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Final Report

The Virtual Slidebox — a new learning paradigm for exploring the microscopic world

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http://www.uq.edu.au/dentistry/virtual-microscopy-catalogue

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Report Contents

1.0 EXECUTIVE SUMMARY

'The Virtual Slidebox' is a project aimed directly at making the study of microscopy exciting once again for a digitally engaged body of tertiary students. By transforming microscopy from the older analogue format of the light microscope to its computerised equivalent ('virtual microscopy'), the eye-straining tediousness of this older format has now been brought into question. In the process, virtual microscopy (VM) transforms the study of microscopic material into a spatially and temporally variable immersion in the world just beyond the limits of human vision.

Microscopy is the first port of call for those students who are keen to learn about this nano-world beyond human vision. It is crucial then that we get both the learning/teaching protocols and the technology right in microscopy so that students can become actively, even deeply engaged in this realm of knowledge. As an entrance into all things nano- (and the increasing importance of this domain of knowledge in many disciplinary areas), the successful integration of VM into the curriculum should be high on the must-do list of the relevant educators.

Much like the difficulties being experienced in the pedagogy of quantitative and mathematical skills, the learning and teaching of analogue microscopy skills has become increasingly difficult, as students have switched off from using this technology in their quest to understand the histology and/or pathology of biological specimens. Students find the analogue microscope an excessive physical and mental strain. Educational administrators have also worried about its cost, from the perspectives of maintenance, capital investment and the number of support personnel involved. This unease has made the study of analogue microscopy ripe for technological and pedagogical innovation.

Virtual microscopy is a relatively new technology emerging in the mid 1990s that turns the computer into a microscope while at the same time keeping the glass slide technology that formed the basis of analogue microscopy. By digitally scanning the glass slide VM makes microscopy more easily amenable to the myriad of ways electronic technologies can represent this nano-world.

The study of histology develops both an understanding of the cellular structure and function of organs and tissues. The ability to recognize tissues at the microscopic level is therefore one of the core subjects in undergraduate curricula for medicine and allied health professions. Histology is an image-intensive discipline as the ability to interpret microscopic images is critically important to understanding disease processes as they manifest themselves in these organs and tissues. Although student learning in histology has traditionally been based around the study of specimens on glass slides, extensive practice with the microscope itself is no longer essential in the modern health care setting.

VM is set to revolutionise the teaching of histology and pathology as microscopic structures and tissues can now be viewed on computer with similar resolution and flexibility of navigation as is experienced under the conventional light microscope. Advantages of VM over traditional microscopy include: online access; reduced infrastructure costs; an enhanced capacity for collaborative learning among students, and among disciplines; along with the provision of an excellent learning tool for regional learning centres. VM can promote collaboration between universities, private practice, industry and professional associations, advance knowledge and provide a tool for continued professional education. Therefore, VM provides a highly flexible, innovative and dynamic learning tool for a diverse range of student groups.

This report then details the results of one project team's efforts at the University of Queensland (UQ) in introducing VM into their curricula. Certainly student response has been overwhelmingly in favour of VM, a response demonstrated again and again in survey after survey. The problem remained institutionally located in integrating VM technology into the UQ intranet. Equally, there is still resistance among some academic and technical staff to this educational innovation.

2.0 AIMS AND INTENDED OUTCOMES

The intended aim for ‘The Virtual Slidebox’ project was the implementation of a state-of-the-art virtual imaging technology system to enhance student engagement and learning of microscopic structure across a wide range of anatomical sciences at UQ.

The specific outcomes to be achieved in this proposal were:

1. Incorporation of virtual microscopy into the curriculum of UQ courses delivered by the project team (dentistry, veterinary science, biomedical science, medicine). This will be done in a staged approach based on our experience during pilot programs using VM.
2. Enhancement of student learning using surveys (formal and informal), group work, self-assessment, and independent learning.
3. Promotion of VM technology to other colleagues within the institution, other higher education providers and regional learning centres, professional bodies, and industry for further collaboration in teaching enhancement and to promote reform in education through reduced reliance on traditional teaching infrastructure, increasing acceptance of VM in various curricula, and expansion of the provision of virtual classrooms with internet access.
4. Production of a virtual slidebox containing over 5000 slides. The material to be converted to virtual slides included specimens from oral histology, oral pathology, veterinary histology, veterinary pathology, human histology and human pathology.

