Introduction and Evaluation of Virtual Microscopy in Teaching Veterinary Cytopathology

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Introduction

Virtual microscopy (VM) is the digitalized equivalent of traditional microscopy, but rather than using a microscope to view glass specimen slides, it uses a computer to view digitized microscopic images of specimens. In order for the virtual microscope and virtual slide to be equivalent to a traditional microscope and glass slide, the system must have the following features: sufficiently high resolution to allow pertinent microscopic features to be identified; high power magnification (equivalent of a 40x objective); the ability to change objectives or magnification; the ability to navigate on the slide (scan and find); and, for some specimens, fine focus. In addition, digitization of the entire slide, or a sufficiently large region for the intended purpose, is also necessary. Technology has now advanced to the point where all of these features can be met in a time and cost effective manner making the use of VM in veterinary and human medical education a viable alternative or supplement to traditional microscopy.

VM offers some distinct educational advantages over traditional microscopy. With virtual slides, there is no loss, breakage or fading of slides, and large numbers of slides do not have to be prepared for teaching sets. Slide quality is uniform and allows all students to see the same thing. Slides can be selected for use based solely on educational value rather than on a combination of educational value and availability of sufficient specimen to complete a slide set. Slides that have previously been too valuable or scarce for use in teaching can now be utilized. Because images are digital, they can be annotated. They can also be accessed at any time outside of the laboratory setting via a high speed internet connection. VM may also reduce the number of microscopes an institution provides – an important consideration for programs with aging microscopes that will need replacing, programs that are expanding to accommodate larger classes, or those that have traditionally required students to purchase or rent their own microscopes.

Although VM is a very good simulation of traditional microscopy, disadvantages to VM include inferior resolution and focusing ability, and inability of slide scanners to routinely provide magnification of 100x or use of oil immersion lenses in the digitization process. Investing in the technology to produce, store and view slides can be expensive, especially if elements such as a large, networked computer laboratory are not already in place. Implementation and maintenance of a storage and viewing system requires expert technical support. Currently, many digitization processes and viewing systems are proprietary leading to potential problems of incompatibility if multiple systems or scanners are used. There is also a risk of technology becoming obsolete or unsupported. In addition, students who learn using VM may not gain technical proficiency with a real microscope.

Despite these potential disadvantages, more and more human medical schools are turning to VM as a supplement to, or replacement for, traditional microscopy for histology and pathology courses. However, to our knowledge no one has examined the use of VM for teaching

and assessment of cytopathology within a veterinary course. Our goals were to: 1) Evaluate student performance on a traditional glass exam and a similar virtual exam. 2) Survey students regarding their perception of the technology and desired uses of it within the curriculum based on their single exposure. 3) Fully integrate the technology into the sophomore VMP 942 Veterinary Clinical Pathology course and the Senior VMP 978 Clinical Pathology, Immunology and Parasitology rotation. 4) Re-survey sophomore students after integration of the technology and compare with previous survey results. 5) Develop a fully functional website for VM at the NCSU College of Veterinary Medicine (CVM) which would be accessible to all individuals. To view examples of virtual slides, please visit http://152.1.116.72/java/index.html, our temporary website.

Methods

2006 Sophomore Students

Student training in cytopathology

Students were trained in cytopathology by the following methods: 1) Students received instructor notes and attended 6 lectures in which PowerPoint presentations were used to illustrate and emphasize important concepts and cytologic interpretations. PowerPoint presentations were available to students on the course website. 2) Students completed two laboratory sessions in which four instructors were available for help and questions. Within each session, students were required to work through five to six unknown cytology specimens for laboratory credit and examine 6-10 additional demonstration slides. Following each laboratory session, one complete set of glass slides was made available for after-hours study within the teaching laboratory; slides were available 24 hours a day, seven days a week. In addition, one set of slides from each laboratory session was set up by the instructor for the weekend prior to the glass practical exam to facilitate student studying.

Exam

Glass Slide Exam

Students were administered a practical cytopathology examination using glass slides and standard light microscopes. The test consisted of 20 glass slides with each assigned the same point value. Students were required to provide an interpretation for each slide; for a list of slides and interpretations, see Table 1. Two sets of 20 slides (sets A and B) were used in order to accommodate the class size and test time constraints. Sets were well matched and the interpretations for each set were identical. A small diagnostic region of the slide representing a single 4x field of view (approximately $20mm^2$) was circled by the instructor and slides were set into this region prior to the exam. Students were instructed to remain within the circled region and could view the slide using 4x, 10x and 40x objectives. Microscope stations consisting of a single slide per microscope were set up and students rotated through the stations. Two minutes were allowed at each station, and students were given an additional 15 minutes at the end of the test to revisit any station. Total test time was 55 minutes. Grading was performed by the instructor.

