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ELECTRONIC BLENDING IN VIRTUAL MICROSCOPY

Terrence S. Maybury

Camile S. Farah

School of Dentistry & University of Queensland Centre for Clinical Research
University of Queensland, Australia
t.maybury@uq.edu.au & c.farah@uq.edu.au

Abstract

Virtual microscopy (VM) is a relatively new technology that transforms the computer into a microscope. In essence, VM allows for the scanning and transfer of glass slides from light microscopy technology to the digital environment of the computer. This transition is also a function of the change from print knowledge to electronic knowledge, or as Gregory Ulmer puts it, a shift 'from literacy to electracy.' Blended learning, of course, is capable of including a wide variety of educational protocols in its definition; it is also at the heart of electronically mediated forms of education. Since 2004, VM has been introduced into Dentistry, Medicine, Biomedical Science and Veterinary Science courses at the University of Queensland, a project aimed at consolidating VM techniques and technologies into their curricula. This paper uses some of the evaluative survey data collected from this embedding process to discuss the role blended learning plays in electronic styles of learning, or 'electracy', before finally reflecting on the quantum world represented in VM imagery.

Keywords

blended learning, medical education, electracy, e-learning, light microscopy, virtual microscopy, multimodality, interdisciplinarity

Introduction

As educators we are now faced with a large number of educational approaches through which to structure our course content: life-long learning, flexible learning, adaptive hypermedia education, simulation/virtual reality education, 'place based education' (Gruenewald, 2008), collaborative learning, multimedia learning, experiential learning, distance education, 'datagogies' (Moxley, 2008) are just some examples. There is also, of course, blended learning. All of these terms, either implicitly or explicitly, indicate a hybridisation of categories, a mixmaster formula that in many respects leads us away from an emphasis on 'taxonomy' (the more objectively rigid division of phenomena into categories by 'experts'), to the concept of a 'folksonomy' (where 'ordinary' people subjectively tag knowledge with their own descriptive language) (Mathes, 2004; Simons, 2008; Stock, 2007). This move from the idea of a top-down taxonomy to the more electronic, bottom-up notion of a folksonomy is also reflected in the move from a teacher-led view of education to a student-focused one. Another instalment of these concomitant changes in higher education is the emergence of an atomic, a molecular, even a quantum view of knowledge and its transfer, which is underscored by a shift from the reality principle fostered by literate knowledge to more of a principle of 'granularity' (Kumar, Smith & Novotny, 2004) or a microscopic understanding of phenomena.

Within the latter domain, virtual microscopy (VM) has emerged out of the analogue technology of the light microscope and as such constitutes a digitally configured educational entry point into this quantum world beyond human vision. The twelfth letter of the Greek alphabet — mu, or μ (10^{-6}) — is now used as a scientific symbol for entry into this domain and without electronic technologies to represent it our understanding of this world would be seriously diminished if not impossible. In a sense then, VM is itself a blended artefact, combining a view of this micro-cosmos beyond human vision, in a situated, macro-level, real world context. As we gaze into images of the cellular world it confirms the existence of this largely quantum reality beyond real-world, technically unaided human vision. Indeed, all forms of electronic knowledge are a blending of at least two or more media modalities and/or concepts and so blended learning itself also would most likely be unthinkable without this technological framework.

As Rojo, García, Mateos, *et al.* (2006) wrote of its origins, "the first virtual microscopy [VM] system was described in 1997 by the Computer Science Department at University of Maryland and the Pathology Department at Johns Hopkins Hospital, Baltimore, Maryland" (p. 286). This makes VM a relatively new technology, at least in the field of medical education where many of the conceptual protocols of electronically mediated forms of learning and teaching have yet to penetrate in any systematic, deeply ingrained way. Nonetheless, digital forms of histology and pathology are gathering strength, and with collectively agreed upon protocols in telemedicine and an open source sentiment in universities also gathering pace, it might well come into its own as a form of microscopic analysis and dissemination. For the moment though we remain in a hybrid period, one that still contains primarily analogue forms, with digital forms of histology and pathology as an emergent phenomenon, a reality reiterated by one student commenting that, "in the real world, light microscopy is by far the most utilized in examining entities." In this intervening period between literate, didactic forms of education and digital, electronic forms, we will have to continue our learning and teaching practices with this fact in mind.

