Implementing Virtual Microscopy Improves Outcomes in a Hematology Morphology Course

MAURI S BRUEGGEMAN, CHERYL SWINEHART, MARY JANE YUE, JANICE M CONWAY-KLAASSEN, STEPHEN M WIESNER

ABSTRACT
In this study, we evaluated the efficacy of virtual microscopy as the primary mode of laboratory instruction in undergraduate level clinical hematology teaching. Distance education (DE) has become a popular option for expanding education and optimizing expenses but continues to be controversial. The challenge of delivering an equitable curriculum to distant locations along with the need to preserve our slide collection directed our effort to digitize the slide sets used in our teaching laboratories. Students enrolled at two performance sites were randomly assigned to either traditional microscopy (TM) or virtual microscopy (VM) instruction. The VM group performed significantly better than the TM group. We anticipate that this approach will play a central role in the distributed delivery of hematology through distance education as new programs are initiated to address workforce shortage needs.

ABBREVIATIONS:
TM - traditional microscopy, VM - virtual microscopy, DE - distance education, CLS - clinical laboratory sciences, CI - classroom instruction, F2F - face to face, GPA - grade point average, RBC - red blood cell, WBC, white blood cell

INDEX TERMS: microscopy, hematology, online, education, digital microscopy, distance education

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Mauri S Brueggeman, MEd, CLS(NCA), *Center for Allied Health Programs, University of Minnesota, Minneapolis, MN*

Cheryl Swinehart, MS, CLS(NCA), *Center for Allied Health Programs, University of Minnesota, Minneapolis, MN*

Mary Jane Yue, MS, MT(ASCP), *Center for Allied Health Programs, University of Minnesota, Minneapolis, MN*

Janice M Conway-Klaassen, PhD, MT(ASCP)SM, *Center for Allied Health Programs, University of Minnesota, Minneapolis, MN*

Stephen M Wiesner, PhD, MT(ASCP), *Center for Allied Health Programs, University of Minnesota, Minneapolis, MN*

Address for Correspondence: Stephen M Wiesner, PhD, MT(ASCP), *Center for Allied Health Programs, University of Minnesota, MMC 711, 420 Delaware St. SE, Minneapolis, MN 55455, 612-625-6465, wiesn003@umn.edu*

INTRODUCTION

Distance education (DE) has become a popular option for expanding education and optimizing expenses but continues to be controversial. Evidence shows both positive and negative outcomes across educational fields, but the effect of DE in place of classroom instruction (CI) is equivocal.[1,2] Published literature on the subject frequently does not account for multiple experimental factors, such as the type of outcome measured, learner demographics, biased sampling, failure to put in place proper experimental controls, and confounding instructional methods that might affect outcomes, leading to potentially conflicting interpretations.[1,3,4]

To address workforce shortage needs, a clinical laboratory sciences (CLS) program at a large Midwestern public institution with one central and 4 coordinate campuses throughout the state has begun to expand its program to one of these coordinate campuses 90 miles away. The expansion of our curriculum to this distant site created several challenges regarding the educational assets used to deliver the program. One of these issues concerned the use of glass slides for instruction of hematologic cell morphology. Traditionally, undergraduate hematology morphology was taught using microscope slides where each student or a very small group of students had an instructional slide set. With our position in a longstanding academic health center, our instructional slide sets contain some of the rarest and most unique hematopathologies. However, glass slides can be damaged or broken and stains fade over time resulting in the loss of these precious resources that cannot be replaced. The challenge of delivering an equitable curriculum to distant locations along with the need to preserve our slide collection directed our effort to digitize the slide sets used in our teaching laboratories. We anticipate that this approach will play a central role in the distributed delivery of hematology through DE as new programs are initiated to address workforce shortage needs.

