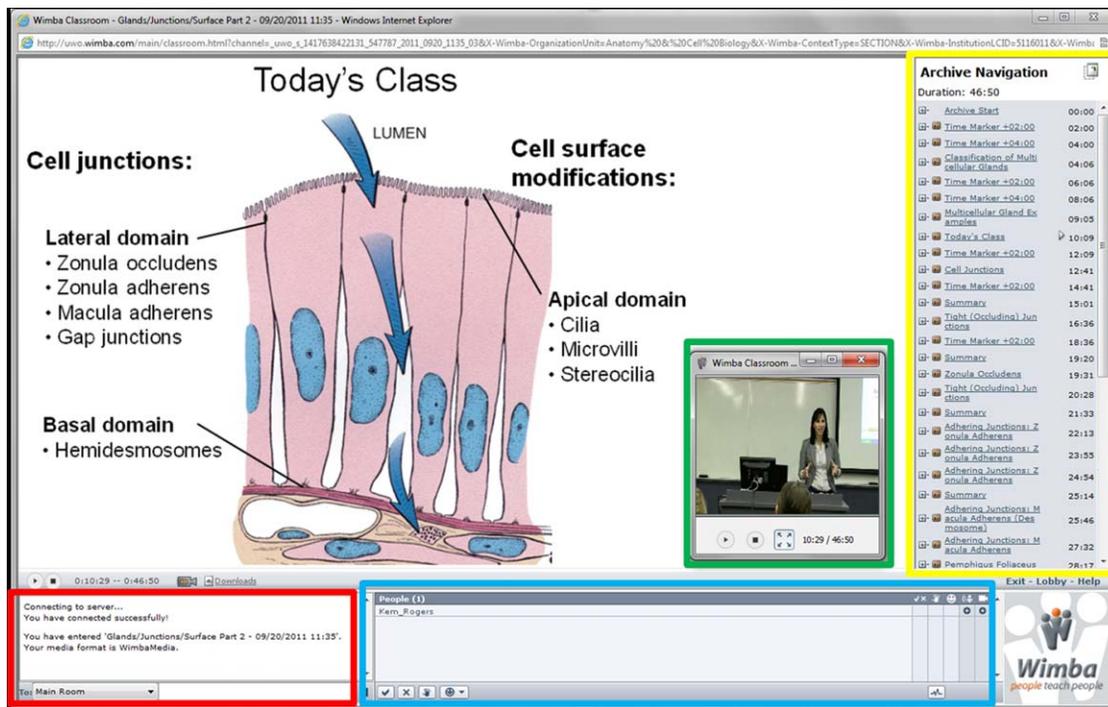


Figure 1.

Image of student view of the interface of an archive from the online classroom. The main area of the screen displays the lecture content. A smaller video window (green box) displays the lecturer or can be directed to show any additional instructional aides. The lower left corner of the screen (red box) is the chat area where students can participate in the lecture using text. Along the bottom of the screen (blue box) is a list of students present along with tools such as a hand raise to alert the instructor that a student has a question. The column on the right (yellow box) displays the list of slides with time markers in the archive allowing students to fast forward or reverse through the lecture. Sample image taken from Ross and Pawlina (2011).