3.0 APPROACH AND METHODOLOGY

3.1. Background

Microscopy of histological and pathological specimens is the staple of practical classes used to teach biology, histology, anatomy and pathology in the biological sciences and in many specialty areas of professionally focussed higher education courses including medicine, dentistry, and veterinary sciences. The viewing and analysis of microscopic structures is also the cornerstone of diagnostic pathology; disease diagnosis and forensic pathology rely on interpretation of tissues and cells via microscopy. Modern medicine and the teaching of this specialty are very much based on the understanding and interpretation of microscopic structure.

The pre-eminence of the conventional analogue microscope as a teaching device, and the delivery of lectures as a teaching mode, have only recently been challenged by medical academics. The consideration of alternatives has largely been driven by:

- financial restrictions
- a reduction in the amount of time allocated to instruction in relevant courses
- a major shift in the design of new curricula to include newer learning approaches such as problem based learning (PBL)
- the reduced staffing resulting from the approaching retirement of “Baby Boomer” staff members with fewer “Generation X” colleagues taking up academic posts.

In addition, students generally dislike using conventional light microscopes for the examination of tissue specimens. They find using the light microscope difficult, frustrating and tiresome, both physically and mentally. They do not find examining tissue specimens with a light microscope interesting, exciting, or highly rewarding, especially without timely support and guidance from a tutor. Even when students are shown how to use the microscope they complain about the quality and consistency of its use. Light microscopes need qualified staff to maintain them and the numerous glass slide sets that are required for practical classes. Traditionally this has required a large amount of physical space and experienced technical assistance. More importantly, the nature of slide preparation where multiple sections of a single specimen are used to produce new slides means that the slides are not identical and quite often may not include all the regions of interest. In addition, students generally do not engage deeply with the subject material, and apply only the bare minimum of effort to pass course components involving analogue microscopy.

With these factors in mind, individually the members of this project team set out several years ago to find alternative approaches to the teaching of microscopy, and discovered a new and highly innovative technology called ‘virtual microscopy’ whereby high resolution images can be digitally scanned and then viewed on a computer screen (ScanScope™, Aperio Technologies Inc, USA, see their website at: http://www.aperio.com). VM technology provides a detailed and interactive ‘virtual’ slide with the ability to alter resolution and viewing area dynamically, rather than a static still digital photo with fixed resolution available through traditional microscopy. (Note that the terms ‘virtual’ and ‘digital’ are used here interchangeably, and in this context Rojo et. al. also make the pertinent point that ‘the term *virtual microscopy* is not an accurate term, and we prefer the term *digital microscopy*’ p.285, italics in the original).

With this newly-developed virtual microscopy technology, glass microscopic slides can be scanned at high magnification and resolution (up to ×40), viewed as fully browser-able virtual slides (Figure 1), and housed on the Internet or any digital medium, allowing them to be easily transmitted and shared worldwide. The central component of this technology includes a high-definition optical scanner that can convert the specimen on a glass slide to a digital equivalent. A specialised algorithm is used to compress the massive amounts of digital data generated from this process and convert it to a workable virtual slide. With the associated software, one can peruse the virtual slide exactly as a physical glass slide. It can be moved in any direction using a computer mouse or keyboard, and can be viewed at any magnification from ×1 to ×40. Furthermore, the virtual slide can be housed on a local server, enabling worldwide remote access of the material through a defined IP address, along with real time consultation regarding the content of the slide between two or more remote sites enabling remote diagnosis of disease. The software required to view the virtual slides — Imagescope™ — is free to download from the Aperio website, making it very easy for anyone to run the application on their computer. The software also includes other utilities including built-in measurement tools and data analysis, and a digital camera whereby static digital images of defined areas of the virtual slide can be taken and emailed instantaneously for professional opinion (Figure 2).