Put simply, VM is an electronic digital technology that takes an original analogue glass slide, scans it at high resolution, which then makes it amenable for study, analysis and dissemination via the computer and the WWW. It is another example among many of the multitude of tools and techniques that now constitute the extraordinarily wide gamut of e-learning. There are also a large number of academic studies examining VM's introduction into the curriculum of various medical related disciplines around the world (for example: Blake, Lavoie & Millette, 2003; Farah & Maybury, 2009a; Farah & Maybury, 2009b; Glatz-Krieger, Glatz & Mihatsch, 2003; Glatz-Krieger, Spornitz, Spatz, *et al*., 2006; Harris, Leaven, Heidger, *et al*., 2001; Mills, Bradley, Woodall, *et al*., 2007; Rocha, Vassallo, Soares, *et al*., 2009; Romer & Suster, 2003). VM promises to transform the highly expensive and time-consuming process of teaching and learning microscopy in a lab-based analogue format, making it potentially accessible globally via a digitally configured online presence. While in the initial phase of introducing VM the expenses are high, over the long-term these costs are reduced because microscope maintenance is phased out, along with the burden of up-keeping and duplicating light slide sets for learning and teaching purposes. In this long-term process of change, the learning and teaching of microscopy will eventually be transferred to the computer lab. Training for both students and faculty staff is also an especially important aspect in the introduction of this technology given its technical complexity. This is not to say that analogue microscopy is finished just yet, a point to which we will return in our survey analysis. At the level both of the technology and conceptually speaking, analogue and digital methods of microscopy are again another instance in which blending takes place.

Indeed, blending of one kind or another might be considered essential to the structural matrix in which all forms of electronic learning and teaching proceed. The lack of conceptual rigor (or theoretical precision) that Oliver and Trigwell (2005) decry in the widespread use of the term 'blended learning' might indeed be a positive factor when examined through the viewpoint of electronic communication because what electracy favours is a mode of thinking and learning that, as Ulmer (1994) insists, is based on associational reasoning and less so on the segregated conceptual rigor of individual elements so familiar to us in didactic, literate styles of pedagogy. In educational contexts, associational reason works best when one specific particle or element (in this instance, the specific content of a slide) is connected by the learner to another particle or element of knowledge, one that could arise anywhere, even from the personal circumstances of the learner concerned. Rather than that element of data being abstracted into a clear, unequivocal definition, its meaning is connected to what is evoked in the memory of the learner. It is this associational connection in the mind of the learner that constitutes the blending of abstract and subjective forms of data that is so endemic to electronically-mediated knowledge. These interconnected issues of electronically-mediated forms of learning and teaching and VM (or, as mentioned, in Ulmer's terms, 'electracy'), are examined more closely elsewhere (Maybury & Farah, 2009).

Before proceeding with this discussion though it is important to note that for the purposes of this article we take a wide-ranging interpretation of what constitutes blended learning. Along with the most common understanding of the term, that is, 'to combine any form of instructional technology … with face-to-face instructor-led training', we also recognise Driscoll's (n.d.) three other interpretations of the term. These other definitions are (1) any combination of web-based technologies; (2) a combination of 'various pedagogical approaches'; (3) or any combination of on-campus (or on-line) learning with real world, work-based learning. In electronically mediated learning, we take a catholic, broad-based view of its blended configurations, which again will require explanation at each location of its iteration. Blended learning is in its very essence a taxonomically imprecise term, one given to a locally enmeshed definition as a starting point rather than any universal or objective clarity imposed from above.

Context and Methods

Since 2004, VM has been progressively introduced into our University of Queensland (UQ) context across a variety of courses in Dentistry, Medicine, Biomedical Science and Veterinary Science, mainly in the areas of histology and pathology. In the process we have conducted fourteen surveys involving 649 students, an investigation that is ongoing. This project — entitled 'The Virtual Slidebox' — was supported by an externally funded major competitive grant from the Australian Learning and Teaching Council (ALTC), which allowed for the technology (and its assessment by students) to be consolidated within this context. The VM system is comprised of an Aperio Technologies™ VM scanner, a *Spectrum*+™ database, *Imagescope*™ viewing software, along with image analysis algorithms that allow for the automation of standardized procedural examinations of slides (Aperio Systems, 2009). We now have a database of over 2200 scanned slides for learning, teaching and research purposes; this is an ongoing analogue-to-digital scanning/databasing process. For those readers seeking further details on 'The Virtual Slidebox', the Final Report is available on the ALTC website: http://www.altc.edu.au/resource-virtual-slidebox-uq-2010.