In our program, hematology is taught across two semesters. Hematology I addresses fundamental laboratory techniques in the hematology laboratory, including basic microscope use, red blood cell (RBC) and platelet assessments, and the performance of routine white blood cell (WBC) differential counts. The majority of the didactic lecture material in this course, as well as the other courses offered in the program, is presented in a hybrid format consisting of both face to face (F2F) instruction and a significant online component delivered via a course management system (Moodle). Only students achieving a grade of C or better in Hematology I advance to the second hematology course.

Hematology II is comprised of both lecture and laboratory components. In the first six weeks of the course, didactic lecture material is presented exclusively online via the course management system. After the first six weeks, didactic lecture material is presented F2F by guest lecturers consisting primarily of pathologists or specialists in hematopathology, cytogenetics or flow cytometry. Traditionally, the laboratory component of this course consisted of a three hour laboratory session each week during which students reviewed case data and viewed associated slides encompassing normal and abnormal hematologic disorders with instructors present to answer questions and assist in the identification of cells.

Despite the needs of our program, we were unsure whether digital microscopy would provide equivalent instruction compared to traditional F2F delivery. The level of personal interaction and guidance provided during regular laboratory sessions seemed essential in developing the ability of students to distinguish subtle morphologic characteristics represented in varying disease states. Others have investigated the efficacy of high power digital microscopy images (400X) for instruction. These studies have focused primarily on professional post-baccalaureate instruction or have investigated the use of digital microscopy in a single exercise of a course.[5-17] Several researchers postulated on the benefits of virtual microscopy (VM) but only surveyed students on their preference for use of VM versus traditional microscopy (TM) without statistical assessment of student achievement.[13,16,18-25] None, to our knowledge, have investigated the use of digital microscopy as the primary instructional tool in an undergraduate course or have utilized digital images scanned under oil immersion at higher magnification (830X) required for adequate morphologic evaluation of blood and bone marrow smears.[5-11]

In this study, we evaluated the efficacy of virtual microscopy as the primary mode of laboratory instruction in undergraduate level clinical hematology teaching. We hypothesized that VM, by mimicking a majority of the psychomotor skills necessary for blood smear evaluation, would perform as well or better than teaching with physical slides and microscopes.

MATERIALS AND METHODS

Digital Slide Preparation

Microscope slides were processed by Aperio Technologies (Vista, CA). Slides were digitally scanned at 830X magnification under oil immersion. Images are accessed by utilizing standard web browsers in combination with ImageScope software (Aperio, free download) allowing users to view and manipulate the images similar to viewing them through a microscope at any magnification between 2 and 830X. Some digital slides were annotated to assist VM students in identifying classic cellular characteristics.

Subjects

Fifty-eight students enrolled in Hematology II at two performance sites were randomly assigned to either traditional microscopy (TM) or virtual microscopy

(VM) instruction (Table 1). Of those, eight students declined to participate, one student withdrew from the study, one student was repeating the course and was excluded from all analyses, and one student withdrew from the program mid-semester. Only data collected from participants that remained in the study at the end of Hematology II (44 students) were included in the final analysis. All subjects had given informed consent for participation in the study and were allowed to withdraw from the study at any time. All students were required to have access to a high speed Internet connection (cable or DSL) and a computer with Windows XP SP3, Windows Vista, or Windows 7 operating system as a condition for enrollment in the CLS program. Students were informed that if there were significant differences between TM and VM cohorts in the mean total course scores, the lower cohort scores would be adjusted to minimize risk to study participants. Both groups had access to identical lecture materials. The VM group had access to links related to VM including a virtual discussion forum, software instructions and manual, synchronous slide viewing sessions with an instructor, and special forms designed for the distributed delivery. The Institutional Review Board at this institution approved this study.

Course Structure

The TM group had a three hour scheduled laboratory session once per week during the semester and were encouraged to view slides on a two headed microscope with an instructor during some of that time. Both groups had a two-hour lecture once per week, though some lectures were also posted online as recorded lectures.