Virtual Slide Exam

Twenty glass slides were digitized by Bacus™ Laboratories Inc using the BLISS™ Virtual Slide Scanning system. Ten slides from glass test set A and 10 slides from glass test set B were selected for scanning. All slides were scanned in entirety for low power viewing at

magnifications of 0.16x, 0.31x, 0.63x and 1.25. A diagnostic region of each slide was selected by the instructor for high power scanning; selection of highest power magnification (20x, 40x or 63x dry) was based on the specimen. Area scanned per slide ranged from 7.5 mm^2 to 110 mm^2 with an average of 39.9 mm^2. Thirteen slides were scanned with a 40x objective resulting in magnifications of 5x, 10x, 20x, and 40x; 2 slides were scanned with a 20x objective for magnifications of 2.5x, 5x, 10x and 20x; 5 slides were scanned with a 63x dry objective for magnifications of 7.88x, 16x, 32x and 63x. Three slides also had z-plane scanning for fine focusing; selection was based on the specimen.

One week after taking the glass exam, students were given the opportunity to retake the exam using VM; prior to this point, students were not aware that a second exam would be administered. The highest of the two exam grades was recorded as the official score for each participating student. The exam was administered in a secure computer laboratory setting using standard PC units and was proctored by the instructor. Students viewed the slides using WebSlide Browser™ software from Bacus™ Laboratories Inc. Students were oriented to the software program at the time of the virtual exam and had no previous exposure to virtual microscopy within the required coursework of the veterinary curriculum. Students were given 55 minutes to complete the exam. No time limit per slide was given, and students could review previously viewed slides at any time. Grading was performed by the instructor using the same key constructed for the glass exam.

Survey

At the end of the virtual exam, students were asked to fill out an anonymous survey. Students were asked to:

- Rate various VM system features (Tables 2 and 3)
- Indicate their preferences for use of glass microscopy versus VM for various course assessment activities (Table 4)
- Indicate preferences for use of VM and traditional microscopy for laboratory sessions (Table 5)
- Estimate current amount of time spent studying glass slides outside of laboratory sessions in preparations for practical exams (Table 6)
- Estimate the amount of additional time they would spend studying slides in preparation for practical exams if VM was available (Table 6)
- Rate various VM test taking features (Table 7)
- Indicate if the number of available computers at the CVM is sufficient to allow significant use of VM within the curriculum (Table 8)

2007 Sophomore Students

Student training in cytopathology

Students were trained in cytopathology in a similar manner as the previous year. Significant differences included increasing the number of laboratory sessions from two to three and incorporation of virtual slides into the laboratory sessions. Slides (virtual or glass) were not made available before laboratory sessions, but were available immediately after laboratory

sessions for study purposes. For the first laboratory, students were required to work through six slides for credit and view a similar number of demonstration slides. Each of the two laboratory sections was divided into groups A and B, each with approximately 18-20 students. Section A was required to use virtual slides for cases 1-3 and glass slides for cases 4-6. Section B was the reverse. Demostration slides were available as both glass and virtual slides. For the second and third laboratories, both virtual and glass slides were available and students were allowed to choose which they preferred to use. One to two instructors were available for help in both the computer laboratory and the microscopy laboratory for all laboratory sections. Following each laboratory session, virtual slides were annotated by the instructor to illustrate pertinent findings on each slide.

Survey

After completion of the cytopathology portion of the course, students were surveyed regarding level of satisfaction with the system and desired uses within the course. The survey was anonymous and questions were identical to previous survey questions (Tables 2-8). 2006 and 2007 results were statistically analyzed using chi square and fisher exact tests. In addition to the 2006 survey questions, students were also asked to:

- Indicate what resources they used to study for the exam (Table 9)
- Indicate if they thought classes using only tissue sections could be successfully taught using virtual microscopy alone (Table 10).
- Rate virtual microscopy learning features (Table 11)
- Indicate if they used glass slides, virtual slides or both to complete the third laboratory session (this data collected by in-class poll).

Website Development

Study authors and DELTA (Distance Education & Learning Technology Applications) co-developed a concept for a master website; this project is ongoing.

Senior Student Rotation

The microscope laboratory for the senior rotation was updated to incorporate virtual microscopy into the curriculum. Computers were added to each double-headed microscope station allowing students to simultaneously examine glass slides and virtual slides and/or access online resources. Virtual slides were incorporated into the senior rotation in both hematology and cytopathology; approximately ½ of slides currently reviewed by students in the rotation are virtual slides. Currently, over 110 virtual hematology, cytology and histopathology slides have been scanned and are available online for viewing.

Results

Sophomore Students 2006

62 students (82.7% of enrolled students) participated in the study. Sixty-two completed the survey and 55 (73.3% of enrolled students) completed the virtual exam for grading. Seven students were unable to complete the virtual exam for grading purposes due to technical difficulties but felt able to complete the survey. All seven were offered the opportunity to retake the exam at a later date but declined.

