Using 'MasteringBiology' to formatively improve student engagement and learning in first year Biology

Gerry Rayner
School of Biological Sciences, Monash University, gerry.rayner@sci.monash.edu.au

Undergraduate students lacking prior learning in a particular discipline area often struggle with subject content and in particular with complex processes or the application of concepts. Consequently, such students may not engage as fully with their learning as students with prior learning. This paper describes the implementation, into a first year biology subject, of a 'Socratic' online learning and assessment tool, MasteringBiology®, to ameliorate the learning discord for students without prior learning in biology. There were a number of very positive outcomes to the implementation, including significantly higher grades on routine assessments for students completing MasteringBiology®, both within and between years, and higher final exam grades. Further, in spite of the increased workload, a high proportion of students engaged with the process of integrating prescribed textbook readings together with pre-lecture, online, formative assessment. Additionally, a high proportion of students considered the combination of readings and pre-lecture assessment to provide reasonable or excellent preparation for lectures and weekly summative assessments. The integration of this type of learning technology, which combines both tutorial and assessment approaches, provides considerable scope for increasing the engagement of students in large enrolment subjects, and enhancing the learning experience for all students, regardless of their degree of prior learning in a particular discipline area.

Keywords: *engagement, assessment, feedback, learning*

Introduction

The student cohorts of large enrolment undergraduate first year subjects typically comprise students from a range of educational and cultural backgrounds, and with different capacities and motivations for learning. Many first year undergraduate subjects do not require prior learning in a discipline area as a prerequisite for enrolment in a corresponding first year subject (Boud, 1995). For example, of a randomly selected sub-sample of 356 students enrolled in the first semester biology unit at Monash University in 2008, 34% had not studied VCE (year 12 or equivalent) biology, 6% had studied VCE biology units 1 and 2, 58% had studied VCE biology units 1-4, and 2% had completed biology as part of the Baccalaureate. Thus, more than a third of all commencing students had little or no knowledge of fundamental biology concepts and processes. Such students often do poorly on initial coursework assessments, resulting in decreased engagement with further coursework and even lower grades on subsequent assessments. At the same time, the answer is not to simply dumb-down the content or expected learning outcomes, as this will potentially disenfranchise students with appropriate levels of prior learning. For lecturers in large enrolment subjects that do not impose prerequisites, a challenge therefore is to provide a pedagogical structure that will facilitate engagement and knowledge acquisition and application by *all* learners.

An important consequence of a broad range of prior learning levels within a cohort is that students come to lectures with both different degrees of preparedness and wide-ranging levels of understanding. For first year biology students with VCE Biology, a lecture on cellular

respiration, for example, will provide some measure of refreshment and reinforcement, while for non-VCE biology students, the material is new, complex and potentially bewildering. A coursework structure that integrates pre-lecture exercises and related materials (e.g. textbook readings) prior to a lecture on cellular respiration should enhance the learning of all students, regardless of their level of prior learning. Targeted use of pre-lecture exercises has been shown to enhance student understanding of the lecture material itself (Widanski, 2005) or of conceptually difficult materials (Gunter, Henrickson and Bonventre, 2005).

Assessment is an important driver of student performance and gauge of student progress, as well as an effective means of objectively examining the effectiveness of teaching programs (Bransford, Brown and Cocking, 2000). In most science subjects, assessment is typically summative in nature, with only occasional use of formative assessment to provide students with a benchmark of their understanding of concepts and processes. Furthermore, many summative assessment tasks encourage surface or rote learning, which provides immediate benefit for short-term examinations, but which does not facilitate deeper learning – the long-term retention of knowledge and application of such knowledge (Dunn, Morgan, O'Reilly and Parry, 2004). The integrated use of formative assessment has been shown to enhance deep learning by students across a range of secondary and undergraduate disciplines (Black and William, 1998; Rushton, 2005).