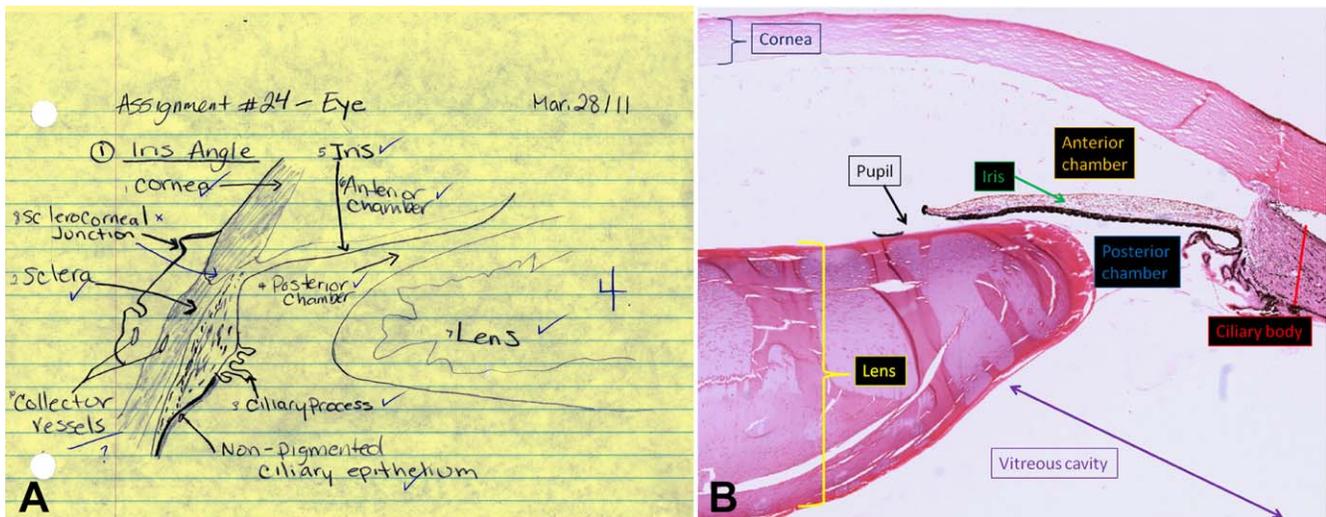


Figure 2.

Comparison of F2F and online laboratory assignments. A: The image shown here is an example of typical laboratory assignments in F2F course. Student draws an image from the microscope and glass slide collection. B: Represents an online assignment completed using annotated images from the virtual slide collection. Students are graded based on appropriately labeled structures.

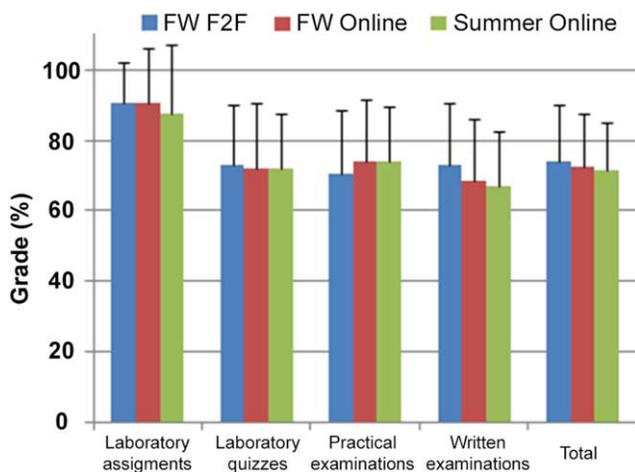


Figure 3.

Comparison of course outcomes expressed as means \pm SD for different course sections: FW F2F, FW Online and Summer Online. Course outcomes shown include laboratory assignments, laboratory quizzes, laboratory practical examinations, and written examinations. Total columns represent the final grade consisting of the combined weighted grades of the previously listed outcomes. There were no significant differences among the course sections for any of the outcomes measured ($P > 0.05$).

For the online evaluations, the questions pertaining to the course were averaged to give an overall grade. This grade was compared to the F2F evaluation question rating the overall effectiveness of the course. Both evaluations contained open ended questions where students were free to comment on both positive and negative aspects of the course. Table 3 is a summary of the number of student responses and the overall course rating. There were no significant differences among overall course ratings ($P > 0.05$). Online student comments were overall very positive with a few notes about occasional technological glitches. One online student, whose opinion was also shared by the majority of respondents, expressed amazement at how technology had been effectively used to deliver the course:

“I very much enjoyed this course! I am astounded at the technologies used to enable students to take labs online and I look forward to being able to take more courses such as this one online again. The archived lectures were amazing for missed points and to be able to watch at your leisure”

Previous Grades as a Predictor of Student Performance

Pearson’s correlation statistics showed that there were significant, positive correlations between the FCA and the student’s final course grade for each section of the course ($P \leq 0.05$) (Fig. 4). In general, most students performed as expected, such that individuals with historically high FCAs performed better than those with lower averages. The correlations were stronger for the FW F2F and Online Summer courses ($r(111) = 0.75, P < 0.05$; $r(64) = 0.67, P < 0.05$) while the correlation for the FW Online was still significant but weaker ($r(41) = 0.55, P < 0.05$).