Survey Results

Tables 2-8 show survey results. Briefly, 80.6% of students found the VM system easy to use and 77% responded favorably to the low power overview that indicates the area of the slide currently being viewed on high power. Just over half of students responded positively to using a computer instead of a microscope while remaining students were divided almost equally between a neutral or a negative rating. 46.8% of students gave a positive rating for the fine focus feature while 37.1% were neutral. Of all the various features, resolution had the lowest positive rating at 37.1% and the highest negative rating at 32.3%.

87.1% of students were not bothered by time delays while navigating on slides. Similarly high percentages of students did not mind the time delay when using the fine focus feature (86.9% non-bothersome rating) or viewing the fine focus feature as a separate pop-up window (80.3% non-bothersome rating). Students found the lack of a 100x objective more disagreeable; only 37.1% of students gave this feature a non-bothersome rating while 17.8% identified this as a negative feature.

Students showed a strong preference for traditional glass microscopy (GM) for graded practical exams but preferred the option of VM for take home quizzes or exercises and for studying. Seventy-one percent of students preferred traditional GM for graded practical exams, 80.6% preferred the option of using VM for take home quizzes or exercises and 72.6% wanted to use virtual slides for studying. Students also showed a strong preference for use of VM in the laboratory sessions with 95.2% indicating they would prefer some combination of glass and virtual slides; 45.2% wanted an in-laboratory mix of virtual and glass slides while 50% preferred laboratories using only glass slides with virtual slides available for studying. Few students wanted only VM for laboratory exercises and no students preferred to use only glass slides for laboratory sessions and for studying. Most students (69.4%) did not feel that the number of computers at the CVM is adequate to support extensive use of VM in the veterinary curriculum.

Survey results indicate most students feel they spend a moderate or high amount of time studying glass slides outside of scheduled laboratory sessions in preparation for graded practical exams, but 30.6% spend little or no time studying. Were virtual slides available, 74.2% of students projected that they would spend a large amount of additional time studying. Of the 30.6% who currently spend little or no time outside of laboratory sessions studying glass slides, 100% indicated they thought they would spend additional time studying if virtual slides were available with 94.7% indicating they felt they would spend a large amount of additional time.

Students identified several VM test taking features as highly advantageous. Features with high positive ratings included the ability to review previously viewed slides at any time (90.4% positive rating), the ability to choose the amount of time spent per slide (83.9% positive rating), and the ability to move freely from slide to slide (77.4% positive rating). Taking the virtual exam in a more comfortable computer laboratory environment was considered advantageous by 61.3% of students. Not having to adjust a microscope was not identified as significantly advantageous; only 35.5% gave this a positive rating while 43.5% indicated there was no test taking advantage to this feature.

Fifty-one students (82.3%) wrote remarks in the additional comments area of the survey with three main themes emerging. The most frequent statement (32.3% of students) was that VM would be most valuable or useful as a study aid. Twenty-five percent of students noted that the virtual slides had poor resolution, were ‘fuzzy’ or there was poor focus at higher magnifications

with some indicating they felt this was a major disadvantage compared with glass slides. The third most common remark (19.4% of students) was regarding the perceived need for continued exposure to traditional microscopy within the curriculum. These students felt strongly that continued practice using microscopes is necessary because they would need to be proficient at microscopy for private practice. Other comments ranged from very positive statements about the technology, to practical statements such as not getting seasick while using VM, or that students would likely become more accustomed to the system with increased exposure.

Test Results

Grade distribution and mean test scores on the glass exam did not differ significantly between students who took the virtual exam and those who did not. Overall, students lost an average of 9.35 percentage points on the virtual exam; 14.5% achieved a higher score, 12.7% received the same grade and 72.7% lost points. For those who improved their grades, improvement ranged from 5 - 22.5 percentage points with half gaining ≤ 7.5 percentage points and half gaining ≥10 percentage points for an average gain of 11.9 percentage points. Of students who lost points on the virtual exam, 27.3% lost 2.5 - 7.5 percentage points, 32.7% lost 10 - 22.5 percentage points and 12.7% lost 25 - 45 percentage points. Fifty percent of students who performed in the bottom quarter on the glass exam remained in the bottom quarter on the virtual exam. 78.6% of students who performed in the top quarter on the glass exam remained in the top quarter on the virtual exam. Students in the bottom quarter on the glass exam lost an average of 3.4 percentage points while those in the top quarter lost an average of 6.6 percentage points. Students in the center 50% had the greatest point loss at an average of 14.7 percentage points.

Sophomore Students 2007

For the first laboratory exercise, no significant difference was observed between students who used virtual slides to complete the assigned cases and those who used glass slides. However, a significant instructor bias was noted indicating that additional preparation time for instructors assisting with the laboratory sessions is needed. For the third laboratory session, 18.6% indicated they used only virtual slides, 31.4% used only glass slides and 50% used a combination of glass and virtual slides (70 responses, 94.6% of enrolled students).