During the course of this consolidation process of VM at UQ, we also developed a survey questionnaire that comprehensively framed a wide range of statements and questions addressed to students in an effort to gauge their response to its uptake. This questionnaire contains both quantitative and qualitative components, that is, 25 statements/questions based on a common 5 point Likert response scale with the following options: SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree, with NA = Not Applicable. The three (3) qualitative questions, situated at the end of the survey, were as follows:

1. I enjoyed learning with the light microscope because …

2. I enjoyed learning with the virtual microscope because …

3. In what ways did you use the scale bars, lines, descriptive phrases and snapshot facilities in the Virtual Microscope software?

In order to keep the analysis brief here, we will concentrate on the specific data collected from one out of the fourteen surveys: a Biomedical Sciences course in Human Reproduction and Fertility, which returned 76 survey forms (Figure 1). Participation in our study was voluntary and was approved by the Human Research Ethics Committee at UQ.

Questions	BIOM 3004 (2008) Human Reproduction and Fertility n=76 % Agree	% Undecided	% Disagree	% NA
1. I preferred the virtual microscope to the light microscope.	43.42	30.26	19.74	6.58
2. Virtual microscopy technology should be expanded to completely eliminate the need for light microscopy in this course.	22.67	22.67	50.67	4.00
3. Using the virtual microscope OUTSIDE scheduled laboratory class time helped me understand the material.	72.37	15.79	2.64	9.21
4. It was necessary to use BOTH the light microscope and the virtual microscope often during the semester to understand the material.	52.63	18.42	25.00	3.95
5. The ability to conduct the laboratory exercises on my own schedule with the virtual microscope was an advantage to my learning.	78.95	6.58	7.9	6.58
6. Navigation of the images with the virtual microscope viewer was easier than that of the glass slides.	44.73	18.42	31.57	5.26
7. The virtual microscope had sufficient magnification potential to allow me to examine the tissues in great detail.	78.94	7.89	7.9	5.26
8. I found the image resolution of the virtual slides to be sufficient for the learning of the material.	81.58	7.89	5.26	5.26
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.	75.00	11.48	7.89	5.26

Figure 1: Student Evaluation of Virtual Microscopy

Results and Discussion

Two related statements initiate this discussion. The first is, 'I preferred the virtual microscope to the light microscope.' In answering this statement, 43.42% agreed, while 19.74% disagreed, with 30.26% remaining undecided. In the second statement: 'The virtual microscope technology should be expanded to completely eliminate the need for light microscopy in this course', the corresponding answers were 22.67% agreed, 50.67% disagreed, with 22.67% remaining undecided. The ambiguity in these figures is clear: while in our other surveys there is a far larger percentage of students preferring VM (see Farah & Maybury, 2009a, 2009b, for a comparison), the latter figures disagreeing with its elimination are roughly the same. Either way there is still some hesitancy in consigning the light microscope to technological history just yet. In essence we remain in a transitional period where it is still necessary to learn and teach with analogue *and* digital technologies, an obvious statement but one that does need reiterating.

The next statement in our survey addresses a traditional rendering of blended learning in VM. In the survey course, VM was used in both a face-to-face context (primarily to show how it worked and as a lecture tool in the light microscope lab), as well as being made available on-line over the UQ intranet. In answer to the statement: 'Using the virtual microscope OUTSIDE of scheduled laboratory class time helped me understand the material', 72.37% of students agreed. As well, 52.63% of students agreed that, 'It was necessary to use BOTH the light microscope and the virtual microscope often to understand the material.' Even though light microscopes can be borrowed for home use they are mostly used in an on-campus laboratory situation, usually in class with tutorial assistance. The resultant figures, then, while not overwhelmingly positive to VM, reinforce the blended situation of analogue and digital technologies in the teaching of microscopy referred to above. There are, however, cost pressures on tutorial assistance, slide maintenance and building upkeep in light microscopy laboratories that are likely to intensify. Hence there are other factors working against the continuing viability of the light microscope not simply educational issues.