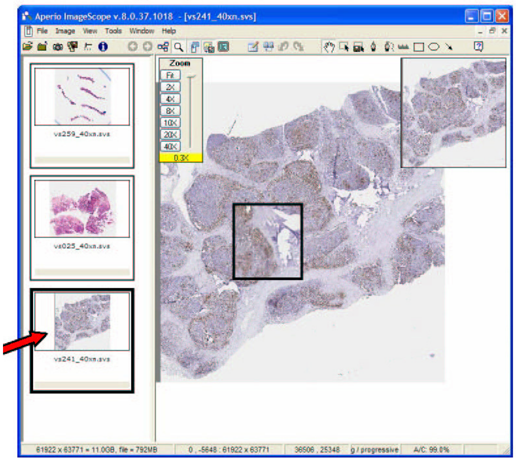

Figure 1

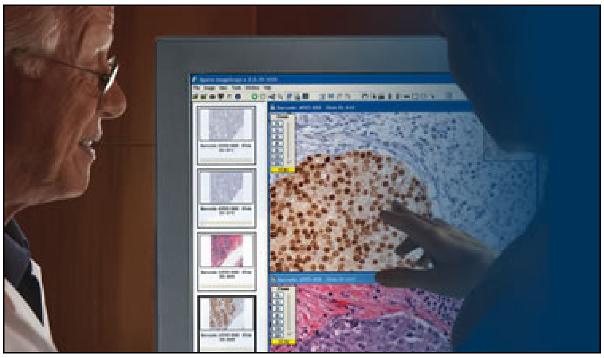

Figure 2

3.2 Theoretical and Pedagogical Foundations

During pilot projects, members of the project team have developed learning-centred approaches to the teaching of histology using VM, that are underpinned by Chickering and Gamson’s (1987) seven principles of good practice in undergraduate education.

New technologies, such as the Internet and VM readily lend themselves to developing learning systems that incorporate elements of effective learning including collaborative learning, learner control, temporally and spatially flexible learning contexts. The electronic technology revolution has therefore been perceived as one offering great potential for creating a comparable pedagogical revolution (Vargo, 1998) through the opportunities they provide to innovate and improve on traditional teacher-centred approaches and move to more effective student-centred approaches (Relan & Gillani, 1997; Lefoe, 1998).

Although many claims have been made in the literature about the increased effectiveness of online environments for promoting learning, Jackson and Anagnostopoulou (2001) point out that, ‘where effectiveness is demonstrated, it can often be attributed to a pedagogical improvement rather than to the use of the technology itself’. New technologies such as multimedia and online technologies are considered ‘tools’ along with face-to-face contact, print and other options with the appropriateness of choices being dependent on an awareness of the attributes of each tool, and the matching of the requirements of a chosen strategy with the ‘tools’ that best serve those requirements (Torrisi-Steele, 2002). It has therefore been argued that inappropriate use of technologies in the teaching and learning environment may be minimized through an approach which does not focus primarily on technology but instead directs focus on learner needs, discipline requirements, learning outcomes and reflection on teaching practices (Torrisi-Steele, 2002). ‘It is not the technology that is important, [rather] it is how it is used by the teacher to create new experiences for the learner’ (Bennet, Priest & Macpherson, 1999).

In summary, when introducing computer-based information technology to a course, one has to be cognizant of the fact that there is no advantage in just using information technology for its own sake, unless it provides an educational benefit, namely to help students engage in a worthwhile learning activity. Computer assisted learning and teaching and online learning are valid and effective educational tools that enhance student learning within the context of the social construction model of learning and teaching.