Table 2 shows the final course and laboratory means for students based on their FCA grouping. There were no significant differences within each FCA grouping among the course formats for either the laboratory grade or the final course grade. Note that, in the two online groups, but not in the F2F group, several outliers could be identified where their performance was not indicative of earlier FCAs.

DISCUSSION

This article describes a method of delivering an undergraduate histology laboratory course that is low-cost and easy for faculty to adopt as a teaching method. Results indicated that it is an effective and equivalent learning experience for students in comparison to the same F2F course. With historically high post secondary enrollments and the expectation that this trend will continue, universities must find novel methods for delivering courses as infrastructure resources approach capacity. Online courses allow students scheduling flexibility, relieve the institution’s infrastructure and faculty limitations, and allow more students to enroll in courses (Zhou and Talburt, 2011). Virtual microscopy, commonly used to teach histology, lends itself beautifully to an online laboratory, thus making microscopic anatomy, taught with a laboratory component, ideally suited to the online environment (Sinn et al., 2008). Indeed, many studies have shown that adding an online laboratory component to a F2F course, as in a blended or hybrid course, enhances student outcomes and is well accepted by the students (Heidger et al., 2002; Rosenberg et al., 2006; Bryner et al., 2008; Dantas and Kemm, 2008; Khogali et al., 2011). The course described in this study had both lecture and laboratory components fully online; therefore, adding to the choices students have for distance education online laboratory courses in the sciences.

The Virtual Classroom

Provided an institution has the software license for a virtual classroom (i.e., Wimba Classroom), the additional equipment required to simultaneously deliver F2F and online lectures is inexpensive and easily obtained. Institutional technical support is also required to deal with any problems that may arise. There were some initial problems with students gaining access to the virtual classroom but these were quickly

Table 3.

Response Rates and Overall Course Score for Institutional Course Evaluations

Course	Responses, n (%)	Overall Score ^a , mean \pm SD
Fall/Winter F2F	108 (93.1)	5.8 \pm 1.1
Fall/Winter Online	3 (6.3)	6.2 \pm 0.8
Summer Online (2011 only)	13 (36)	5.5 \pm 1.1

^aOverall score was based on a seven-point Likert scale: 1 = very poor and 7 = outstanding; There were no significant differences among overall scores ($P > 0.05$); F2F, face-to-face.

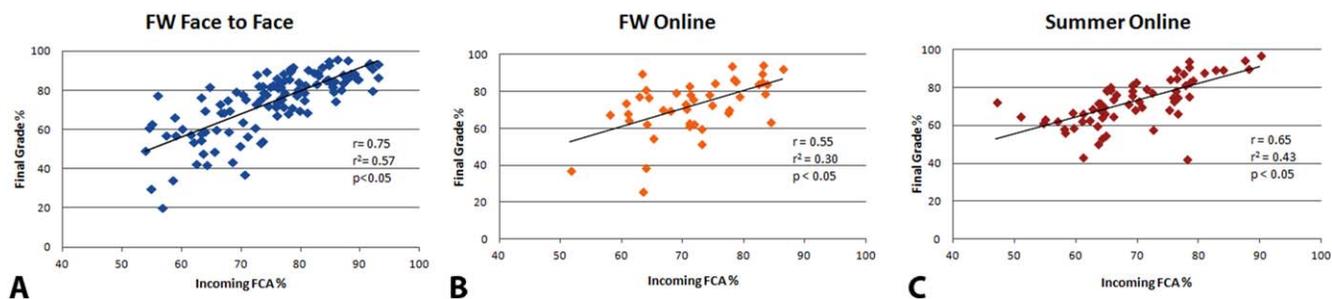


Figure 4.

