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EDUCATION NOTE

Integrating Histology and Histopathology Teaching in Practical Classes Using Virtual Slides

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The new medicine program at the University of New South Wales employs scenario-based learning with vertically integrated classes of year 1 and year 2 students, as well as horizontally integrated teaching with no discipline-specific courses. Coinciding with its introduction, we undertook comprehensive revision of the approach to teaching microscopic anatomy and pathology. We designed practical classes around virtual slides, which are high-magnification digital images of tissue sections stored in a multiresolution file format, viewable in a Web browser in a manner closely simulating conventional microscopy. In these classes, we integrated the teaching of histology and histopathology, introducing students to the microscopic features of tissues and organs, and giving them the opportunity to compare and contrast the normal with the abnormal in various disease states. Members of academic staff from both anatomy and pathology were present to promote discussion and respond to questions. Worksheets defined learning objectives and provided clinical cases as contexts for learning in each class. Evaluation revealed that students strongly supported the integrated approach. The efficiency of the teaching method meant that it was possible to work through 5–8 virtual slides per 2-hr class without difficulty. Students displayed considerable initiative in exploring the histological features of tissues, identifying the changes in various pathological states, and recognizing their relationship to clinical manifestations. We believe that the approach we have developed should help to minimize the potential adverse impact of curriculum reform on the teaching of morphology, while ensuring that learning remains both meaningful and interesting. ***Anat Rec (Part B: New Anat) 289B:128–133, 2006.*** **© 2006 Wiley-Liss, Inc.**

KEY WORDS: virtual microscopy; integrated learning; histology; histopathology; curriculum reform

INTRODUCTION

Curriculum reform in medical schools worldwide has focused on reduction in contact hours to decompress crowded programs, an increased emphasis on independent learning, development of interpersonal skills, and problem-solving (General Medical Council, 2002; Williams and Lau, 2004). Achieving these objectives has inevitably meant that time has been reallocated from traditional areas of emphasis to new educational activities deemed to be more important. In some medical schools, this has led to curricula that offer diminished opportunity and little encouragement for students to learn the basic medical sciences (Williams and Lau, 2004). Even in less extreme implementations of reform, teaching of microscopic anatomy and pathology has often suffered disproportionately.

As the last of the major Australian medical schools to undertake significant curriculum revision in the past decade, the University of New South Wales (UNSW) introduced sweeping changes with the launch of its new medicine program in 2004. This is comprised of modular courses that are integrated both horizontally and vertically. There is a particular focus on graduate outcomes, aligned with an integrated assessment scheme (Toohey and Kumar, 2004). Teaching and learning utilize all available modes but emphasize student-centered experiential learning, research, reflection, and collaborative activities. Many aspects of the new program represent major improvements, while

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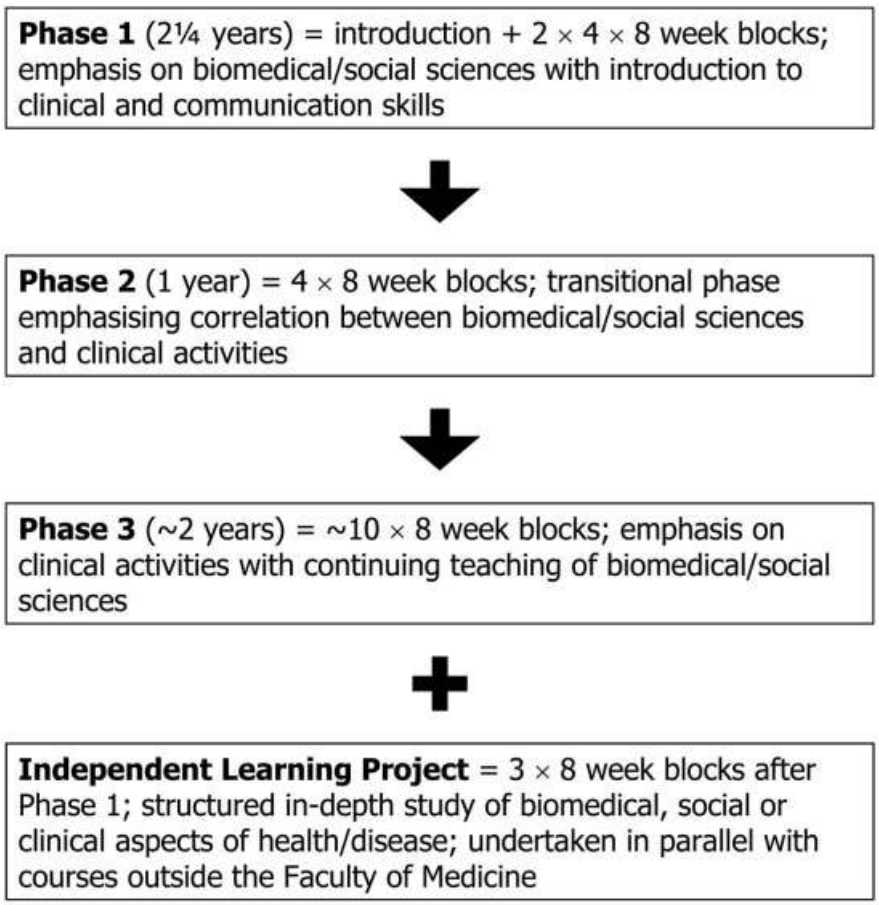