4.0 ACTUAL OUTCOMES: ADVANCES IN KNOWLEDGE

The most significant ALTC priority (#4) that relates to this project is 'innovation in teaching and learning, particularly in relation to new technologies'. The term 'new technologies' though is not nearly accurate enough; what is more precise is the phrase 'electronic technologies', not all of which are new. Anyone working in education is familiar with electronic technologies of one kind or another. VM is clearly an electronic technology and the one advance that this project advocated strongly for was to place its pedagogic potential in the realm of what Gregory Ulmer (2003) calls 'electracy'. And it is this evolution of 'literacy into electracy' that he explains more fully on his website for this textbook:

> What literacy is to the analytical mind, electracy is to the affective body: a prosthesis that enhances and augments a natural or organic human potential. Alphabetic writing is an artificial memory that supports long complex chains of reasoning impossible to sustain within the organic mind. Digital imaging similarly supports extensive complexes of mood atmospheres beyond organic capacity. Electrate logic proposes to design these atmospheres into affective group intelligence. Literacy and electracy in collaboration produce a civilizational left-brain right-brain integration. If literacy focused on universally valid methodologies of knowledge (sciences), electracy focuses on the individual state of mind within which knowing takes place (arts).

Currently we are all embroiled in this transition from 'literacy to electracy', one in which a wide range of electronically arbitrated, new media technologies (along with broader cultural, social, political, and economic shifts) are significantly reshaping the production of knowledge. Most pertinently for the science-based disciplines we are dealing with in introducing VM into UQ, there is now a much greater interaction between these disciplines and the arts based methods of knowledge gathering. This is a point project participants' Dr Terry Maybury and A/Professor Camile Farah elaborate on in 'Electronic Systems of Knowledge in the World of Virtual Microscopy' when they write:

> VM technologies and practices are clearly a component of this idiosyncratic combination of both a scientific/medical paradigm and a humanistic, arts orientation in education as these technologies and practices have themselves emerged in the medical curriculum over the last ten to fifteen years or so.

This broad connection between electracy and virtual microscopy is also applied more closely in other published papers produced during the course of this project. These academic papers are listed in the Dissemination section (8).

Another significant advance is the setting up of a database: Aperio Technologies' Spectrum+™ software, to accommodate the storage of the VM slides. It is into the Spectrum+™ database that the scanned slides are directed and stored, where important metadata is located, and from which this information is retrievable in a wide range of search fields, a process known as data mining. Located on a server at the UQ Centre for Clinical Research, the VM database is where the approximately 1500 slides already scanned can be accessed. Additionally, through a link established on the School of Dentistry website, interested educators can search a descriptive spreadsheet of these slides and follow the instructions for free access to the slides of their choose. The address for this website is:
http://www.uq.edu.au/dentistry/index.html?page=118775&pid=0.

Perhaps the most significant advance in knowledge though comes less in the form of institutional or conceptual innovation or even in academic papers but in the active engagement of UQ students' with the learning capacity of the virtual slides themselves. In survey after survey conducted by the project team (now going back to 2005), the student feedback on VM has been positively effusive. It is worth recounting in numerical detail this effusiveness over this extended survey period. In the course Oral Biology of 2005 (with 58 students), 82.76% agreed with the statement: 'Using the virtual microscope positively enhanced my learning of the material in this course'. In the same course in 2006 (53 students), and in response to the same statement, 88.68% agreed. Once again, in Oral Biology in 2007 (60 students), 88.34% agreed with the same statement. Finally, the 2008 survey of the same course (46 students) produced 89.13% agreement with this core statement. By way of contrast, the respective percentages agreeing with the opposing statement: 'Using the light microscope positively enhanced my learning of the material for this course', were 52.17% in 2005, 77.35% in 2006, 83.05% in 2007 and 52.17% in 2008. While students were clearly more enthusiastic in their responses to VM it was not at the expense of the complete elimination of the light microscope, a fondness encapsulated in the qualitative comments of a number of students that the glass slide contained the 'real specimen'. These positive figures in support of VM were duplicated in all the surveys conducted by the project team (with a total number of 649 students involved). This is a clear indication that students are advancing their own knowledge of the microscopic arena via this new electronic mode of pedagogic delivery.