VM learners had access to the digital slide library at any time from any computer with Internet access. VM learners were also encouraged to participate in a weekly online synchronous slide viewing session with an instructor. These sessions were provided using Adobe Connect (Adobe Systems, San Jose, CA). Participants were able to view the instructors shared computer screen and interact via live chat while the instructor narrated synchronous viewing of digital slides or reviewed case data. The instructors of the VM group also offered to synchronously view slides or materials at the request of any virtual student at their convenience for more flexibility in scheduling, similar to the F2F laboratory. Learners from both treatment groups were encouraged to bring questions to instructors via the online discussion forums in the course management system, to the laboratory (TM), or to synchronous online slide viewing sessions (VM).

Table 1. Student Demographics

	n	# Female (%)	Age at Start of Sr. Yr. Avg(SE)	Initial GPA Avg(SE)	# w/Previous BA or BS (%)	# w/ MA or MS
Class						
Overall	44	28 (64)	26.2 (1.0)	3.14 (0.06)	16(36)	1
Class TM	28	17 (61)	25.1 (0.7)	3.06 (0.08)	9 (32)	1
Class VM	16	11 (69)	28.1 (2.5)	3.27 (0.10)	7 (44)	0
PS1a	29	18 (62)	26.3 (1.3)	3.10 (0.07)	4 (14)	0
PS2a	15	10 (67)	26.0 (1.5)	3.22 (0.11)	12 (80)	1

a PS=Performance Site

Data Collection

Students participated in three surveys requesting feedback on preparedness, perception and expectations of the course before, during and after delivery. All students took identical laboratory practical and written exams mid-term and at the end of the semester. All exams were administered on campus. The mid-term practical exam consisted of projected images of cells requiring identification based on morphologic characteristics. The first portion of the end-term practical exam used microscopes to scan slides to perform cell identification, assess RBC and WBCs (morphology and correlation with disease). The second portion of this exam used projected images for single cell identification. Both the written exams administered at mid- and end-semester were multiple choice and those scores were analyzed only as part of the cumulative course scores.

Statistical Analysis

Graphing and statistical analysis were performed using JMP software (SAS Institute, Cary, NC).

RESULTS

Evaluation of groups demonstrates no statistically significant difference between TM and VM groups with respect to age or gender. Though not statistically significant, the VM group showed a slightly higher average age as well as a slightly higher initial GPA (Table 1). Initial GPA is the students' grade point average immediately prior to enrollment in Hematology

II. Demographics at the two performance sites were also comparable (Table 1).

Historical data demonstrated no statistical significance in student performance with respect to previous years for the course total (including written exams) (Figure 1A).

Within the current cohort, we did not find significant differences between TM and VM groups with respect to group means for the midterm laboratory exam, the final laboratory exam, or the course total (Figure 1B) While no significant differences were found in these analyses, we were concerned that our evaluation did not account for individual student performance relative to course delivery format. Non-parametric matched pairs analysis followed by the Wilcoxon signed rank post hoc test for significant difference was performed due to the non-random sampling and distribution of students. This analysis allows comparison of each student's past student performance (each individual student's initial GPA as they entered the course) with their individual current outcome (the grade points earned in the Hematology II course) (Figure 2). Both student groups performed at lower levels (grade points earned) in this course compared to previous performance (initial GPA). The average difference between grade points earned and initial GPA was -0.04 and -0.23 for VM and TM student groups, respectively (Figure 2). This magnitude of difference between grade point earned and initial GPA for the VM group was significantly different from that of the TM group (Figure 2).

In addition to student achievement data, surveys were conducted to explore students' perceptions of the experience. The initial survey was administered in class the first day of the semester, which all students were required to attend. Additional surveys were administered at mid-semester and at the end of the course (Table 2). The importance of F2F contact with instructors, the importance of synchronous slide viewing with an instructor, and flexible access to slides decreased over time for the TM group while the VM students' ratings of these aspects of the course remained stable during the semester. The TM students' perceptions that learning is enhanced when some or all course material is delivered online and that technological advances enhance student learning, increased through the semester, while perceptions of VM learners in the same areas decreased. VM student comfort with their mode of course delivery went up over time, which might be expected, assuming increased familiarity with the software and technology, as well as discovery of individual strategies in terms of learning the course material. Conversely, TM learner's ratings of their comfort level in their mode of course delivery decreased over time.