One of the detrimental elements often mentioned in the actual use of light microscopes is the physically deleterious affect they frequently have. Students across all our surveys have indicated the perseverance of this problem in comments like, 'I do not like using the light microscope as I find that its use causes eye-strain, neck pain and headaches. I find it difficult to focus using the light microscope and the limited magnification ability is annoying.' Likewise, 'it hurt my eyes.' This physically debilitating aspect of light microscopy is yet another reminder of the physical labour involved in analogue technologies even though they are an information technology of one kind or another. With the advent of digital technologies, the physical labour component is reduced (although certainly not eradicated because there are still serious ergonomic along with occupational health and safety issues associated with uninterrupted and excessive computer usage), which in some respects allows their virtual dimension to have greater sway over our learning and teaching processes. It is also a physical manifestation of the blended attributes of virtual processes as they encounter real-world, embodied work processes, a combination that is at the very heart of all knowledge work.

The statement, 'The ability to conduct the laboratory exercises on my own schedule with the virtual microscope was an advantage to my learning,' is also one worth examining further. Not only is the cost of supplying a lab and its attendant outlays quite high, there is also a high cost in face-to-face attendance for the learner (Kerres & de Witt, 2003). This cost might be constituted in either a monetary or a time value. So while in the face-to-face situation the learner is able to come to grips with the introductory basics of how VM operates, they are much freer to explore the possibilities inherent in the technology via on-line contact. The time-constricted contexts of face-to-face contact almost rarely allow for a full engagement with VM's possibilities. But when learners are able to 'conduct laboratory experiments on their own schedule,' a deeper engagement with the microscopic material via longer contact time is the likely result. This assertion is reflected in the response to this statement where 78.95% of students agreed. And while there were technical difficulties in arranging slide availability for both on- and off-campus delivery, in the words of one student, 'You could study material in your own time and space.' This instance is another example of the traditional understanding of blended learning in that it juxtaposes face-to-face contact with online contact.

The issue of 'navigation' is usually related specifically to e-learning in on-line contexts of education. But knowing where one is, along with 'wayfinding' (Morville, 2005), is an issue of intensifying importance in both virtual data-saturated pedagogical environments and the real globally-configured world. When viewed through analogue technology, microscopic material can be spatially disorientating because there are few markers to indicate the relation of the specific viewing location to the entire specimen. Given also that everyone's position in the general field of pedagogy, as both learner and teacher, is more amorphous — we are all now part of learning regions, learning cities or learning communities, as much as communities per se (Longworth, 2006) — the certainties of knowledge are also reduced. Microscopic material then is a good example of how 'reality' is extended in a quantum direction while at the same time the WWW is a communicational extension of national communities into global ones. Certainly, VM slides are easier to navigate by virtue of having an image of the whole specimen situated permanently in the top right-hand corner while simultaneously examining tissue at closer magnifications. In response to the statement: 'Navigation of the images with the virtual microscope viewer was easier than that of the glass slides,' 44.73% of students agreed. While certainly the results here are not overwhelmingly supportive of VM, an advanced understanding of navigation in the spaces of electronic knowledge is crucial. It is even more fundamental when e-learning is joined with face-to-face contexts, or where there are a variety of delivery modalities, or a diversity of pedagogical approaches used. It is critical, then, that learners *and* teachers understand what navigation means, both from a practical and conceptual standpoint, because any blended learning environment will inevitably be constituted in and by a wide range of systems, processes and paradigms, the intersection of which is usually synthesised in a unique location by a particular learner and/or a particular teacher. It is this complexity around the subject of navigation in data saturated real and virtual worlds that might account for the low level of agreement with the ease of moving around the VM slides. What this navigational complexity suggests is that serious attention should be given the design of the learning activity in which the VM slides are used. The importance of navigation to both an enlightened cognitive *and* practical pedagogical strategy in multiplexed situations like blended learning, then, should never be underestimated (Montello, 2005).