Scatter plots comparing final course grade with incoming grades (FCA). A: FW F2F; (B) FW Online; (C) summer online courses. Significant positive correlations were found for all formats with stronger correlations for FW F2F and Summer Online compared to FW Online. Outliers whose FCAs were not predictive of their final course grade could be identified in both online sections (panel B and C).

resolved by adjusting computer settings. After the first week of class, there were very few student access issues.

The virtual classroom backpack allows the virtual classroom to be set up in any lecture hall with a high speed internet connection. The virtual classroom equipment can be quickly assembled or disassembled during the short time between lectures, typically 10 min at our institution. Instructors can easily upload presentations into the virtual classroom and use the instructor tools to annotate slides during the lecture. Teaching aids such as videos and web links commonly used to enhance traditional lectures can also be incorporated into the online classroom. In order for students to get the best experience in the online class, a high speed internet connection is required, thus preventing individuals from participating in remote underserved areas.

Student Outcomes

For the most part, student performance in the online and F2F versions of the course was the same. Despite the fact that students self selected for the course version (random enrollment could not ethically be forced upon the students) there was no significant difference between these groups with respect to their FCAs. This allowed each group to be treated as initially equivalent in terms of past performance. In addition, online students had the option to attend lectures live online or view the lecture archive at a later time, while the F2F students only had the option of the live lecture. There was a direct correlation between student's FCAs and their performance in this course irrespective of the format. The correlation was weaker for the FW Online format, possibly because of a smaller *n* or the presence of several outliers in the data set. The Summer Online students had a significantly lower FCA compared to the FW F2F students. Often, summer students are making up a missed course or one where they had performed poorly, giving this group a lower FCA. However, there were no differences in the outcome means for these students compared to the other groups.

An examination of the final grade and laboratory grade means based on student's FCA groupings also showed that students performed as expected with no differences among the course sections for any of the FCA grade ranges. This

finding was especially important for students with FCA's less than 75% as online courses have been suggested to be not as effective for weaker students (Jaggars and Bailey, 2010). A previous study, comparing predictors of academic performance in distance education delivery platforms to science/math grade point average and Pharmacy College Admissions Test scores (PCAT), showed these measures to be significant predictors of performance in both test groups (Ried and Byers, 2009). However, these students were admitted to a program (Pharmacy) based on their incoming grades and PCAT scores, thus biasing the data in favor of high achieving students. Similarly, a study which examined factors which predicted medical student's performance in a microscopic pathology course found a significant correlation between the previous histology and cell biology grade and the results on microscopy examinations as well as final examination grades (Helle et al., 2010). These students would also be high achieving students for entry into medical school. In contrast, previous performance of undergraduate students examined in our study was highly variable. Despite these differences these studies found similar predictive relationships between prior performance and course outcomes.

Reductions in instructor-to-student and student-to-student interactions have been identified as possible weaknesses in online courses (Stuckey-Mickell and Stuckey-Danner, 2007; Hale et al., 2009). There is a perception that online courses inherently limit student access to the instructor, and thus weaker students taking an online course may be at a disadvantage in comparison to traditional F2F offerings (Leasure et al., 2000; Jaggars and Bailey, 2010). Similarly, limited contact with classmates may also hinder the weaker student more than a strong student. However, it has been shown that students' final course outcome was strongly correlated to their previous grades across all grade levels and therefore, the decreased interaction with instructors or other students did not seem to have an impact. Despite this finding, more research is needed to investigate effective ways to increase student engagement in the online classroom.

Students who were identified as outliers in Figure 4 neglected to complete major components of the course or did very poorly on assessments with high outcome weightings. While the presence of the archives for the online students allows them more flexibility to attend the lectures, it also

gives those students who may be prone to procrastination the opportunity to fall behind (Donovan et al., 2006). These outliers possibly allowed themselves to get too far behind which is reflected in their grades. When designing an online course, it is important to recognize that procrastination is enabled with the archives and that frequent assessments may be required to promote timely viewing of the archives (Wesp, 1986).

