A COMPARISON OF THE EFFECTIVENESS OF AN INTERACTIVE, ONLINE MODULE VERSUS A LABORATORY BASED EXERCISE WHICH INTRODUCES MICROSCOPY TO FIRST YEAR BIOLOGY STUDENTS

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ABSTRACT

Microscopy is an essential technical skill for biology students to master because they will use it throughout their undergraduate course and potentially in their working life. The aim of this project was to compare student learning of microscopy from an interactive, online Introduction to Microscopy module with a laboratory based exercise. Effectiveness of the two methods (online versus laboratory class) was evaluated with observations of students setting up a microscope late in semester. A quiz was also administered at both the start and end of semester to quantify the learning achieved as a result of a combination of the introductory exercise and subsequent use of microscopes during the semester-long laboratory program. Overall, the online Introduction to Microscopy module achieved learning outcomes that were equivalent to or better than the laboratory program. Quiz results from both years revealed that understanding of the function of the condenser and iris diaphragm was limited and the in-class observations confirmed that students rarely adjusted the condenser or iris diaphragm when using the microscope. Feedback from students about the effectiveness of the online module was sought with an online survey. Although response rate was low, some students identified that the content, design and interactivity of the online module assisted their learning of microscopy.

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INTRODUCTION

Practical work is viewed as an essential component of studying the natural sciences. The 'hands on' approach has the potential to stimulate student interest in the subject matter, teach laboratory skills, enhance the learning of knowledge, give insight into the scientific method and develop scientific attitudes such as objectivity (Gorst & Lee, 2005). Saunders and Dickinson (1979) showed that biology students who attended laboratory classes learned more biology and acquired more positive attitudes to science than lecture-only students. Practical work also gives students the opportunity to learn and practice the type of activities involved in working as scientists (Meester & Maskill, 1995). Laboratory exercises such as biological dissections offer a sensory as well as an intellectual experience and students develop a sense of personal discovery which stimulates intellectual curiosity (Kinzie, Strauss & Foss, 1993). Despite these benefits, virtual laboratory experiences are becoming more common in response to increased financial pressure, larger class sizes and reduced levels of staffing (Hughes, 2000; Peat & Franklin, 2001). Ethical issues regarding the use of animals and animal tissues for teaching purposes have also been cited as reasons for offering virtual alternatives to wet laboratory exercises (Hughes, 2000; Peat & Taylor, 2004). Virtual laboratories can also create opportunities for students to enhance their learning of scientific knowledge when equivalent wet-laboratory programs are not available or affordable (Stuckey-Mickell & Stuckey-Danner, 2007).

The use of information and communication technologies (ICTs) to support and facilitate learning in higher education has increased significantly in recent years (Krause & McEwen, 2009) and first year students are highly positive about the benefits of using ICTs for study-related purposes (James, Krause & Jennings, 2010). Virtual learning environments created by ICTs, such as virtual laboratory experiences, allow flexible delivery of resources to students juggling work/study/life commitments (Franklin & Peat, 1998; Harris et al., 2001; Peat, 2000). If designed well, virtual learning environments provide a broad range of opportunities for large, diverse student cohorts with differing levels of experience with the subject matter and/or different learning styles (Krause & McEwen, 2009).

Research has shown that student learning of scientific knowledge is equivalent in virtual laboratory exercises and wet laboratory exercises. First year biology students at the University of Glasgow were offered an alternative to a rat dissection (models and charts) and the final exam performance (conceptual learning was tested) of students who chose the alternative did not differ significantly from that of students who did the real dissection (Downie & Meadows, 1995). Completion of virtual rather than real animal dissections has also been shown to result in equivalent student learning of anatomy and function of organs (Franklin, Peat & Lewis, 2002). Students who completed online simulations rather than actual laboratory experiments performed equally well on final assessment questions relating to the concepts illustrated by the experiment (Hughes, 2000). Virtual microscope laboratories (repositories of whole mounts and histological sections of biological material) give students access to high quality, consistent images (Peat & Taylor, 2004) without students needing to master the skill of using a microscope correctly. In one study, medical students rated a virtual microscope laboratory class higher for efficiency, clear directions, clear images, navigation of slides, focus on the information needed and accessibility than a regular microscope laboratory class (Harris et al., 2001).