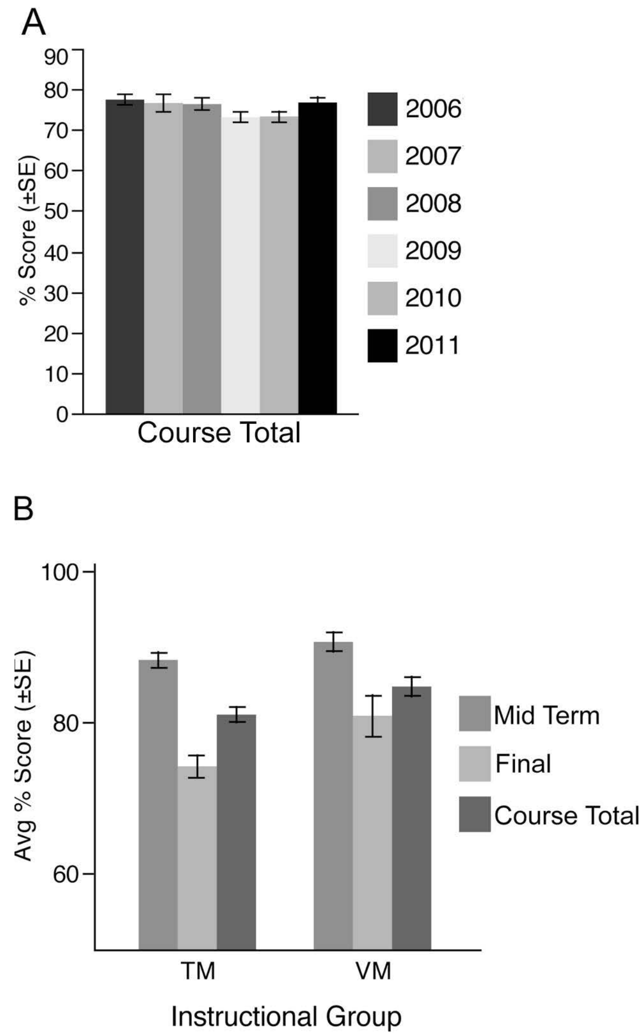

Figure 1. Historical and current student performance. Mean scores are not significantly different. A) No significant difference can be found between the current cohort and previous cohorts for the total percentage of points earned in the course, including practical and written exam scores, over the last five years. B) No significant difference can be found between TM and VM groups in the current cohort for the mid term and final practical exams or the total percentage of points earned in the course.

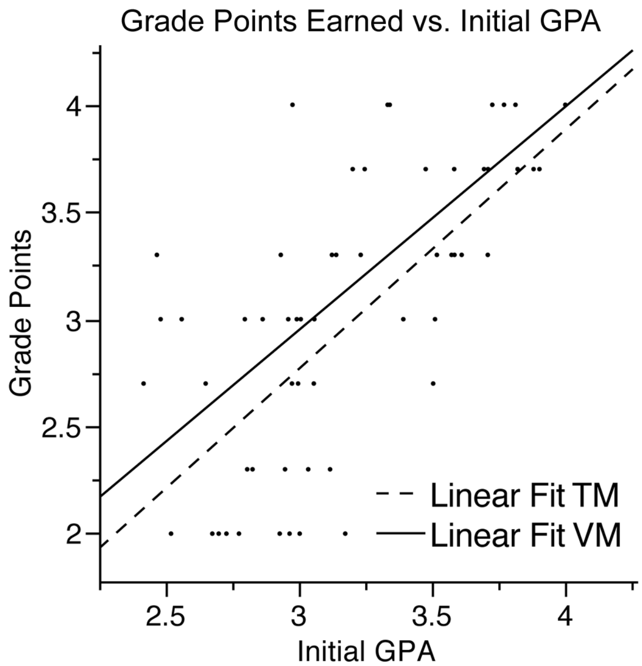

Figure 2. VM students outperformed TM students. VM students performed better than TM students. Bivariate plot of earned grade points for each student against their initial grade point average shows overall better performance by VM students (p = 0.04, Matched pairs analysis followed by Wilcoxon signed rank post hoc test for significant difference).