5.0 FACTORS IMPACTING ON THE PROJECT

5.1 Factors ensuring success

Given there were a number of obstacles to the success of this project (see below) there is one factor worth mentioning that was crucial to its success. The dogged persistence of the Project Leader, Associate Professor Camile Farah in attempting to overcome these obstacles serves as a clear example of what Southwell et. al. see (in *Strategies for Effective Dissemination of Project Outcomes*), as crucial to a project's success and that is enthusiastic and supportive leadership and management for any given innovation to be institutionally embedded and up-scaled. Without this dogged persistence this project could have floundered in a sea of institutional inertia and technical problems. Equally, it is important to mention that one manager's enthusiasm is sometimes not enough. Pedagogic projects containing large IT components inevitably cut across institutional contexts and disciplinary boundaries, meaning that enthusiasm and commitment, along with a shared vision, needs to come from a range of managers in each of the differing contexts related to the project. At their heart, electronic technologies upset these traditional territorial demarcations and hence it is wise to develop a strategy for their successful negotiation beforehand.

One practical factor that helped ensure the success of this project was through the development of a standardised LIKART survey form that constituted the basis of the data gathering on the pedagogic value of VM. Students who had the opportunity of using the technology in their learning of microscopic material were issued with this survey form, which contains both quantitative and qualitative questions, giving us an invaluable data set to work with. The courses surveyed during late 2007, 2008 and 2009 were:

1. Oral Biology (DENT-2012)
2. Foundations of Medical Practice (MEDI-1000)
3. Oral Pathology (DENT-4062)
4. Human Histology and Embryology (BIOM-2034)
5. Systemic Pathology (DENT-3062) ×2
6. Human Reproduction and Fertility (BIOM-3004)
7. Introduction to Pathology (BIOM-3034)

These eight surveys now join six separate course surveys from previous years giving a total of fourteen (14) student surveys devoted exclusively to assessing the pedagogic value of VM at UQ. The total number of students involved was 649. Furthermore, the data from these surveys has been collated into spreadsheets and has provided the ballast to the arguments of our academic papers referred to elsewhere in this report. We can clearly and unambiguously say that there is overwhelming support for VM in these surveys. For instance (and to further reiterate student enthusiasm for VM), in Oral Pathology for 2008, 88.24% of students agreed with the survey proposition that, 'Using the virtual microscope positively enhanced my learning of the material in this course'. This high level of approval was largely replicated in the other course surveys. A pro-forma of the survey form (which was also submitted and approved through the Ethics Committee at UQ) is attached as an appendix.

5.2 Factors impeding success

One of the critical factors impeding the success of 'The Virtual Slidebox' was a technical one. Given that Aperio Technologies are an external software/hardware supplier (with their own coding structures and computing technology) and the UQ IT network (again with its own means of configuring hardware and software) are fundamentally different entities, the successful linking of the two was crucial to the success of the project. The disjunction between these two systems became apparent when it was discovered at the stage of installation of the scanner and related software for the VM system. Advice from Aperio suggested that the scanning process was being carried out correctly. However, the problem persisted and a large number of slides were scanned before the problem was resolved. Along with the shift from a slide scanner that could accommodate 120 slides per session (located at QIMR and no longer in commission) to one that could scan only five at time, these difficulties significantly slowed the pace at which slides were scanned. These technical difficulties (some of which are ongoing) have meant that the VM database has approximately 1500 slides rather than the anticipated 5000.

6.0 APPLICABILITY TO OTHER INSTITUTIONS/CONTEXTS

VM is certainly applicable to other institutions and contexts wherever microscopy is taught. There are however a range of issues to consider. The first of these issues might have more applicability to lecturers and faculty staff than to students. It was the experience of the project team that generally speaking students accommodated the introduction of VM without too much trouble, an assertion the survey results confirmed. On the other hand, faculty staff of all persuasions might themselves be a more appropriate target for learning and development when considering the introduction of an electronic technology like VM. Given that lecturers have extensive knowledge of their content area but are, generally speaking, less well informed about the extensive pedagogic possibilities that a combination of electracy/electronic technologies present, a well thought out program aimed at informing and equipping lecturers with this latter knowledge should be seriously considered. Once faculty staff has an inkling of the creative possibilities of teaching with a technology like VM, they might then have a clear channel to funnel that content knowledge into their teaching with a greater degree of enthusiasm. The lesson here is a simple one: before introducing VM technology in any context ensure that academic, administrative and technical staff themselves are informed, enthusiastic and educated about the transformation.