One of the intended learning outcomes of the first year biology subject Animal Diversity, Ecology and Behavior (ADEB) is that students have developed the skill of using a microscope correctly, so providing students with only a virtual microscope repository would not achieve that learning outcome. The compound microscope is introduced early in the semester, and ADEB students have the opportunity to practice throughout the semester as they examine microscope slide material. The old model of introducing microscopy was a laboratory based exercise comprising an integrated package of print material, laboratory exercises and video sequences. This model was replaced by a new, interactive, online *Introduction to Microscopy* (IM) module in 2009. The new IM online module was introduced to increase efficiencies in the use of costly, laboratory space and to reinvigorate the laboratory based exercise which was becoming increasingly difficult to run in a teaching laboratory with minimal and poorly performing audio-visual equipment. The IM module was developed in conjunction with staff at the University's Flexible Teaching and Learning Team, and combines explanatory text, video footage, static images and audio recordings to explain how a microscope works, explain magnification and describe the function of the different parts of the compound microscope. The IM module also contains problem solving exercises which allow students to interactively adjust a virtual microscope to achieve the best quality image possible. A list of 7 steps for adjusting the microscope can be printed off and taken to their next practical class. ADEB students in 2009 were given access to the online module through the University's learning management system throughout the semester. Learning achieved by engagement with the online module was reinforced with subsequent use of microscopes during the semester-long laboratory program.

The aim of this project was to compare student learning of the components, function and correct adjustment of a compound microscope from a new, interactive, online *Introduction to Microscopy* module with an old laboratory based exercise.

METHODS

The comparison was made between student cohorts in the years 2008 (laboratory based exercise) and 2009 (online module). The median ENTER (university entrance) score was calculated to confirm that the cohorts of students were of similar academic potential (67.1 and 68.5 in 2008 and 2009 respectively). Effectiveness of the laboratory program versus the online module was compared with a quiz and in-class observations of students using a microscope. The quiz was administered in week 1 of semester (prior to the compound microscope being introduced) and then again in week 12 (at the end of the practical course). The quiz was administered during a practical session and participation was voluntary and anonymous. The quiz consisted of multiple choice questions assessing knowledge of the components of a microscope and how to use it (see Table 1 for questions). The number of students who answered each question correctly was compared within and between years using chi-squared analysis. For the within-year analysis, week 1 (March) data were used to calculate the expected values and week 12 (May) data were the observed values. For the between-year analysis, year 1 data (May 2008) were used to calculate the expected values and week 12 (May 2009) data were the observed values.The in-class observations of students using microscopes were done in week 10 of semester. The observations were made by demonstrators during a practical session. Observers used a checklist of questions to make the observations (see Table 2 for checklist). Again participation was voluntary (students were approached prior to the observation) and data was recorded anonymously. Feedback from students about the effectiveness and design of the online module was sought with an online survey of two open-ended questions/statements: *Which two or three specific aspects of this online module have contributed most to your learning of microscopy?* and *Please suggest two or three specific, practical changes which could improve learning in this online module.* Response rate was low because the survey was voluntary and administered online after students had completed the online module. Only a few responses to the open-ended questions/statements will be reported in this paper to illustrate key points.

RESULTS

A significant increase in the number of correct responses (from week 1 to week 12 of semester) was found for three out of the six questions in 2008 and five out of the six questions in 2009 (Table 1), indicating that the online module achieved greater success at instructing students on the components of the microscope and their function than the laboratory based exercise. The comparison between years revealed no significant differences in the numbers of correct responses in week 12 of semester, except for question 3 (function of the condenser) which was answered correctly by a significantly greater proportion of the class in 2009 (chi-square, χ^2 8.3, d.f. 1, $p<0.01$). At the end of semester 1 in 2008 and 2009, a majority of students knew in theory where the magnification lenses were (question 1) and that the 40x objective was never used for initial observations (question 6). In comparison, students could not recall the correct order of steps to set up a microscope (question 5). It was also clear that students were confused about the function of the condenser and iris diaphragm (questions 2, 3, 4). In-class observations confirmed that students rarely adjusted the condenser and iris diaphragm when using the microscope.

Table 1: Percentage of students who responded correctly to the quiz question. Symbols denote a significantly greater number of correct responses (within years) at the significance level of $p<0.001$(*) and $p<0.05$ ($^{\#}$).