Figure 1. Diagrammatic representation of the structure of the new medicine program at UNSW.

many others are major challenges. One of these is that there has been a significant reduction in practical class time available for the medical sciences in the early years of the program.

We chose to treat the introduction of the new program as an opportunity rather than a threat to the teaching of microscopic anatomy and pathology. Abandoning the use of conventional student microscopes and glass slides, we decided to rely on virtual microscopy to facilitate learning in these areas, and to radically redesign practical classes for simultaneous teaching of histology and histopathology. This article describes our experience with this experiment and some of the surprises we encountered in the evaluation by students.

CONTEXT

The new medicine program at UNSW is a post-high school entry 6-year bachelor degree, which had its first intake in 2004. In parallel with reform of the curriculum, a new selection procedure was introduced based on a combination of grades obtained in high school, results in a nationally available test of problem-solving and reasoning skills (the Undergraduate Medical Admissions Test, offered by the Australian Council for Educational Research on behalf of a consortium of Australian universities), and a structured ~ 45-min interview developed by UNSW.

The program has a three-phase design, with biomedical sciences featuring prominently throughout (Fig. 1). The iterative or spiral curriculum revisits topic areas at increasing levels of complexity in each phase. It is taught as a series of 8-week-long courses that are strongly integrated both horizontally and vertically, emphasizing relationships between biomedical science disciplines, across years of the program, and between biomedical sciences and clinical disciplines.

This has led to major changes in the way disciplines involved in phase 1 participate in the teaching program. The most obvious of these is that there are no discipline-specific courses at all. Clinical or population health scenarios provide the focus for learning; these scenarios are associated with small group sessions in the style of problem-based learning. These sessions also help to bring together discipline-based components, which include limited numbers of lectures, tutorials, and practical classes, timetabled in relation to the scenarios. There are some additional cross-disciplinary teaching sessions, notably including the practical classes described in this study. A unique feature is that the program is deliberately designed to encourage building of a student community and to promote peer teaching by having year 1 and year 2 students learn new material together in vertically integrated classes. The program design for these 2 years comprises alternating cycles of four modular courses. The integrated assessment scheme has been described in detail elsewhere (Toohey and Kumar, 2004).

VIRTUAL MICROSCOPY AT UNSW

Virtual slides are high-resolution digital images of tissue sections, acquired at high magnification, which are stored in a multiresolution file format. They can be viewed in a Web browser, simulating conventional microscopy. As is now well documented (Harris et al., 2001; Kumar et al., 2004), this technology eliminates the skill barrier for students coming to grips with interpretation of microscopic specimens. Among its many virtues are that the image is always in focus, with optimized contrast and adjustable virtual illumination. Moreover, at high magnifications it is easy for the student to maintain orientation with respect to the entire section. For teaching large groups of students, the use of virtual slides also solves problems associated with section variability, as well as with maintenance and loss of glass slides.