56 students (75.7% of enrolled) completed the survey. Most results were not different significantly from previous results (Tables 2-8). Results which were significantly different include the following: Students were more positive in 2007 about viewing slides with a computer (76.8% positive rating; 53.2% previously) and rated resolution higher than in 2006(60.7% positive rating; 37.1% previously), but had decreased tolerance of VM time delays (28.6 and 20% negative ratings; 4.8 and 3.3% previously) and the lack of a 100x view (43.6% negative ratings; 17.8% previously). While most students still preferred VM for quizzes, take-home exercises and studying, greater numbers had no preference for glass or virtual in 2007; 20% had no preference for take home exercises and quizzes (1.6% previously) and 27.3% had no preference for studying (11.3% previously). Similar to 2006, most students indicated they would spend moderate to large amounts of additional time studying for all practical exams were VM universally available; however the number of students who felt they would spend large amounts of time decreased (44.6%; 74.2% previously) while those who felt they would spend moderate amounts increased (28.6%; 16.1% previously). Percent of students who felt they would spend little or no additional time studying also increased (26.8%; 9.7% previously). Regarding VM test-taking features, 2007 students rated the ability to review slides at any time moderately lower

(59.2% positive rating; 90.4% previously), but rated the ability to test a more comfortable environment (90.7% positive rating; 61.3% previously) and not having to adjust a microscope significantly higher (90.8% positive rating, 35.5% previously) than in 2006.

Additional 2007 results (Tables 9-11) indicate that most students found VM superior to GM for learning to effectively utilize low power views of a slide and for learning to identify good regions of a slide for high-power examination. Only 32.7% thought that VM was no better than GM for leaning to successfully utilize low power views while 23.6% rated VM at a 1 or 2 for this activity indicating they felt VM was much better for learning this skill. 25.5% gave a rating of 1 or 2 for using VM to learn to identify good regions for high power examination while 29.1% felt VM was no better than GM for learning this activity. Students also found VM superior for group learning, interacting with instructors and student-student interactions. 53.5% felt VM was much better (rating of 1 or 2) than GM for group learning while only 16.1% felt VM was no better than GM for this activity. For interactions with instructors and assistants, 48.2% gave a strong positive rating (1 or 2) while 26.8% felt VM was no better than GM. Regarding the ability to interact with other students during lab, 53.6% rated VM highly for this activity and 19.6% thought VM no better than GM. Students were divided between VM and GM for learning slide navigation with approximately 50% feeling that VM was no better than GM for this purpose and 50% feeling that VM was somewhat better to much better for learning this skill.

Most students believe VM could potentially replace GM for courses using tissue sections, but many remain concerned that any reduction in the amount of traditional microscopy in the curriculum might negatively impact their ability to become proficient at microscopy. 14.5% felt courses using only tissue sections could be taught using VM as long as some courses were still taught using glass slides to allow students to gain microscopy skills. 47.3% felt it may be possible to teach such courses using only VM but were concerned that any decrease in real microcopy could negatively impact their ability to become proficient in this activity. 38.2% maintained that all courses using microscopy should continue to be taught with glass slides.

Website Development

A website design has been created and classification systems allowing each slide to be classified up to 4 ways has been developed for hematology and cytology slides. A group of test slides have been selected and currently are being linked into the website to test the system.

Senior Rotation

Formal assessment of senior students has not been performed, but informal feedback obtained by instructors indicates students like the availability of computers at each workstation and instructors have observed that virtually all students use the computers to access online course materials or other available online resources. Computers receive heavy use, even during microscopy portions of the course which do not use virtual slides (urinalysis, parasitology). Student reactions to the virtual slides and VM system are positive. In particular, students have commented on the ease of being able to demonstrate or discuss items viewed on a computer screen (as opposed to the microscope), they like the uniformity of the virtual slides (i.e., everyone sees the same thing), they like being able to compare glass and virtual slides side by side, and that viewing virtual slides is less tiresome than glass slides.

Discussion

Overall, most survey responses were not significantly different for 2006 and 2007 students indicating that student perception of VM was generally positive and desired uses within were similar between years with few changes noted following increased exposure to the technology. A very high proportion of both 2006 and 2007 students found the VM system easy to use and the system has been easily integrated into both the sophomore clinical pathology course and the senior clinical pathology rotation. Resolution of the system was somewhat problematic, but 2007 students rated it higher than 2006 indicating students may be more accepting of resolution limits with increased exposure to VM. Resolution on virtual slides does not yet compare with the resolution of a good microscope. However, in the opinions of the instructors who have worked with the VM system, it is more than sufficient for slides in which very fine detail is not required for a diagnosis and was certainly sufficient for a correct interpretation on all virtual test slides used in the study. We have observed that uniform focus is more consistent with tissue sections compared with cytology specimens, which often have varying levels of thickness throughout the slide. In addition, cytology often emphasizes fine cellular detail whereas histology and histopathology focus more on tissue architecture with less attention to fine high power detail. Increased use of z-axis scanning for fine focusing does improve focus ability in cytology specimens and advances in the technology may improve further improve resolution.