Questions	**Responses 2008**		**Responses 2009**	
Section 1 – Essential parts of the microscope	**March n = 282**	**May n = 200**	**March n = 305**	**May n = 318**
1. Which microscope components contain lenses that are involved in producing the magnified image of the specimen?	53	66*	25	70*
2. Which microscope component regulates the depth of focus of the microscope?	10	11	6	13*
3. Which microscope component is used to focus light onto the specimen?	20	$27^{\#}$	17	34*
4. Which components of the microscope must, because of their function, be located between the light source and the specimen?	37	50*	14	50*
Section 2 – Using the microscope				
5. What is the most appropriate sequence of the listed steps for setting up the microscope for specimen examination? Step 1. Securing and centering the specimen Step 2. Ensuring adequate clearance between the stage and the objectives Step 3. Positioning and focusing the specimen Step 4. Ensuring proper illumination of the specimen	19	23	21	25
6. Which objective is never used for initial examination of a specimen?	79	78	47	75*

In-class observations were made of 34 students in 2008 and 13 students in 2009. In both years, all or nearly all students placed the slide on the stage correctly, and began their examination with a low power lens (Table 2). In both years, very few students attempted to keep both eyes open whilst viewing the image with the microscope which may result in eye strain if microscopes are used regularly (Table 2). A clear majority of students did not correctly set the condenser or use the iris diaphragm whilst examining a specimen in either year (Table 2).

Only 25 students (<1% of the 2009 class) responded to the request for feedback about the effectiveness and design of the online module. Even so, some interesting and helpful feedback was gained. Aspects of the online module which students identified as important contributors to their learning of microscopy were the content "… *clarification of which parts magnify and how to focus*", the design "*The easy, understandable layout that allows you to choose which segment of the module you would like to go over*", the interactive nature of the module "*The ability to zoom in or zoom out on specific components of the microscope and information*" and the problem solving exercises. Suggestions for improving the online module included the opportunity to pause during explanations and better integration or linking with the subsequent practical classes which require students to use microscopes to examine specimens.

Table 2: Percentage of students who were observed completing each task in 2008 and 2009.

Tasks	2008	2009
Student checks the slide before securing it on the stage	100	100
Student secures the slide on the stage adequately	100	100
Student begins specimen examination with the x4 or x10 objective	97	93
Student attempts to keep both eyes open when examining a specimen	12	8
Student correctly sets the condenser and the iris diaphragm	15	0

DISCUSSION

Overall, the online *Introduction to Microscopy* module achieved better learning outcomes than the laboratory exercise. This finding agrees with other studies that have shown that virtual laboratory exercises, such as dissections and experiments, can result in conceptual learning outcomes equivalent to wet laboratory exercises (Kinzie et al., 1993; Hughes, 2000; Franklin et al., 2002). Despite this result, the quiz revealed gaps in knowledge in both years, particularly regarding understanding of the function of the condenser and iris diaphragm, and the correct order of steps to set up a microscope. In-class observations confirmed that students rarely adjusted the condenser and iris diaphragm when using the microscope.

Allocating time to practice laboratory skills such as microscopy is essential for developing competency, and students are often not given the opportunity to develop that skill to a level where it can be used effectively (Peat & Taylor, 2004). It has been argued that better learning outcomes could be achieved if skills are taught independently before students are required to apply those skills to new problems (Friedler & Tamir, 1986; Johnstone & Letton, 1988-89; Johnstone & Wham, 1982). The ADBE online module introduces the microscope components and their functions, and provides some of the background information needed to understand how a microscope works. The use of microscopes in subsequent laboratory classes reinforces what students learn in the introductory training and allows students to practice the skill, but in the current practical timetable for ADBE, the microscope is not used for several weeks after completion of the introductory module. The link between the introductory online module and microscope use in class could be consolidated with a short focused laboratory exercise (which gets students to use the knowledge they've just gained) scheduled immediately after completion of the online module. The online problem solving exercises were identified as important contributors to student learning of microscopy by some students, so the complementary laboratory exercise could include a set of practical problem solving exercises e.g. a comparison of two different microscope slides requiring different condenser and iris diaphragm settings.

Several students were positive about the design and interactive nature of the module, indicating that students were engaging positively with the ICT learning resource as found by James et al., (2010). The effectiveness of the online module depends on its integration into the rest of the practical program and provision of many opportunities for students to practice the skill as well as consolidate the theoretical learning. Embedding the IM module in the curriculum of all four first year biology subjects will streamline the teaching of microscopy at La Trobe University and provide additional opportunities for students to practice and consolidate their knowledge of how to use a microscope. Flexible delivery of this learning resource (via the University's learning management system) will allow students to revise as needed through the year.

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