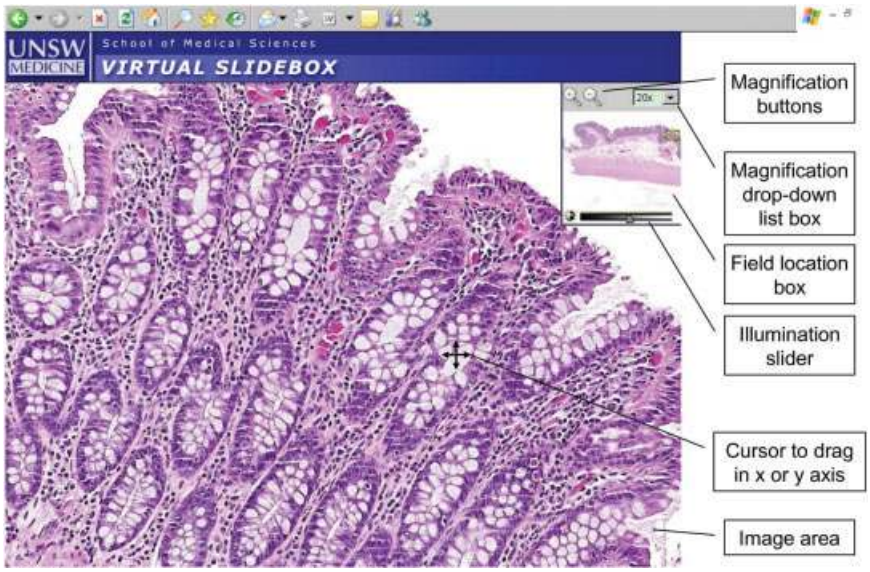

Figure 2. Screen shot of the virtual slide display, labeled to show key components of the interface.

We successfully introduced virtual microscopy at UNSW in 2003–2004, in the year 3 pathology course within the previous medicine program (Kumar et al., 2004). The primary slide collection we use is that developed by Fred R. Dee and colleagues at the University of Iowa, with grant support from the U.S. Public Health Service National Library of Medicine (www.path.uiowa.edu/virtualslidebox) (Dee and Heidger, 2005). Images are served using the virtual slide server software Neuroinfo (currently version 1.0.5; MicroBrightField, Williston, VT) and accessed via a Java applet within the Web browser on computers in the teaching laboratory (Fig. 2). Our computer teaching laboratories are deliberately based on shared workstations to promote discussion and collaborative learning. Technical features of the system have previously been described in detail (Kumar et al., 2004). We have also prepared some multimagnification image sets for individual histology slides not available in the University of Iowa collection, which we have provided to students as hyperlinked PowerPoint presentations. Various additional resources are available, such as a digital atlas of electron microscopy (Brueckner, 2003) and online access to sites such as Hematocell (http://www.med.univ-angers.fr/disciplines/lab_hema/indexbr.html) and WebMic (Ogilvie et al., 2005).

STRATEGIES IN NEW PROGRAM

The excellent outcomes that were achieved in the initial introduction of virtual microscopy in a discipline-based course provided a firm foundation for a completely new approach to teaching microscopic anatomy and pathology in the new UNSW medicine program. Following an introductory class in which conventional microscopes and computers are used in parallel, we have completely replaced glass slides with virtual slides for both histology and histopathology practical classes. We designed as many cross-disciplinary classes as were feasible within the constraints of scenario-based learning, with team teaching by staff from anatomy and pathology. In these classes, we used case studies related to (but distinct from) the scenarios to provide a clinical context. For example, in a class on the heart, we showed virtual slides illustrating normal myocardium and valves as a precursor to a case study with virtual slides of myocardial infarction; in a class on the respiratory tract, we showed slides illustrating normal airways and lung tissue as a precursor to discussing the diagnosis and morphology of pneumonia.

Teachers of both anatomy and pathology made a point of emphasizing the value of understanding the normal in order to be able to explain abnormalities. In each laboratory class, we provided students with worksheets that defined learning objectives and provided a framework for interpretation. After introductory comments, students were expected to work through these independently or in groups during the class and then review what they had learnt during the discussion of cases. We also made an effort to challenge students, for example, by offering multiple clinical presentations and asking them to match the most appropriate one to the slide(s) provided. To encourage student participation, we conducted question-and-answer interpretation of case histories and slides for the whole class, or required presentations by subgroups of students seated at each laboratory bench. The focus was deliberately on interpretation of histology and histopathology rather than on detailed knowledge of microscopic features, as this corresponded to the approach taken in the integrated end-of-course assessments.

All practical classes in the new medicine program simultaneously introduced year 1 and year 2 students to new material. However, because the year 2 students had significantly more background knowledge of the medical sciences, including anatomy and pathology, it was always challenging to strike a balance between the needs of the two populations in the integrated cohort. Not explaining basic concepts immediately led to confusion for the year 1 students, but excessive repetition of introductory material ran the risk of disengaging the year 2 students.