A critical component of the evolving acceptance of VM is the quality of the images it provides. With its high resolution, digital pathology is able to show microscopic samples of extraordinary clarity. We have now passed that stage where the quality of digital imagery has far surpassed that of analogue, or chemical based imagery. Indeed, it is no exaggeration to say that digital renditions of the microscopic world also surpass a purely scientific or medical interest; they can also incorporate an artistic or an aesthetic component, in part because of this high visual quality. There are hints of this technical transformation in student responses to the following statement: 'The virtual microscope had sufficient magnification potential to allow me to examine the tissues and cells in great detail,' where 78.94% of students agreed. Similarly, for the statement, 'I found the image resolution of the virtual slides using the virtual microscope to be sufficient for learning of the material,' 81.58% of students agreed. Finally, in the related statement, '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,' 75% of students agreed. Clearly, the image quality of VM is a driving factor in convincing students of its efficacy in creating an authentic learning experience; this is also assisted with recent improvements in computer monitors.

There is possibly an equally or an even more important extension to this notion of image quality that is a factor in the success of VM, and it is one that is important to all forms of electronically mediated information. Many writers in this arena have been marking digital information as ‘multimodal’ for some time now (Kress, 2000; Kress & Van Leeuwen, 2001). Put simply, multimodality refers to digital data’s ability to incorporate a wide range of communicational modes (images, text, voice, music, light, graphics, colour, for instance) into the one digital artefact, or by a process of linking or tagging. Multimodality, then, clearly has a blended aspect in relation to the various modes that can be incorporated into any given digital object. While it might seem obvious that digital pathology only references the image modality, this is not always the case. Digital pathology can potentially reference a range of modalities in its makeup: in the Aperio Technologies™ viewing software — *Imagescope*™ — there are tools to add text, graphics, measurement indices, alter the colour balance of a specimen, while at the same time keep intact the original scanned slide. If necessary, after adding text, graphics and measurement indices, for instance, you are then able to cut and paste this region of a slide and save it as a .jpg file. Indeed, for those institutional contexts that may not be able to afford to purchase a full VM scanning/database set-up there is an alternative: *Imagescope*™ is available as a free download from the Aperio Systems website, after which all you need to do is to arrange a scan of some teaching slides and then open one in this software. Although we have discussed the pedagogic possibilities of *Imagescope*™ in more detail elsewhere (Maybury & Farah, 2010, in press), it is possible to use these already mentioned tools to construct a simple learning exercise without the necessity of using the complete scanning/database set-up. Certainly though, as in other digital contexts, metadata (the data that references the data about the slide itself and which is particularly important for medical personnel to document the discussion around a slide and to use as an aide-mémoire), is easily incorporated into the database via the annotations tool. *Imagescope*™ also has a teleconferencing tool that also requires this extra infrastructure to work.

The multimodal nature of digital knowledge then is yet another level at which blending takes place: once a slide is scanned into Aperio’s *Spectrum+*™ database, a wide variety of informational modes can be linked to it. It is most likely that a spoken word rendition on the pathological propensities of a virtual slide, recorded as a Podcast, would be a useful learning tool to illustrate the point that even experts have to debate its diagnosis (both intrapersonally and interpersonally with colleagues), its research potential, or simply its morphological properties. This open-ended process of microscopic slide examination, then, is a blending of both the various modes of data that underpin it, along with the potential blending of the opinions of the various professionals committed to the specific examination at hand. This latter instance is, of course, an aspect of ‘interprofessional education’ (Morison, Marley, Stevenson, & Milner, 2008) and unless this debating, blending and cohering of professional opinion is modelled at the pedagogic stage it is less than likely that learners will take this skill into the workplace when they graduate.

At the broader macro level of the university itself, the concept of blended learning is manifested in the practice of interdisciplinarity. While this concept was not canvassed in our surveys it has enormous if largely unspoken ramifications. In contrast to the usually young learner population universities cater to, the teacher element of the equation is embedded in a highly segmented disciplinary apparatus sometimes characterised as a ‘silo’ mentality (Penny, 2009, pp. 37–38). This disciplinary segmentation is not only an aspect of the academic culture of universities; it is also embedded in their administrative and technical support systems, most notably the information technology departments. While Penny (2009) says that, ‘interdisciplinarity has of late become a mantra of universities’ (p. 35), it is a mantra that most likely has not arisen out of the above-mentioned culture but has, in all likelihood, been imposed on it by the increasingly cut and paste, or the mash-up culture encouraged by electronic artefacts. In other words, it has the character of an exterior imposition rather than an organic growth. The new media technologies that Penny references are at the heart of these current pedagogical transformations, of which VM is clearly a component part. While certainly not wholly responsible for the emergence of interdisciplinary forms of knowledge, new media technologies and techniques have been highly influential in driving the blending agenda of the disciplines.