Course Evaluations

Student evaluations of the course showed that all groups of students scored the courses highly with no significant differences among overall course scores for any of the groups (Table 3). Student comments supported the overall favorable perception of the online formats; they indicated their surprise at how effective an online course can be.

Student performance indicators (see Fig. 3) for both the lecture and various laboratory components showed that the online format and the compressed timeframe of the Summer Online course are as effective as a F2F course covering the same material. This conclusion was supported by student feedback in the course evaluations. Our study also shows that a virtual classroom can be used to offer a high quality online histology laboratory as effectively as a traditional F2F microscopy laboratory using conventional microscopy with glass slides.

Limitations

There are several limitations to this study. It would have been preferable to randomly assign students to the experimental groups; however, as this was a study of an actual course, it would have been unethical to force students either group. Comparison of the previous grades provided sufficient evidence to suggest that the groups were initially equal. Also, it would have been preferable to have had a better response rate from the online students for the course evaluation. Low survey response rates have also been described by others and are thought to be due to the novelty of the virtual classroom (Parker et al., 2010). A third limitation to this study was the varied access the online students had to the course material. Students could either participate live online or view the archives at a later time. These options may provide different learning experiences for the students; however, the majority of students participated using both options over the period of the course.

CONCLUSIONS

A method for delivering a fully online microscopic anatomy laboratory course either on its own or in conjunction with a F2F course has been presented. Table 4 summarizes the strengths and weaknesses of delivering an online histology course. Virtual classroom software, while not inexpensive, is available at most institutions. Additional equipment, which is inexpensive and readily obtainable from local electronics stores, along with minimal technological knowledge required for set up and operation, allows this course to be offered in both formats. For instructional faculty, the training required to operate the virtual classroom software is also minimal. This course is available to all students with a high speed internet connection, allowing them to overcome issues such

Table 4.

Summary of Strengths and Weaknesses of Online Histology Laboratory Course Using Wimba Classroom and Virtual Microscopy Software

Online course strengths	Online course weaknesses
Inexpensive equipment for simultaneous online F2F course delivery	Initial cost of slide scanning
Synchronous or asynchronous student access	Technology support for virtual slide collection and classroom
Virtual slide collection gives uniform access to quality slides	Students require high speed internet connection for best experience
Virtual microscopy software allows slide annotation for student assignments or teaching materials	Reduction in student-to-instructor and student-to-student contact
Students perform as expected based on previous grades	Students do not gain light microscopy skills
Allows increased course enrollment	

as timetable conflicts, geographical and health issues which can interfere with access to traditional F2F courses. It has been shown that student performance in the FW Online course is equivalent to that seen in the F2F course, including material based on the laboratory. The introduction of the online version of the course to our program has allowed enrollment to increase beyond what our physical laboratory can accommodate. It has also enabled the introduction of a summer version of the course with minimal impact on faculty as the teaching is entirely online and can be delivered from their offices on campus or at home. In summary, the capacity of this course has been increased with little impact on infrastructure and faculty time while maintaining very high educational standards.

NOTES ON CONTRIBUTORS

MICHELE L. BARBEAU, M.Sc., is a graduate student Ph.D. candidate in the Department of Anatomy and Cell Biology at Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada. She teaches histology and anatomy and her research interest is distance education.

MARJORIE JOHNSON, Ph.D., is an assistant professor of anatomy in the Department of Anatomy and Cell Biology at Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada. She is director of the Clinical Anatomy Division, teaches anatomy and histology, and her research interests are in developing of e-learning tools for medical education.

CANDACE GIBSON, Ph.D., is an associate professor of pathology in the Department of Pathology at Schulich School of Medicine and Dentistry, Western University, London,

Ontario, Canada. She teaches pathology, health informatics, and health information management and her research interests include e-learning tools, curriculum development, collaborative leadership, and team building in health care.

KEM A. ROGERS Ph.D., is a professor and Chair of the Department of Anatomy of Cell Biology at Schulich School of Medicine and Dentistry, Western University, London, Ontario, Canada. He is the coordinator and instructor for the undergraduate histology course and his research interests range from models of cardiovascular disease to educational scholarship.