2007 students were less tolerant of system time delays and lack of a 100x view. This is not unexpected since these students had a greater chance to work with the system and thus are more likely to be critical of perceived shortcomings. Regardless, time delays were identified as a significant problem by a minority of the class. Lack of a 100x view was more concerning with more than 40% viewing this as significant problem. Instructor perception is somewhat different. Most cytology specimens can be adequately evaluated using a 40x objective with the exception of some very small structures or etiology agents. In fact, most students spend too much time trying to evaluate cells and structures on 100x and end up overlooking the larger picture; forcing students to rely primarily on a 40x view may be beneficial.

Use of VM for testing can offer some distinct advantages over traditional microscopy and VM has even been incorporated into the American Board of Pathology board certification exams. From the instructor point of view, use of virtual slides eliminates the need to have more than one set of exam slides, eliminates physical set-up and break-down of exams, and ensures that each student has the same view of the slides. However, major disadvantages include the need to administer exams in a secure setting, having enough computers available for testing purposes and the possibility of a system failure. In our survey, students clearly felt that many of the features available in the virtual exam offered a major advantage over glass practical exams at our institute with some variability noted between the survey years.

Despite identifying significant potential advantages for using VM as a testing modality, students from both years overwhelmingly preferred glass slides for practical exams, primarily because students felt testing with glass slides was more indicative of what they would need to do in the ‘real world’ or because they felt the higher resolution of the glass slide was advantageous. While students favored traditional microscopy for exams, both years indicated an overall preference for virtual slides for studying and take home exercises although a higher percentage of 2007 students had no preference of material type. Preference for glass slides for these exercises remained similar for both years which indicates that students without a preference may feel that glass and virtual slides are equivalent for study purposes and take home exercises.

Our results suggest that students may spend more time studying slides (as opposed to static images) in preparation for exams if virtual slides are available. For students who indicated they typically spend little or no time outside of laboratory sessions studying glass slides in preparation for practical exams, nearly all thought they would spend additional time studying if virtual slides were universally available, and most felt they would spend a moderate or large amount of additional time. In 2007, 75% of students indicated they studied virtual slides in order to prepare for the exam while 78.6% said they used glass slides to prepare (percentages using all glass or all virtual slides was not determined). These results show that students are willing to use VM for test preparation, even if they will not be tested using virtual slides. What remains to be determined is if the availability of virtual slides has resulted in more time spent studying or simply a shift in use of available resources.

Students from both survey years overwhelming desired some mix of glass and virtual slides for laboratory sessions either as an in laboratory mix or as glass slides only for the laboratory and virtual slides available online for study and review. Student preference for laboratory sessions is further supported by the pattern of slide use for the third laboratory session in 2007 in which 68.6% of students reported using either glass and virtual slides or virtual slides only to complete the laboratory exercise. For laboratory session one in 2007, no significant difference was found between students assigned virtual slides for the laboratory exercise and those who were assigned glass slides. However, the finding of significant instructor bias is somewhat confounding. What impact increased use of virtual slides for learning purposes will have on student ability to perform using glass slides on tests or in clinical practice remains to be determined.

Because the features of VM accurately simulate traditional microscopy, use of virtual slides allows students to hone skills essential to cytopathology that can't be easily or effectively mastered using static digital images. These skills include effective low power scanning, identification of good regions for high power examination (thin region, good stain quality, intact cells), and the necessity of examining multiple regions on high power before rendering a diagnosis. 2007 survey results show that students felt that VM was superior for learning how to utilize low power views of slides and choosing regions of slides for high power examination while approximately half felt VM was better for learning to effectively navigate on slides. These results are quite significant as such skills are essential and must be mastered in order to successfully examine slides in a clinical setting. What remains to be determined is if student who learn these skills via VM can then translate them for use with glass slides in a clinical environment.

In most traditional microscopy systems used for teaching large numbers of students, only a single person or two people (if using a dual-headed microscope) can easily view a slide at a time. This creates an obstacle for students trying to share information about what they are seeing on different slides or for instructors attempting to demonstrate various features of a slide to small groups of students. Often, this leads to repetitive actions such as students waiting to take turns looking in different microscopes and instructors demonstrating the same items over and over to multiple students. While this can be alleviated to some degree by demonstrating slides via a video or digital camera, it does easily facilitate small group discussions by students or students and instructors during an active laboratory session; rather, it is more effective when reviewing slides with the entire group. By viewing slides on a screen, more individuals can view the slides at once which could allow students to more easily compare slides and instructors to more

efficiently demonstrated or discuss important features of a slide with larger numbers of students while still maintaining a small group focus. 2007 survey results indicate most students felt VM provided a better environment for group learning and student-instructor and student-student interactions. Instructor feedback also indicates they felt that it was easier to teach in small groups when using the VM system because it was easier to point out features on a computer screen and allowed for more interactions between members of the group.