A further problem with summative assessment of student learning is that it is often conducted at the end point of coursework. In many of the science disciplines, the assessment typically comprises an exam that is a make-or-break component of the subject. However, as Earl (2003) points out, assessment should be educationally useful, by using combinations and techniques of assessment that actually help students to learn. As such, the integration of formative methods of assessment into course or unit curricula can enlighten students about what they know and to help fill the gaps in their knowledge. Further, object-oriented formats that place students at the centre of the learning process – the notion of *student-centred learning* – addresses the need, as Sparrow, Sparrow and Swan (2000) contend, for students to assume a high level of responsibility in the learning situation and be actively choosing their goals and managing their learning.

Computer-assisted assessment packages such as Questionmark® and Respondus® are commonly embedded in the learning management systems of undergraduate courses. They are increasingly being used as a method of summative assessment, and also to supplement other learning methods such as lectures and tutorials, or for revision purposes (Brown, Bull and Pendlebury, 1997). The assessment software has become increasingly sophisticated over the past decade, to the extent that the most recent generation of these packages integrates something of a 'Socratic' approach to the assessment. With this capability, the assessment can be both formative and summative in nature. For example, at the University of Sydney, MasteringPhysics® has been used for both learning and assessment since 2004 (O'Byrne and Thompson, 2005).

This study reports on the use of MasteringBiology® as a formative assessment tool in a first year undergraduate biology subject. The aims of this approach were twofold: (a) to improve student preparedness for lectures, such that students without VCE biology could gain knowledge and familiarity re the nomenclature, concepts and processes to be covered in lectures, leading to; (b) improved longer-term learning outcomes for all students, as measured by ongoing assessment tasks and the final exam, thereby providing momentum and motivation for further learning.

Methods

MasteringBiology is a Pearson Education product packaged free with the prescribed textbook for the first year Biology unit at Monash University. What sets MasteringBiology apart from other online assessment packages is its 'Socratic' nature. This essentially describes the capacity of the software to ask questions, and then provide hints and other learning objects, such as animations, images and videos, which assist in the learning process. This can be especially valuable in the science disciplines, which for deep learning should rely less on memorizing material and more on understanding concepts and processes, some of which can be quite challenging.

Each MasteringBiology assignment in the unit was constructed using a variety of learning and assessment activities, including test bank and tutorial-type questions, ranking questions and 3-D animations. The content of each MasteringBiology assignment was aligned with prescribed lecture readings, and each assignment was available to students up until the first lecture in each week. This timing aimed to better prepare students for lectures, improve their engagement with the learning process and facilitate deeper learning. Given that obtaining marks is a strong motivating factor for students to undertake assessments (Brown, Bull and Pendlebury, 1997), an aggregate of 5% of the final mark was allocated for performance in MasteringBiology assignments. Figure 1 illustrates the structure of a weekly learning module in the unit, integrating prescribed textbook readings, a MasteringBiology assignment, lectures and summative Blackboard miniquiz.