ACKNOWLEDGMENTS

The authors wish to acknowledge Ms. Joan Estabrooks for supplying the foundation course data, Ms. Jane Winkler for technical expertise in the development and support of the course, and Mr. Michael Wu for his technical support.

LITERATURE CITED

- Allen IE, Seaman J. 2010. Learning on Demand: Online Education in the United States, 2009. 1st Ed. Newburyport, MA: Babson Survey Research Group, The Sloan Consortium, Inc. 29 p.
- Arroyo-Morales M, Cantarero-Villanueva I, Fernández-Lao C, Guirao-Piñeyro M, Castro-Martín E, Díaz-Rodríguez L. 2012. A blended learning approach to palpation and ultrasound imaging skills through supplementation of traditional classroom teaching with an e-learning package. *Man Ther* 17:474–478.
- Bernard RM, Abrami PC, Lou Y, Borokhovski E, Wade A, Wozney L, Waiet PA, Fiset M, Huang B. 2004. How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. *Rev Educ Res* 74:379–439.
- Bloodgood R. 2012. Active learning: A small group histology laboratory exercise in a whole class setting utilizing virtual slides and peer education. *Anat Sci Educ* 5:367–373.
- Bloodgood RA, Ogilvie RW. 2006. Trends in histology laboratory teaching in United States medical schools. *Anat Rec* 289B:169–175.
- Braun MW, Kearns KD. 2008. Improved learning efficiency and increased student collaboration through use of virtual microscopy in the teaching of human pathology. *Anat Sci Educ* 1:240–246.
- Bryner BS, Saddawi-Konefka D, Gest TR. 2008. The impact of interactive, computerized educational modules on preclinical medical education. *Anat Sci Educ* 1:247–251.
- Coleman R. 2009. Can histology and pathology be taught without microscopes? The advantages and disadvantages of virtual histology. *Acta Histochem* 111:1–4.
- Collier L, Dunham S, Braun MW, O'Loughlin VD. 2012. Optical versus virtual: Teaching assistant perceptions of the use of virtual microscopy in an undergraduate human anatomy course. *Anat Sci Educ* 5:10–19.
- Cook D, Levinson A, Garside S, Dupras D, Erwin P, Montori V. 2008. Internet-based learning in the health professions: A meta-analysis. *JAMA* 300:1181–1196.
- Cotter JR. 2001. Laboratory instruction in histology at the University at Buffalo: Recent replacement of microscope exercises with computer applications. *Anat Rec* 265:212–221.
- Dantas A, Kemm R. 2008. A blended approach to active learning in a physiology laboratory-based subject facilitated by an e-learning component. *Adv Physiol Educ* 32:65–75.
- DiLullo C, McGee P, Kriebel RM. 2011. Demystifying the Millennial student: A reassessment in measures of character and engagement in professional education. *Anat Sci Educ* 4:214–226.
- Donovan C, Figlio D, Rush M. 2006. Cramming: The Effects of School Accountability on College-Bound Students. Working paper. 1st Ed. Washington, DC: National Center for the Analysis of Longitudinal Data in Education Research (CALDER). 38 p. URL: http://www.caldercenter.org/PDF/1001068_Cramming.pdf [accessed 12 October 2012].
- Drake RL, McBride JM, Lachman N, Pawlina W. 2009. Medical education in the anatomical sciences: The winds of change continue to blow. *Anat Sci Educ* 2:253–259.
- Fred FR. 2009. Virtual microscopy in pathology education. *Hum Pathol* 40:1112–1121.
- Gilman SL. 2006. Do online labs work? An assessment of an online lab on cell division. *Amer Biol Teach* 68:131–134.
- Goldberg HR, Dintzis R. 2007. The positive impact of team-based virtual microscopy on student learning in physiology and histology. *Adv Physiol Educ* 31:261–265.
- Hale LS, Mirakian EA, Day DB. 2009. Online vs classroom instruction: Student satisfaction and learning outcomes in an undergraduate allied health pharmacology course. *J Allied Health* 38:e36–e42.
- Hango D, de Broucker P. 2007. Postsecondary Enrolment Trends to 2031: Three Scenarios. 1st Ed. Ottawa, Canada: Culture, Tourism and the Centre for Education Statistics Division. 108 p.
- Harris T, Leaven T, Heidger P, Kreiter C, Duncan J, Dick F. 2001. Comparison of a virtual microscope laboratory to a regular microscope laboratory for teaching histology. *Anat Rec* 265:10–14.
- Heidger PM Jr, Dee F, Consoer D, Leaven T, Duncan J, Kreiter C. 2002. Integrated approach to teaching and testing in histology with real and virtual imaging. *Anat Rec* 269:107–112.
- Helle L, Säljö R. 2012. Collaborating with digital tools and peers in medical education: Cases and simulations as interventions in learning. *Instrum Sci* 40:737–744.