Most noteworthy are ratings of participation in synchronous slide viewing sessions and time students spent viewing slides between the two groups. VM students reported spending slightly more time viewing digital slides online than TM students spent with glass slides in the laboratory. While the ratings differed, the disparity between groups does not suggest that VM students were compelled to dedicate more time than TM students to compensate for the mode of delivery. Also of significance, VM students on average reported participation in more sessions of synchronous slide viewing than TM students during the course (Table 2). These final two factors may be significant contributors to our findings that VM students, overall, performed better in the course than TM students.

DISCUSSION

The intent of the present study was to compare the efficacy of teaching hematologic morphology via a virtual instead of the traditional method of delivery. We hypothesized that students would do as well or better in the course utilizing VM in place of TM. Historically, converting traditional courses to e-learning courses has not been shown to have an effect on outcomes when comparing the literature as a whole.[1] However, Zhao found that DE studies had better outcomes when examining multiple individual factors such as levels of instructor involvement, student grades, attitudes and student satisfaction instead of student learning alone.[1] In their meta-analysis, Zhao also compared the content area of each study and how that affected DE versus F2F outcomes.[1] They found that in areas of science, there was no significant difference on student outcomes. Schoenfeld-Tacher found that their online students outperformed on-campus students in a science course with laboratory when measuring pre- and post-test outcomes.[2] These findings correlate with the findings in our study. Through both quantitative and qualitative data analysis, our study found that VM students had better outcomes than TM students. For VM students, instructor involvement was present but not immediate, allowing students to contemplate problems encountered, while feedback was immediate for TM students. One significant difference between the published literature and our study, however, is that those studies investigate didactic learning, whereas our study examines didactic learning and psychomotor performance. Sitzman, et al. found that there was no difference in outcomes for procedural knowledge independent of content presentation type (DE or CI).[3,23] Our students were able to perform as well as TM students on the final practical exam that included manipulation of a microscope to view a slide, and ultimately outperformed TM students in the course. While we would expect higher performing students to do better in the course, VM learners performed better regardless of their initial GPA. Helle found that VM learners outperformed the control group but only analyzed data from high achievers, as they had poor participation with lower achievers.[15] In other reported findings, researchers have implemented VM and seen improved student performance but have not had an experimental control group.[6] Our data supports not only the result that high achievers outperform TM learners, but that low achievers outperform TM as well.

The quantitative results of our study correlated with our qualitative data in that, while we saw unexpected ratings from both groups, it appears that TM learners became increasingly disengaged from the course over time, which may also have contributed to the differences in their overall course performance. In other studies investigating the use of VM, learners had the perception

Table 2. Longitudinal Data from Surveys 1-3

Question:	TM VM	Survey 1 n=28 n=16 Mean	SD	Survey 2 n=21 n=16 Mean	SD	Survey 3 n=14 n=15 Mean	SD
Importance of F2F contact with instructors (1 to 4)	TM	3.5	0.6	3.3	0.8	3.2	0.8
	VM	2.6	0.7	2.3	0.9	2.5	0.9
Importance of Synchronous Slide viewing with an instructor (1 to 4)	TM	3.2	0.8	3.0	1.0	2.6	1.0
	VM	2.8	0.4	2.4	1.1	2.7	1.1
Flexible access to slides (1 to 4)	TM	3.4	0.6	3.0	1.0	2.9	0.8
	VM	3.6	0.6	3.8	0.4	3.8	0.6
Perception: Learning is enhanced when some or all course material is delivered online (1 to 4)	TM	2.5	1.0	2.7	1.2	3.1	0.7
	VM	3.0	0.5	3.2	0.9	3.1	0.8
Perception: Technological advances enhance my learning (1 to 4)	TM	2.9	0.8	3.2	0.7	3.2	0.7
	VM	3.3	0.4	3.4	0.5	3.1	0.8
How comfortable are you with your mode of course delivery (1 to 7)	TM	6.0	1.0	6.1	1.0	5.5	1.6
	VM	4.7	1.8	4.8	1.3	5.2	1.1
				(Range: 1-6)		**(Range: 1-10)**	
How many sessions of synchronous slide viewing with an instructor have you participated in? (Ranges provided)	TM			1.4	1.9	1.8	0.6
	VM			1.5	1.8	2.4	1.1
How much time (in hours) per week on average do you spend looking at slides? (No ranges given)	TM			2.9	0.8	3.1	1.1
	VM			4.0	0.8	3.8	1.0