STUDENT EVALUATION AND STAFF FEEDBACK

We undertook a comprehensive evaluation of the new approach at the end of the first year of vertically integrated classes. A questionnaire was distributed to all students, who were asked to provide ratings from 1 (low) to 5 (high) for effectiveness, image quality, ease of use, usefulness for promoting cooperative discussion, and whether the virtual slides were fun to use. They were also asked to rate specifically the usefulness of integrated practical classes in anatomy and pathology. In addition, space was provided for

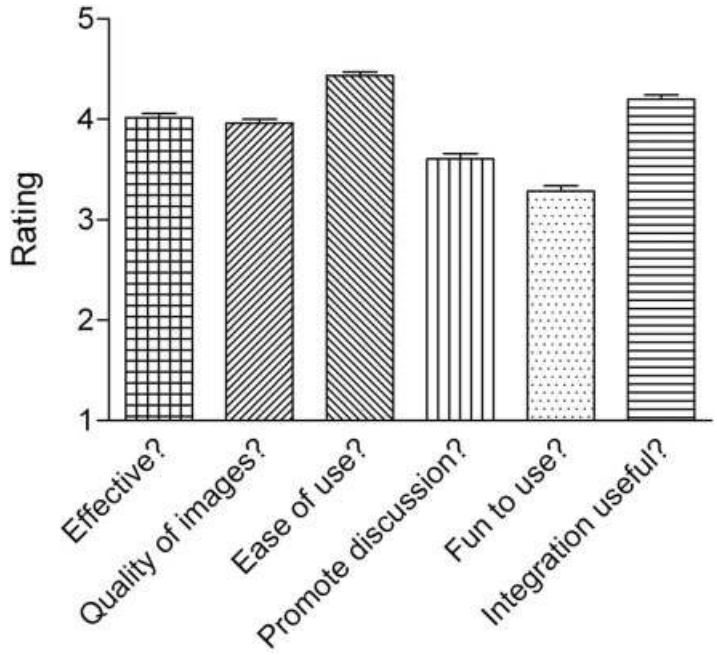

Figure 3. Student ratings of the use of virtual slides in the integrated practical classes (mean ± SEM; n = 361–365 responses)

comments about each of these issues, as well as a question about how their learning was affected by having both year 1 and year 2 students in the same laboratory class.

We collected data from 365 of the 445 students in years 1 and 2 (82%) with response rates of > 98% to specific questions requiring a rating. Overall, the evaluation was overwhelmingly positive. The students rated the effectiveness of both the virtual slides and the viewer software very highly (Fig. 3). Of particular interest was the very strong support for anatomy-pathology integration. Not all students offered free-response comments. We coded comments in response to the question "How useful were the practical classes that integrated microscopic anatomy and pathology?" as either positive or negative. There were 230 positive and only 15 negative comments. Typical of the comments were: "Great! It's good to learn when you can see the clinical application. It's what keeps us interested." "Integrating normal and abnormal really allows a direct comparison and aids my understanding. I really like working through case studies as it integrates clinically as well." "They've been brilliant, because it's good to see what is normal and what is abnormal, as presented by those who know about it, and that's what these classes achieve."

During the year, a number of students had made negative comments to staff members about the vertically integrated approach. We were therefore surprised by the strength of support for vertical integration that was revealed by the questionnaire, especially given the difficulties for staff of teaching in the combined year 1 and year 2 classes. We coded the free-response comments to the question "How is your learning affected by having both year 1 and year 2 students in the same practical class?" as positive, no effect, or negative. There were 173 responses indicating that vertical integration had a positive impact on learning, 110 that learning was not affected, and 64 negative comments. Representative positive comments included: "I believe my learning as a first year has greatly benefited. The second years have pushed me to learn more and have been fantastic in answering my questions. However, at times I have felt left behind as they know more." "Year 2 students at times help with explanations. A good idea that improves as the year progresses and we get to know one another a little better." "One of the main ways I learn is by teaching people—obviously second years have more background knowledge than first years and I found that I consolidated my knowledge by talking to them about basics." Negative comments were either that the classes were intimidating for year 1 students or that the presence of year 1 students held the class back for the year 2 students, although statements were usually not entirely critical: "As a year 2 student I do feel that our rate of learning has to be slowed a little in order to teach year 1s some concepts. However, the revision is helpful."