- Helle L, Nivala M, Kronqvist P, Ericsson KA, Lehtinen E. 2010. Do prior knowledge, personality and visual perceptual ability predict student performance in microscopic pathology? *Med Educ* 44:621–629.
- Helle L, Nivala M, Kronqvist P, Gegenfurtner A, Björk P, Säljö R. 2011. Traditional microscopy instruction versus process-oriented virtual microscopy instruction: A naturalistic experiment with control group. *Diagn Pathol* 6:58.
- Higazi TB. 2011. Use of interactive live digital imaging to enhance histology learning in introductory level anatomy and physiology classes. *Anat Sci Educ* 4:78–83.
- Huijser H, Kimmins L, Evans P. 2008. Peer assisted learning in fleximode: Developing an online learning community. *Australas J Peer Learn* 1:51–60.
- Husmann PR, O'Loughlin VD, Braun MW. 2009. Quantitative and qualitative changes in teaching histology by means of virtual microscopy in an introductory course in human anatomy. *Anat Sci Educ* 2:218–226.
- Jaggars SS, Bailey T. 2010. Effectiveness of fully online courses for college students: Response to a Department of Education meta-analysis. Community College Research Center (CCRC), Institute on Education and the Economy, Teachers College, Columbia University, New York, NY. URL: <http://ccrc.tc.columbia.edu/Publication.asp?uid=796> [accessed 12 October 2012].
- Khogali SE, Davies DA, Donnan PT, Gray A, Harden RM, McDonald J, Pippard MJ, Pringle SD, Yu N. 2011. Integration of e-learning resources into a medical school curriculum. *Med Teach* 33:311–318.
- Krippendorf BB, Lough J. 2005. Complete and rapid switch from light microscopy to virtual microscopy for teaching medical histology. *Anat Rec* 285B:19–25.
- Leasure AR, Davis L, Thievon SL. 2000. Comparison of student outcomes and preferences in a traditional vs. World Wide Web-based baccalaureate nursing research course. *J Nurs Educ* 39:149–154.
- Lundin M, Lundin J, Helin H, Isola J. 2004. A digital atlas of breast histopathology: An application of web based virtual microscopy. *J Clin Pathol* 57:1288–1291.
- Lundin M, Szymas J, Linder E, Beck H, de Wilde P, van Krieken H, García Rojo M, Moreno I, Ariza A, Tuzlali S, et al. 2009. A European network for virtual microscopy—Design, implementation and evaluation of performance. *Virchows Arch* 454:421–429.
- Mahnken AH, Baumann M, Meister M, Schmitt V, Fischer MR. 2011. Blended learning in radiology: Is self-determined learning really more effective? *Eur J Radiol* 78:384–387.
- Mangold K. 2007. Educating a new generation: Teaching baby boomer faculty about millennial students. *Nurs Educ* 32:21–23.
- Mayer RE, Stull A, DeLeeuw K, Almeroth K, Bimber B, Chun D, Bulger M, Campbell J, Knight A, Zhang H. 2009. Clickers in college classrooms: Fostering learning with questioning methods in large lecture classes. *Contemp Educ Psychol* 34:51–57.
- McNulty JA, Sonntag B, Sinacore JM. 2009. Evaluation of computer-aided instruction in a gross anatomy course: A six-year study. *Anat Sci Educ* 2:2–8.
- Parker MA, Grace ER, Martin F. 2010. Do you teach in a virtual classroom? Measuring student's perceptions of the features and characteristics. *Int J Inst Tech Dist Educ* 7:17–28.
- Pinder KE, Ford JC, Ovale WK. 2008. A new paradigm for teaching histology laboratories in Canada's first distributed medical school. *Anat Sci Educ* 1:95–101.
- Pratt RL. 2009. Are we throwing histology out with the microscope? A look at histology from the physician's perspective. *Anat Sci Educ* 2:205–209.
- Ried LD, Byers K. 2009. Comparison of two lecture delivery platforms in a hybrid distance education program. *Am J Pharm Educ* 73:95.
- Rosenberg H, Kermalli J, Freeman E, Tenenbaum H, Locker D, Cohen H. 2006. Effectiveness of an electronic histology tutorial for first-year dental students and improvement in “normalized” test scores. *J Dent Educ* 70:1339–1345.
- Ross MH, Pawlina W. 2011. *Histology: A Text and Atlas with Correlated Cell and Molecular Biology*. 6th Ed. Philadelphia, PA: Lippincott, Williams & Wilkins. 974 p.
- Ruiz J, Mintzer M, Leipzig R. 2006. The impact of e-learning in medical education. *Acad Med* 81:207–212.
- Schoenfeld-Tacher R, McConnell S, Graham M. 2001. Do no harm—A comparison of the effects of on-line vs. traditional delivery media on a science course. *J Sci Educ Tech* 10:257–265.