Some students felt very strongly that continued use of traditional microscopy within the veterinary curriculum is essential since they will need use microscopes in clinical practice to examine a variety of in-house preparations. We believe that traditional microscopy is a skill that veterinary students need to master, but this does not exclude using VM as a teaching and learning tool. However, there are some specimens that private veterinary practitioners are unlikely to examine in practice due to specialized processing equipment or advance training needed for evaluation (histology and histopathology slides). It is possible that courses utilizing these types of specimens could be taught using only VM while courses such as clinical pathology and parasitology could be taught with a combination of glass and virtual slides to allow students to gain microscope proficiency. It is also possible that exposure to 'real' microscopy could occur primarily in the clinical year. 2007 survey results indicate students feel this may be feasible, but concern remains about potential loss of microscopy skill if VM replaces a portion of GM in the curriculum. Additional studies may be necessary to assess the impact of incorporation of VM within the veterinary curriculum on student mastery of microscopy.

Several flaws in the study prevent a true comparison of student performance on the glass and virtual exams, but results do indicate that VM can be used for student assessment in veterinary cytopathology education and that there was general agreement between the exams in terms of student performance (i.e. ranking on the glass exam was generally predictive of ranking on the virtual exam). These flaws have almost certainly introduced a bias against performance on the virtual test and student preferences for graded practical exams and include: 1. Students could not lower their grades by taking the virtual test; they could only improve them, so for those who were currently satisfied with their course performance, there was no incentive to try and achieve a higher score. 2. The overall stakes were low as the cytopathology practical exam was worth only 3.33% of the total course grade. 3. As the virtual exam was offered one week after the glass practical exam and coincided with the first day of final exams week, it is unlikely that students devoted additional study time in preparation for the virtual exam and may have actually been less well prepared compared with the glass exam. 4. The technology was new; students were not trained in cytopathology using virtual slides and did not have the opportunity to work with the computer program or virtual slides prior to being oriented at the time of the exam. 5. Viewing area of the slides differed between the glass and virtual slides. The virtual slides typically had a larger area available for high power viewing with some having up to 4 or 5 times as much available viewing area. Because of this, students had to be able to navigate to a suitable region as well as identify and interpret the cytologic findings on the virtual exam. Thus, the virtual exam may have tested a broader (and more realistic) range of skills compared with the glass practical exam which tested only recognition skills and not the ability to find appropriate regions for examination. In light of these study flaws, the grades and survey results are encouraging and may be more positive than the data suggest. On the virtual exam, 54.5% of students improved their grade, achieved the same grade or lost a small amount of points and overall student survey results from both years were positive.

Within the senior clinical rotation, integration of virtual slides has been well received by students and instructors, and it has also has had the very practical effect of reducing the amount of time students spend looking in a microscope. This rotation is very microscopy intensive with students typically spending 20-25 hours during week one looking at slides. Individuals who are not used to microscopy normally find spending this much time looking through a microscope exhausting. Integrating virtual slides into the course work has resulted in many the positive benefits previously discussed and also appears to alleviate some of the fatigue associated with slide review. In addition, demonstrating virtual slides using a computer and overhead projector has proved to be superior to demonstrating glass slides using the currently available microscope, video camera and overhead projector as the color fidelity, resolution and clarity of the VM system is superior.

The primary obstacles to fully integrating VM into the veterinary curriculum are the lack of sufficient numbers of computers, the limited number of computer laboratories and the current configuration of the main microscopy laboratory. Until these items are addressed, it is likely that VM will not be utilized to its full potential. Currently at the CVM there is one main student computer laboratory with 20 PC units. This number of computers could, in theory, be sufficient to teach a laboratory for half a class at a time (if two students use one computer). Currently, the sophomore clinical pathology course already splits the class into two sections for most laboratories to allow better student-instructor ratios and prevent student fatigue. However, the reality is that the space in the computer lab is really only large enough to comfortably accommodate 20 individuals (1 per computer). Many students own their own laptops and this eases some of the computer strains, but significant slowdown of the system will occur if large numbers of students attempt to connect to the server wirelessly and currently there is no other option for large numbers of students to access the internet using personal laptop computers other than wireless access. Testing using only 20 computers can be done, but requires administering the test to students in 4 groups. This is not time effective for instructors, ties up computer resources for greater amounts of time, and increases the chances of a security breach. The configuration of the senior rotation laboratory is ideal: Each 2-person workstation has a double-headed microscope and a computer. While we would like to reproduce this configuration in the main student laboratory, it is not feasible to add computers to the laboratory because available counter space is also used for wet-labs and there is no space available for separate dry and wet laboratories. In addition, renovation costs for adding internet connections is prohibitive. On a positive note, however, recent updates in the teaching laboratory include installation of 16 large flat screen panels and an integrated computer, microscope and digital camera system which will allow virtual and glass slides to be effectively demonstrated during laboratory session. This is a significant improvement. Previously only glass slides could be demonstrated via a microscope and video camera with the images projected on television monitors and there was no way to show digital media (PowerPoint presentations, digital images) in the laboratory.