As already hinted, other institutions and contexts should carefully examine the technological configurations in which they are embedded, especially network configurations. The idea of ‘open access’, while certainly an honourable one, is sometimes difficult to uphold in university contexts where firewalls erect digital barriers that disallow easy access to their resources. It makes sense that a technology like VM (with its high capital costs for the hardware and labour costs for database management) is shared among as many contexts as possible. The firewall issue (along with concerns over copyright) make open access to a slide database a difficult idea in practice. A related idea here is ‘interoperability’, which is the functional compatibility of the various technologies involved in any innovation requiring two or more systems. In all things electronic almost every institution/context will have a differing views (and practicalities) on all of these issues: open/closed access, firewalls, funding availability for hardware and software, staff readiness and the types of network systems involved. Before VM is implemented in these other institutions/contexts all of these issues should be dealt with in a comprehensive manner.

7.0 DISSEMINATION

One often-heralded benefit of electronically mediated forms of pedagogy is their ability to be globally disseminated in an instantaneous fashion. Clearly, in these circumstances global dissemination goes hand in hand with national and local dissemination. As mentioned (and in line with the terms of the agreement between this project and the ALTC), a link on the UQ School of Dentistry website has now been set up which points to a document listing all the approximately 1500 scanned slides from the various disciplines involved that are now in the database. An administrative system is in place that allows potential users to make an application for cost-free usage of these slides for a period of up to three years. Dissemination is now guaranteed to any interested party.

Another important component to sharing knowledge across the higher education sector both nationally and internationally is the publication of academic papers. In this respect, Group Leader, Associate Professor Camile Farah and Project Officer, Dr Terry Maybury have co-authored a number of essays on the implementation and uptake of VM in the UQ context that have been accepted for publication in a range of respected journals or are currently under peer review. These are:

1. ‘Electronic Systems of Knowledge in the World of Virtual Microscopy’, an essay which places the uptake of VM in the broader pedagogic transition from literacy to electracy (or electronic forms of learning and teaching). It was accepted for publication in the highly respected U.S. medical education journal *Academic Medicine*, 84(9), 2009, pp. 1244–1249.

2. ‘Implementing Digital Technology to Enhance Student Learning of Pathology’, an essay that places the introduction of VM in the context of a suite of changes Dr Farah implemented in a course in Systemic Pathology. This essay has been accepted for publication in the *European Journal of Dental Education*, 73(8), 2009, pp. 942–949.

3. ‘The e-Evolution of Microscopy in Dental Education’, which examines the results of student surveys of VM conducted in Dr Farah’s courses in Oral Biology and Oral Pathology. This analysis has longitudinal validity because the same cohort of students was involved in both courses. It was accepted for publication in the U.S. based *Journal of Dental Education*, 13(3), 2009, pp. 172–178.

4. ‘The Self-Organizing Imperative: The Adaptive Learning Potential of Virtual Microscopy’, which links the scientific idea of self-organisation with adaptive hypermedia learning environments and the potential this connection offers for a more dynamic conception of electrate learning and teaching. ‘The Self-Organizing Imperative’ is currently under peer review by the international journal *Computers and Education*.

5. ‘Electronic Blending in Virtual Microscopy’, an essay that continues with the theme of VM as an electrate pedagogical practice, this time examining it through the lens of blended learning. ‘Electronic Blending in Virtual Microscopy’ is currently under peer review by the QUT based *Journal of Learning Design*.

6. Lastly, given that we now have compiled surveys from 14 courses covering 649 students, there is ample room for further papers to be developed especially in relation to the, veterinary studies, anatomical sciences and medicine.