- Scoville SA, Buskirk TD. 2007. Traditional and virtual microscopy compared experimentally in a classroom setting. *Clin Anat* 20:565–570.
- Shachar M, Neumann Y. 2010. Twenty years of research on the academic performance differences between traditional and distance learning: Summative meta-analysis and trend examination. *MERLOT J Online Learn Teach* 6:318–334.
- Shaw PA, Friedman ES. 2012. Clinico-histologic conferences: Histology and disease. *Anat Sci Educ* 5:55–61.
- Sinn HP, Andrulis M, Mogler C, Schirmacher P. 2008. Virtual microscopy in pathology teaching and postgraduate training (continuing education). *Pathologie* 29:S255–S258.
- Snyder TD, Dillow SA. 2011. Digest of Education Statistics 2010 (NCES 2011-015). 46th Ed. Washington DC: U.S. Department of Education, Institute of Education Sciences (IES), National Center for Education Statistics (NCES). 744 p. URL: <http://nces.ed.gov/programs/digest> [accessed 10 July 2012].
- Strauss W, Howe N. 1991. *Generations: The History of America's Future, 1584 to 2069*. 1st Ed. New York, NY: William Morrow and Company, Inc. 544 p.
- Stuckey-Mickell TA, Stuckey-Danner BD. 2007. Virtual labs in the online biology course: Student perceptions of effectiveness and usability. *MERLOT J Online Learn Teach* 3:105–111.
- Sung YH, Kwon IG, Ryu E. 2008. Blended learning on medication administration for new nurses: Integration of e-learning and face-to-face instruction in the classroom. *Nurs Educ Today* 28:943–952.
- Tagge N. 2009. Jing and Yang: Balancing asynchronous and synchronous training. *Libr Hi Tech News* 10:6–7.
- Travis H. 2011. Western to welcome largest first-year class. *The University of Western Ontario's Newspaper of Record*. The University of Western Ontario, Department of Communications and Public Affairs, London, Ontario, Canada. *Western News* 47:8.
- Wesp R. 1986. Reducing procrastination through required course involvement. *Teach Psychol* 13:128–130.
- Zhou Y, Talburt JR. 2011. Campus-centric distance education using Wimba Live Classroom. In: *Proceedings of the 2011 International Symposium on Information Technology in Medicine and Education (ITME 2011)*: Guangzhou, China, 2011 Dec 9–11. p 713–716. Institute of Electrical and Electronics Engineers (IEEE), Washington, DC.