that VM was a helpful aid for studying and that its ease in availability contributed to a positive attitude towards VM.[5,6,12] These studies, however, did not have separate student groups with access to a single laboratory delivery type and learners were able to compare TM to VM. In our case, TM learners could only speculate as to the benefits of VM, while VM learners had initially been trained using TM and could make a slight comparison. We do know that students in our study saw each other daily in other classes. It is therefore possible that each group conjectured about a benefit in the others' delivery format and this affected their responses. TM learners may have been affected by incidental exposure to VM learners' comments. This may have had an influence on our students' attitudes, and ultimately on their performance. In addition, VM students had more control over their learning and could be more self-directed during the course, which may have been a contributing factor in their performance. They had less immediate access to instructors which may have forced them to work through problems or questions on their own, rather than relying on immediate instructor feedback. This is consistent with published literature on the benefits of self-directed learning, student engagement, and knowledge transfer.[26]

It was also interesting to note that TM learners' ratings of their comfort level with their mode of course delivery decreased over time. Conversely, VM students' comfort with their mode of course delivery went up over time, perhaps as they became more familiar with the technology.

The effect measured for TM students in this regard is somewhat counter-intuitive, as comfort with an already familiar technology (TM) would be expected to increase with experience. However, it may be that this same familiarity led to over familiarity and therefore disenchantment with the method. Again, TM learners may have been affected by incidental exposure to VM learners' discussions during other classes potentially causing additional disillusionment.

Each student in this cohort was monitored throughout their clinical experience in hematology and their board certification exam but that data was not available at the time of press. In addition, further studies will be conducted on data collected from future cohorts.

Many in medical education agree that virtual microscopy has tremendous benefits, particularly in the areas of histology, pathology, and cytology.[5-18] Utilization of virtual microscopy in the field of clinical laboratory science is expanding quickly and while its use in quality assurance, certification board testing situations, and even clinical applications is likely imminent, we found that virtual microscopy can be an efficient and powerful tool useful in hematology education for both large and small numbers of students without compromising the quality of instruction.

REFERENCES:

1. Zhao Y, Lei J, Yan B, Lai C, Tan HS. What makes the difference? A practical analysis of research on the effectiveness of distance education. Teach Coll Rec. 2005;107(8):1836-84.
2. Schoenfeld-Tacher R, McConnell S, Graham M. Do no harm - A comparison of the effects of on-line vs. traditional delivery media on a science course. J Sci Educ Technol. 2001;10(3):257-65.
3. Sitzmann T, Kraiger K, Stewart D, Wisher R. The comparative effectiveness of web-based and classroom instruction: A meta-analysis. Pers Psychol. 2006;59(3):623-64.
4. Bernard RM, Abrami PC, Lou YP, Borokhovski E, Wade A, Wozney L, et al. How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. Rev Educ Res. 2004;74(3):379-439.
5. Neel JA, Grindem CB, Bristol DG. Introduction and evaluation of virtual microscopy in teaching veterinary cytopathology. J Vet Med Educ. 2007;34(4):437-44.
6. Husmann PR, O'Loughlin VD, Braun MW. Quantitative and qualitative changes in teaching histology by means of virtual microscopy in an introductory course in human anatomy. Anat Sci Educ. 2009;2(5):218-26.
7. Farah CS, Maybury T. Implementing digital technology to enhance student learning of pathology. Eur J Dent Educ. 2009;13(3):172-8.
8. Blake CA, Lavoie HA, Millette CF. Teaching medical histology at the University of South Carolina School of Medicine: Transition to virtual slides and virtual microscopes. Anat Rec B New Anat. 2003;275(1):196-206.
9. Hutchinson CV, Brereton ML, Burthem J. Digital imaging of haematological morphology. Clin Lab Haematol. 2005;27(6):357-62.
10. Scoville SA, Buskirk TD. Traditional and virtual microscopy compared experimentally in a classroom setting. Clin Anat. 2007;20(5):565-70.
11. Stewart J, 3rd, Bevans-Wilkins K, Bhattacharya A, Ye C, Miyazaki K, Kurtycz DF. Virtual microscopy: an educator's tool for the enhancement of cytotechnology students' locator skills. Diagn Cytopathol. 2008;36(6):363-8.
12. Weaker FJ, Herbert DC. Transition of a dental histology course from light to virtual microscopy. J Dent Educ. 2009;73(10):1213-21.
13. Dee FR, Meyerholz DK. Teaching medical pathology in the twenty-first century: virtual microscopy applications. J Vet Med Educ. 2007;34(4):431-6.
14. Lundin M, Lundin J, Helin H, Isola J. A digital atlas of breast histopathology: an application of web based virtual microscopy. J Clin Pathol. 2004;57(12):1288-91.
15. Helle L, Nivala M, Kronqvist P, Gegenfurtner A, Bjork P, Saljo R. Traditional microscopy instruction versus process-oriented virtual microscopy instruction: a naturalistic experiment with control group. Diagn Pathol. 2011;6 Suppl 1:S8.
16. Merk M, Knuechel R, Perez-Bouza A. Web-based virtual microscopy at the RWTH Aachen University: didactic concept, methods and analysis of acceptance by the students. Ann Anat. 2010;192(6):383-7.
17. Triola MM, Holloway WJ. Enhanced virtual microscopy for collaborative education. BMC Med Educ. 2011;11:4.
18. Lundin M, Szymas J, Linder E, Beck H, de Wilde P, van Krieken H, et al. A European network for virtual microscopy--design, implementation and evaluation of performance. Virchows Arch. 2009;454(4):421-9.
19. Dee FR. Virtual microscopy in pathology education. Hum Pathol. 2009;40(8):1112-1121
20. Paulsen FP, Eichhorn M, Brauer L. Virtual microscopy-The future of teaching histology in the medical curriculum? Ann Anat. 2010;192(6):378-82.
21. Cunningham CM, Larzelere ED, Arar I. Conventional microscopy vs. computer imagery in chiropractic education. J Chiropr Educ. 2008;22(2):138-44.
22. Glatz-Krieger K, Spornitz U, Spatz A, Mihatsch MJ, Glatz D. Factors to keep in mind when introducing virtual microscopy. Virchows Arch. 2006;448(3):248-55.
23. Goldberg HR, Dintzis R. The positive impact of team-based virtual microscopy on student learning in physiology and histology. Adv Physiol Educ. 2007;31(3):261-5.
24. Kumar RK, Freeman B, Velan GM, De Permentier PJ. Integrating histology and histopathology teaching in practical classes using virtual slides. Anat Rec B New Anat. 2006;289(4):128-33.
25. Kumar RK, Velan GM, Korell SO, Kandara M, Dee FR, Wakefield D. Virtual microscopy for learning and assessment in pathology. J Pathol. 2004;204(5):613-8.
26. Wilson BG. Constructivist learning environments: case studies in instructional design. Wilson BG, editor. Englewood Cliffs, NJ: Educational Technology Publications, Inc.; 1996.