There are also a number of conference presentations that both A/Professor Farah and Dr Maybury have delivered across the course of the project that shared the knowledge gathered to a wider audience. These were:

1. ‘Pathology Visions’, San Diego, September 2008, Dr Farah.

2. ‘Learning and Teaching as Research’, UQ School of Dentistry Research Day, September 2008, Dr Maybury.

3. ‘VM Explained’, UQ School of Medicine Colloquium, October 2008, Dr Farah.

4. ‘The Virtual Slidebox: An Overview’, ALTC Grants Showcase, UQ Teaching and Learning Week, October 2008, Dr Maybury.

5. ‘Electronic Blending in Virtual Microscopy’, Blended Learning Conference, University of Queensland, June 2009, Dr Maybury.

8.0 LINKS WITH OTHER ALTC PROJECTS

The one link this project has had with other ALTC projects is with UNSW's Professor Rakesh Kumar's project 'Virtual Microscopy for Enhancing Learning and Teaching'. This linkage entailed demarcating various disciplinary areas on which to concentrate. Professor Kumar's project will pursue Botany and Zoology, and this project will take the lead on Dentistry, Medicine and Veterinary Science. Our catalogue will be made available to Professor Kumar's group and we anticipate theirs will be made available to us.

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10.0 APPENDIX #1: STUDENT EVALUATION SURVEY FORM

The Virtual Slidebox

Student Evaluation of Virtual vs Light Microscopy
[Course Code] — [Course Name]
[Date]

Please tick one box per question that best describes your response. There are also three open-ended questions for you to respond to as you see fit.

(Strongly Agree=SA, A=Agree, U=Undecided, D=Disagree, SD=Strongly Disagree, N/A=Not Applicable)

	QUESTION	SA	A	U	D	SD	N/A
1.	I preferred the light microscope to the virtual microscope						
2.	I found the quality of the glass slides using the light microscope to be sufficient for learning of the material						
3.	Using the light microscope positively enhanced my learning of the material for this course						
4.	I feel that using the light microscope positively affected my grade for this course						
5.	It was necessary to use BOTH the light microscope and the virtual microscope often during the semester to understand the material						
6.	Navigation of the images with the virtual microscope viewer was easier than that of the glass slides						
7.	The virtual microscope technology saved me time more than the light microscope						
8.	The software viewing technology used in the virtual microscope was effective for the purposes of this course						
9.	The manoeuvrable images studied with the virtual microscope were of sufficient resolution to allow identification of the required organs, tissues and cells in great detail						
10.	The virtual microscope had sufficient magnification potential to allow me to examine the tissues and cells in great detail						
11.	I found the image resolution of the virtual slides using the virtual microscope to be sufficient for learning of the material						
12.	It was relatively simple to use Blackboard to interface with the virtual microscopy information						
13.	The virtual microscopy technology should be expanded to completely eliminate the need for light microscopy in this course						

14.	The ability to conduct the laboratory exercises on my own schedule with the virtual microscope was an advantage to my learning						
15.	Using the virtual microscope OUTSIDE of scheduled laboratory class time helped me to understand the material						
16.	Using the virtual microscope DURING scheduled laboratory class time helped me to understand the material						
17.	I preferred the virtual microscope to the light microscope						
18.	Using the virtual microscope positively enhanced my learning of the material in this course						
19.	I feel that using the virtual microscope positively affected my grade for this course						
20.	Using the virtual microscope was more fun than using the light microscope						
21.	The virtual microscope was superior to the light microscope in helping me understand the material						
22.	The virtual microscope software allowed for greater degree of collaboration with other students						
23.	Computer access procedures to the virtual microscopy material were relatively simple and easy to follow						
24.	I felt that that the download speeds of the virtual microscopy material were acceptable						
25.	I very much appreciated the virtual microscopy software's ability to insert scale bars, lines, descriptive phrases, and take snapshots						

26.I enjoyed learning with the light microscope because …

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27.I enjoyed learning with the virtual microscope because …

____

____

28.In what ways did you use the scale bars, lines, descriptive phrases and snapshot facilities in the virtual microscopy software?

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