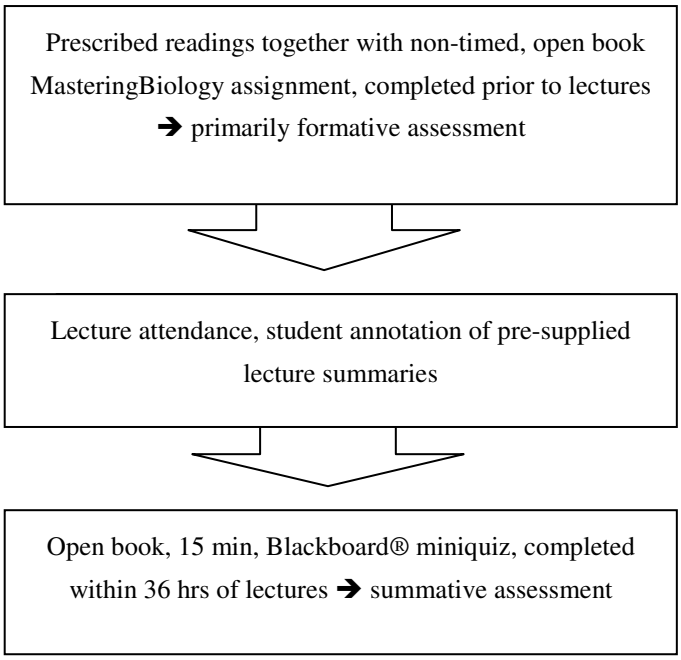


Figure 1: Flowchart of the weekly structure

Thus, students were encouraged to complete each MasteringBiology assignment in conjunction with the readings for the lecture series, then attend the lectures, annotate the summary lecture notes, and complete the associated miniquiz within 48 hours of the final lecture in that week. To provide for consistency and degree of difficulty, and to allow comparison of assignments, all MasteringBiology assignments were open book and non-

timed, and each comprised 25 components, these being a mix of activity, tutorial and multiple choice-type questions.

At the end of semester, students were surveyed anonymously in the course management system (Blackboard) in regard to their MasteringBiology interaction. Survey questions related to students' level of prior learning in biology, their completion rate of MasteringBiology assignments, the use of learning tools embedded in the MasteringBiology format, and their perception of the effectiveness of MasteringBiology as preparation for lectures and miniquizzes. As the survey was administered anonymously, student responses (e.g. level of prior learning) could not be paired with their summatively assessed learning outcomes (e.g. miniquiz or final exam marks).

The number of students completing each MasteringBiology assignment was monitored and compared with completions of the corresponding weekly miniquiz. The miniquiz results of students who completed each MasteringBiology assignment were compared to those of students who did not undertake the assignment. Given that such results might be affected by factors such as student motivation and/or time constraints, miniquiz results for 2008 (with integration of MasteringBiology) were compared with those for 2007 (prior to the introduction of MasteringBiology). To eliminate any possible confounding factors, the sequence, time allocation, number and types of questions, and degree of difficulty of miniquizzes were maintained between years.

To investigate the possible effect of MasteringBiology on final exam performance, final exam marks for the 2007 and 2008 were compared. The exams consisted of the same questions and were of the same duration, and to eliminate confounding effects, the results for students repeating the unit in 2008 were omitted from the analysis.

Since 2005, Monash University has garnered student feedback re the quality of administration, teaching and assessment of its units. The evaluations comprise 10 standard questions, and include an additional option for personal written comments about the unit, seeking student opinions on (i) what they considered to be the best aspects of the unit and (ii), aspects of the unit they considered to be most in need of improvement. Student comments that related in any way to the implementation, use and effectiveness of MasteringBiology in 2008 were compiled and analysed.

Results

In regard to the amount of time required to complete the MasteringBiology assignments, students were approximately evenly divided between those who considered that the assignments took little or an adequate amount of time, and those that felt the assignments took a little too much or far too much time to complete (Table 1).

Table 1: Student responses regarding the time required to complete MasteringBiology assignments

Criterion	% responses
Took very little or an adequate amount of time to complete	48.6
Took a little, or far too much time to complete	51.4

Further scrutiny of the results in Table 1 suggests a possible inverse relationship between the level of students' prior learning and the time required to complete the MasteringBiology assignments (Figure 2). Of the students without any VCE Biology, a higher proportion considered the MasteringBiology assignments to take too much or far too much time (Figure 2). This pattern is reversed for students with Baccalaureate or VCE Biology, with the greater majority considering the MasteringBiology assignments to take little or very little time (Figure 2).