We plan to continue expanding the role of VM in the clinical pathology course and senior rotation. Currently, over 110 cytology, hematology and histopathology slides have been digitized and more than 100 additional slides are in process for scanning. In addition, more than 170 histology and histopathology (including a good collection of ophthalmologic pathology slides) are available from the virtual slide collection of the University of Tennessee. We plan to finish developing the VM website which will serve as the main access point for all virtual slides and will be freely available online (non-wrapped). Hopefully it can serve as a valuable resource beyond the clinical pathology courses or even the CVM. We would also like to see other

disciplines utilize the VM technology; at this time some histopathology slides have been scanned, but hope to have other disciplines and groups use the system as well.

Tables

Table 1. Cytopathology Practical Exam Specimens and Interpretations, 2006

Slide #	Specimen	Interpretation*
1	Canine lymph node	Lymphoma
2	Canine perianal mass	Apocrine gland adenocarcinoma
3	Canine lymph node	Metastatic carcinoma
4	Canine perianal mass	Perianal gland adenoma
5	Canine pleural fluid	Carcinoma
6	Canine mandibular lymph node	Salivary tissue
7	Canine skin mass	Mast cell tumor
8	Canine skin mass	Histiocytoma
9	Canine skin mass	Plasmacytoma
10	Canine subcutaneous mass	Lipoma
11	Canine subcutaneous mass	Epithelial/follicular cyst or tumor with follicular differentiation
12	Canine submandibular mass	Mucocele
13	Canine ulcerated cutaneous lesion	Blastomycosis
14	Canine subcutaneous mass	Sarcoma
15	Equine abdominal fluid	Septic suppurative inflammation
16	Feline lymph node	Eosinophilic lymphadenitis
17	Feline mandibular mass	Melanoma
18	Feline nasal mass	Cryptococcosis
19	Feline pleural fluid	Chylous effusion
20	Canine lymph node	Reactive/hyperplastic lymph tissue

*****Interpretation does not include alternative full credit or partial credit answers

Table 2. Student Survey Results for VM System Features Set I, 2006 and 2007

Virtual microscopy system features	Number Rating							
	1-2 2006	1-2 2007	3 2006	3 2007	4-5 2006	4-5 2007	Mean 2006	Mean 2007
Ease of use	80.6%	85.7%	11.3%	8.9%	8.1	5.4%	1.9	1.8
Low power orientation view showing area currently viewed on high power	77.0%	87.5%	13.1%	10.7%	9.8	1.8%	1.8	1.5
Ability to use a computer instead of a microscope to view slides	53.2%	76.8%	22.6%	19.6%	24.2	3.6%	2.5	1.8
Fine focus feature	46.8%	58.2%	37.1%	30.9%	16.2	10.9%	2.5	2.4
Resolution (ability to see detail)	37.1%	60.7%	30.6%	33.9%	32.3	5.4%	3.0	2.3

Scale is from 1 to 5 with 1 indicating 'excellent/I liked it a lot' and 5 indicating 'poor/I didn't like it at all'. Ratings of 1 or 2 are considered positive, rating of 3 is considered neutral, and ratings or 4 or 5 are considered negative.

Table 3. Student Survey Results for VM System Features Set II, 2006 and 2007

Virtual microscopy system features	Number Rating							
	1-2 2006	1-2 2007	3 2006	3 2007	4-5 2006	4-5 2007	Mean 2006	Mean 2007
Time delay when moving around on the slide	87.1%	51.8%	8.1%	19.6%	4.8	28.6%	1.5	2.7
Time delay when using the fine-focus feature	86.9%	58.2%	9.8%	21.8%	3.3	20.0%	1.5	2.4
Viewing the fine focus in a separate pop-up window	80.3%	67.9%	11.5%	13.2%	8.2	18.8%	1.8	2.2
Lack of a 100x objective view	59.7%	38.2%	22.6%	18.2%	17.8	43.6%	2.3	3.1

Scale is from 1 to 5 with 1 indicating 'feature didn't bother me at all' and 5 indicating 'feature bothered me a lot'. Ratings of 1 or 2 are considered non-bothersome, rating of 3 is considered neutral, and ratings of 4 or 5 are considered negative or bothersome.