As in our earlier use of virtual microscopy at UNSW, staff valued the efficiency of the approach, which facilitated working through 5–8 slides per 2-hr class, with wide-ranging discussion. Staff members were pleasantly surprised by the striking evidence of active and independent learning within practical classes, as well as the extent to which the students were willing to undertake collaborative group work. Moreover, many students asked questions seeking further detail about normal histology so that they could understand the relationship of morphological changes to the clinical manifestations of disease. Equally gratifying was how well our students coped with understanding histopathology when they had only just learnt the relevant normal histology. In the classes, they often asked probing and thoughtful questions about how abnormalities that they identified had developed.

DISCUSSION

In an environment of curriculum reform and reduced contact hours, many strategies have been employed to improve the student experience of learning histology. These have ranged from the use of digitized images and/or animations delivered via the Web (Cotter, 2001; Brisbourne et al., 2002) to the restructuring of class formats and the relative emphasis given to lectures versus laboratory teaching (Gona et al., 2005). Because even well-annotated online atlases of static images simply cannot substitute for examining a slide in terms of learning microscopic morphology, the most significant technological innovation has been the introduction of virtual slides (Harris et al., 2001; Heidger et al., 2002). While different medical schools have adopted virtual slides either gradually (Blake et al., 2003) or

precipitously (Krippendorf and Lough, 2005), the future of virtual slides is assured, especially with steady improvements in scanning and display technology as well as the development of teaching collections such as those at the University of Iowa.

In our previous report on virtual slides, we demonstrated that because of their significant benefits to the user, they are in fact preferred by many students who never achieve technical competence with a microscope (Kumar et al., 2004). In the new medicine program at UNSW, we have taken the application of virtual microscopy considerably further, completely abandoning the use of glass slides and integrating the teaching of histology and histopathology in the one class. The program design itself added another layer of integration, namely that of year 1 and year 2 medical students learning new material together. The novel approach was therefore an experiment with three simultaneous variables, providing ample opportunity for mishap. Naturally, we were delighted that students gave it enthusiastic endorsement.

That the experiment was successful was in no small part a testament to the excellent service provided by the UNSW Medicine Computing Support Unit. Although various minor technical difficulties did arise periodically, they were dealt with promptly and there were no significant disruptions of the teaching sessions during 2004–2005.

One of the major points to emerge from the evaluation data was the importance of providing an appropriate context for learning. Students clearly perceived benefit from studying histology in relation to case studies and the relevant histopathology. Such an approach is likely to be advantageous for learning in both anatomy and pathology in comparison to sequential discipline-based courses. Our previous experience in a traditional program was that despite some cross-disciplinary efforts over the years, students often did not appreciate the value of understanding normal histology in years 1 and 2, so that it was frequently exasperating when they exhibited little knowledge of histology during histopathology classes in year 3. As one student commented: "I think that looking at normal and then abnormal soon after is much more effective than waiting another 2 years; you'd probably forget everything by then. Integration is really effective."

We believe that team teaching in integrated classes had important benefits for staff as well, improving staff relationships and helping to break down boundaries between disciplines. Moreover, with the use of virtual slides, staff felt that their time was being employed more effectively because the questions from students generally related to the substance of the class rather than to technical problems or inability to find relevant areas of the slide. We believe that an integrated approach was considerably facilitated by the availability of virtual slides for teaching and learning.

The biggest surprise to emerge from the formal feedback, given the number of negative anecdotal comments each of us had heard from students and colleagues, was the perceived success of the classes comprised of both year 1 and year 2 students. This arrangement is logistically challenging, because the annual intake of students into medicine at UNSW is $\geq$ 220 students, requiring multiple repetition of classes. It also poses problems with respect to sequencing of material, as alternate years study topics in reverse order. Nevertheless, our data suggest that, at least in the setting in which we evaluated this approach, it has been successful. Approximately 50% of students suggested that vertical integration in practical classes made a positive contribution to their learning, while most others indicated that there had been no significant positive or negative impact. Of course, vertical integration offers other intangible benefits, most notably by helping to build a community of students.

Overall, therefore, we believe this novel approach has been a success. We wish to emphasize that student learning with virtual slides will not terminate after the first 2 years of the program; the iterative design requires revisiting topic areas at increasing levels of complexity in later years, and histopathology teaching will continue through at least the third and fourth years of the 6-year program. We currently have plans to add to the virtual slide collection, notably with respect to incorporating various special stains for histology. To date, we have not taken advantage of the ability of virtual slide software to annotate specific views (i.e., a selected field at an appropriate magnification), but this is also on the agenda for future improvements.

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