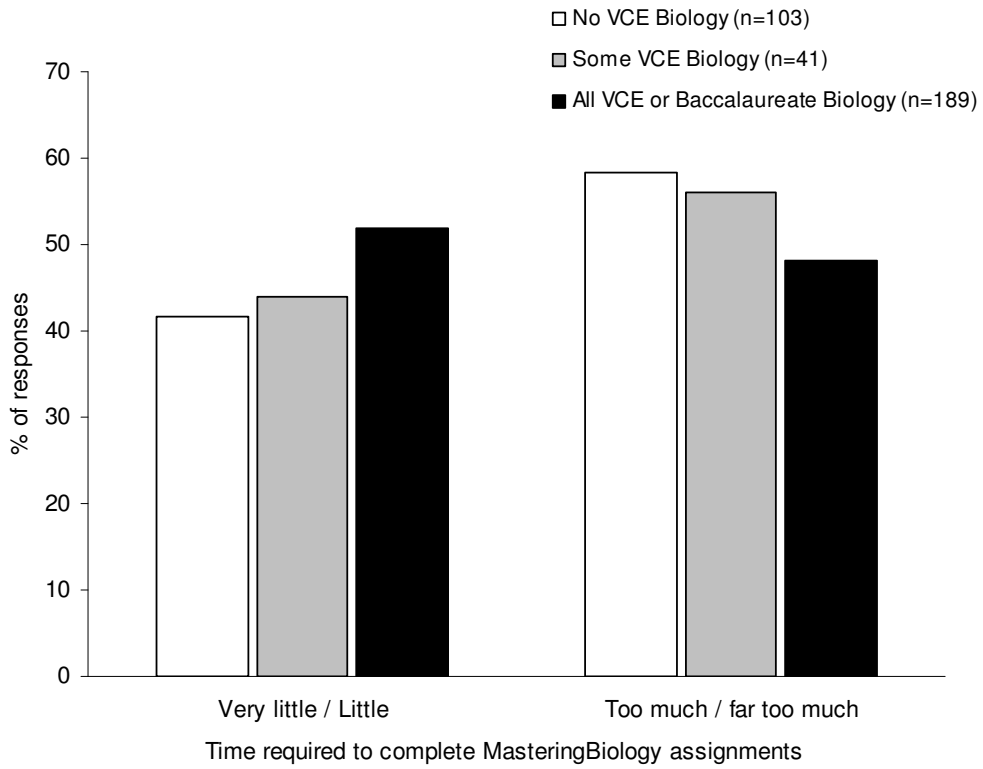


Figure 2: Student perceptions re the time required to complete MasteringBiology assignments, grouped according to their level of prior learning of Biology

Irrespective of their level of prior learning, a very high proportion of students considered that the MasteringBiology assignments provided reasonable or excellent preparation for both lectures and miniquizzes (Table 2). The results appear to be somewhat bimodal, as students without any VCE biology and with complete VCE biology rated MasteringBiology more highly than students with only some VCE biology (Table 2).

Table 2: Student perceptions re the value of MasteringBio assignments as preparation for lectures and miniquizzes

Value as preparation for lectures	No VCE Biology	Some VCE Biology	Units 1-4 VCE Biology
Reasonable or excellent	84.2	75.7	87.7
Some or none	15.8	24.3	12.3
Value as preparation for miniquizzes	**No VCE Biology**	**Some VCE Biology**	**Units 1-4 VCE Biology**
Reasonable or excellent	74.8	70.3	77.5
Some or none	25.2	29.7	22.5

Apart from some minor aberrations (e.g. between weeks 8-10 for miniquizzes), there was a gradual decline in completion of both MasteringBio assignments and miniquiz over the course of the semester (Figure 3). Given their relative contribution to a student's final aggregate mark, it's perhaps not surprising that there was a gradual decline in completion of both MasteringBiology assignments and miniquizzes (Figure 3).