Table 4. Student Survey Results of Preferences for Virtual vs. Traditional Microscopy in Course Assessment Activities, 2006 and 2007

Activity	Preference

	Virtual 2006	Virtual 2007	Glass 2006	Glass 2007	No Preference 2006	No Preference 2007
Graded practical exams	16.1%	16.4%	71%	70.9%	12.9%	12.7%
Take home quizzes or exercises†	80.6%	63.6%	17.7%	18.2%	1.6%	20.0%
Studying*	72.6%	47.3%	27.4%	32.7%	11.3%	27.3%

*11.3% of 2006 students and 7.3% of 2007 students selected both virtual and glass
†1.8% of 2007 students selected both virtual and glass

Table 5. Student Survey Results of Preferences for Virtual vs. Traditional Microscopy for Laboratories, 2006 and 2007

Laboratory Sessions Conducted using:	Preference 2006	Preference 2007
Only virtual slides	4.8%	1.8%
A mix of glass slides and virtual slides	45.2%	57.1%
Using only glass slides during sessions with virtual slides available for studying	50%	39.3%
Only glass for both the laboratory sessions and for studying	0%	1.8%

Table 6. Student Survey Results for Current Study Habits and Projected VM Study Habits, 2006 and 2007

Studying habits	Number Rating							
	1-2 2006	1-2 2007	3 2006	3 2007	4-5 2006*	4-5 2007†	Mean 2006	Mean 2007
Time currently spent outside of scheduled lab sessions reviewing glass slides for practical exams	24.2%	28.6%	45.2%	44.6%	30.6	26.8	3.2	3.0
Additional time you would spend studying outside of scheduled lab sessions if virtual slides were available	74.2%	44.6%	16.1%	28.6%	9.7	26.8	2.1	2.7

Scale for time currently sent outside of scheduled lab sessions reviewing glass slides is from 1 to 5 with 1 indicating 'I spend a lot of time outside of lab' and 5 indicating 'I don't spend any time outside lab'. Scale for additional time studying if virtual slides were available is from 1 to 5 with 1 indicating 'I would spend a lot more time' and 5 indicating 'I wouldn't spend any more time'. Ratings of 1 or 2 are considered indicative of large amounts of time, rating of 3 is considered

indicative of moderate amounts of time, ratings of 4 or 5 are considered indicative of little or no time.

Table 7. Student Survey Results for VM Test Taking Features, 2006 and 2007

Virtual microscopy test features	Number Rating							
	1-2 2006	1-2 2007	3 2006	3 2007	4-5 2006	4-5 2007	Mean 2006	Mean 2007
Ability to review previously viewed slides at any time	90.4%	59.2%	8.1%	18.5%	1.6%	22.3%	1.4	2.4
Ability to choose how much time to spend on each slide	83.9%	81.2%	8.1%	13.2%	8.1%	5.7%	1.6	1.6
Ability to move freely from slide to slide	77.4%	72.2%	14.5%	13.0%	8.0%	14.8%	1.7	2.0
Ability to take the test in a more comfortable environment	61.3%	90.7%	24.2%	3.7%	14.6%	5.6%	2.2	1.6
Not having to adjust a microscope	35.5%	90.8%	21%	3.7%	43.5%	5.6%	3.1	1.4

Scale is from 1 to 5 with 1 indicating 'feature is a major test taking advantage' and 5 indicating 'feature provides no test taking advantage'. Ratings of 1 or 2 are considered advantageous, rating of 3 is considered neutral, and ratings or 4 or 5 are considered indicative of little or no advantage.

Table 8. Student Survey Results for Adequacy of Computers, 2006 and 2007

Are computers numbers (excluding privately owned laptop computers) adequate to support extensive use of VM in the veterinary curriculum?	2006	2007
Yes	30.6%	40%
No	69.4%	60%

Table 9. Student Survey Results for Practical Exam Preparation, 2007

I Studied for the Practical exam using:	**Positive response**
The notes/PowerPoint presentations	98.2%
Recommended textbooks	14.3%
Glass slides outside of regularly scheduled laboratory sessions	78.6%

Virtual slides outside of regularly scheduled laboratory sessions	75.0%

Table 10. Student Survey Results for Use of VM in Courses Utilizing Only Tissue Specimens, 2007

Can courses which use only tissue specimens be taught successfully only VM?	Percent agreement
Yes, as long as some courses continue to utilize glass microscopy so I can learn to correctly use a microscope	14.5%
Maybe, but I am concerned that any reduction in use of real microscopes may negatively affect my ability to correctly use a microscope in practice	47.3%
No, microscopy is an essential skill and all courses which utilize it should continue to have glass microscopy	38.2%

Table 11. Student Survey Results for Virtual Microscopy Learning Features, 2007

Virtual microscopy learning features	Number Rating					
	1	2	3	4	5	Mean
Learning to navigate on slides	12.7%	5.5%	18.2%	14.5%	49.1%	3.8
Learning to successfully utilize low power views	14.5%	9.1%	34.5%	9.1%	32.7%	3.4
Learning to identify good regions for high power examination	18.2%	7.3%	32.7%	12.7%	29.1%	3.3
Group learning	33.9%	19.6%	30.4%	0.0%	16.1%	2.4
Interactions with instructor and laboratory assistants	32.1%	16.1%	17.9%	7.1%	26.8%	2.8
Ability to interact with other students during laboratory sessions	30.4%	23.2%	19.6%	7.1%	19.6%	2.6

Scale is from 1 to 5 with 1 indicating ‘virtual microscopy is much better than glass microscopy’ and 5 indicating ‘virtual microscopy is no better than glass microscopy’.