The interrelationship between new media technologies and blended learning might here then be recast in the following light: blending in educational contexts cannot only refer to a mixing and matching of forms of delivery, or to a variety of differing modes that those forms of delivery might be constituted in or through. Rather, the more rigorous definition of blended learning that Oliver and Trigwell (2005) call for should also include some reference to a wider range of factors, including issues like multimodality and the 'deep interdisciplinarity' that Penny articulates. Deep interdisciplinarity is not merely the happy or unhappy juxtaposition or interaction of disparate disciplines, it questions the hidden assumptions and very foundations of the way each discipline constructs knowledge (Penny 2009, pp. 35–36). While this is not the place to expand on this broader theme on interdisciplinarity, the widespread take-up of blended learning in pedagogical contexts exposes this debate's pragmatic manifestations in action. Considered through an electronic lens, blended learning is an additive process more so than a subtractive one.

Conclusion

Both blended learning and electronically mediated pedagogy are large topics and this small discussion cannot hope to cover all its detail. From the psychology of learners and lecturers, through to the university itself, to the global trade in education services, currently there is a wide range of factors influencing the changes permeating the tertiary field. Overall, we can report that students working with VM at UQ are generally happy with this transition from analogue to digital slides with the proviso that we continue to teach with the light microscope for the time being. UQ students generally were in favour of learning with VM, an outcome that has been agreed to in all the surveys we have conducted on the topic. The drawbacks are the initial expense and the hi-tech nature of the technology. We also found that system compatibility between university computing technology and protocols and those of external suppliers can be a barrier for the unwary. Nonetheless, this discussion has attempted to place VM within both a broader understanding of blended learning as well as amongst the widespread shifts in electronically mediated education.

Clearly, there are a large number of these interconnected problems and opportunities in the widespread pedagogical changes going on in our universities. Many of these issues exist at the ground level and have a pragmatic orientation: cost pressures, staff/student skill and training levels, along with institutional and disciplinary divisions. There are also broad philosophical and epistemological issues associated with the contrast between the more abstract mode of written forms of representation in the literate tradition and the more active, 'performative' and 'embodied' modes of learning within electronic environments (Penny, 2009, p. 45). One thing seems clear, at least to us, we are in midst of a highly variable transition from a literate to an electrate stage in the history of human communication and thus education, or more succinctly, a move 'from literacy to electracy' (Ulmer, 2003). This brings with it a concomitant shift from education considered as a collective or as a national project to one where every student is a self-organising and an always open element in their own lifelong learning process; that is, where each and every one of us becomes nodally interconnected to every other potential lifelong learner *and* the vast body of all human knowledge, learning from and contributing to our own intellectual development as well as to this broader body of knowledge in a kind of globalised learning matrix. With assistance from our mentors and peers, it is our own responsibility to hopefully blend pertinent elements of this data diversity with our own wise purposes.

This notion of a nodally formulated helical matrix is implicit in the complex interconnections on display in environments available to us through microscopic analysis. It is important to note that it is not only digital forms of data that are more amenable to constant adaptation and change (an electronic blending machine par excellence), it is also a feature of biological systems, and at different scales of intensity this also applies to all systems. Literate culture's implicit emphasis on unchanging stability and traditional continuity might then prove to be an evolutionary dead end as we move to fertilise our students' cognitive framework for future uncertainties via an electrate framework of learning and teaching. Finally, it is instructive to contemplate at length the notion that microscopic interrogation concentrates so heavily on the examination of disease, for it is plain to see that this introductory aspect of the nano-universe under consideration here also has broader metaphorical lessons for the educational, social, political and cultural changes in which we are all currently enmeshed.

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