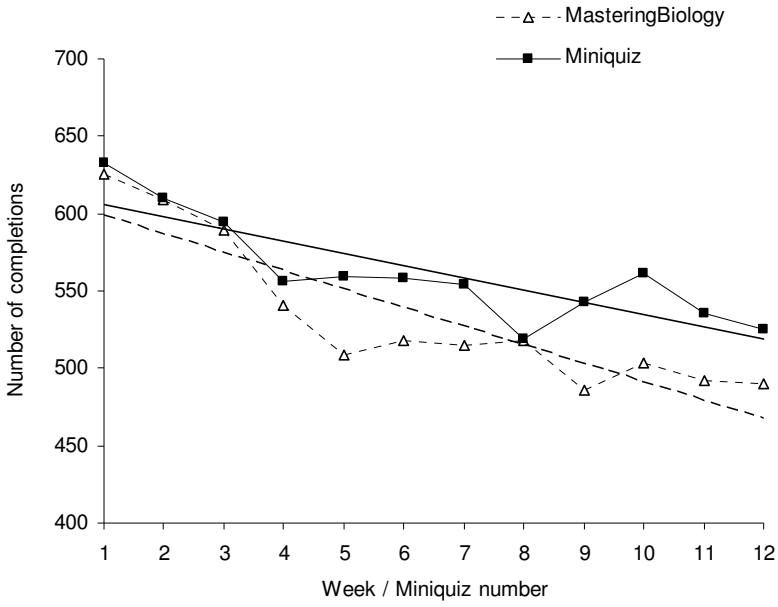


Figure 3: Number of completions (with respective lines of best fit) of weekly pre-lecture MasteringBiology assignments and equivalent post-lecture miniquizzes

With regard to the relationship between pre- and post-lecture assessments, completion of MasteringBiology assignments had a significant positive effect on the subsequent miniquiz mark (Figure 4). This effect was also evident between years, with mean miniquiz marks for 2008 (with MasteringBiology) being significantly higher than respective miniquiz marks for 2007 (prior to MasteringBiology) (Figure 5).

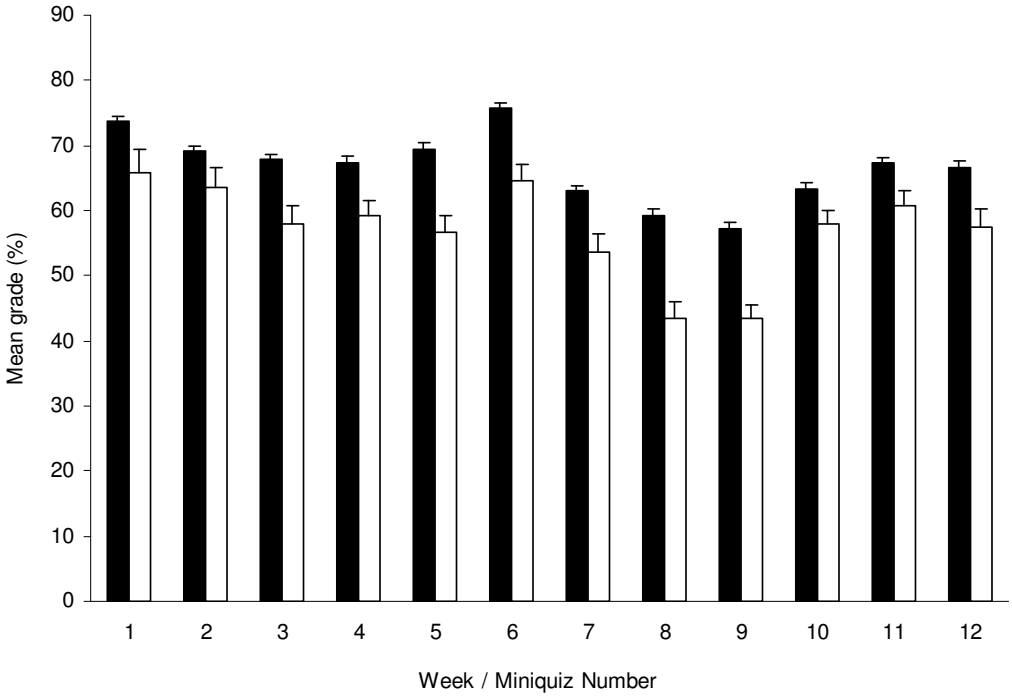


Figure 4: 2008 weekly miniquiz marks (mean ± standard error) for students who completed (closed bars) or did not complete (open bars) MasteringBiology assignments

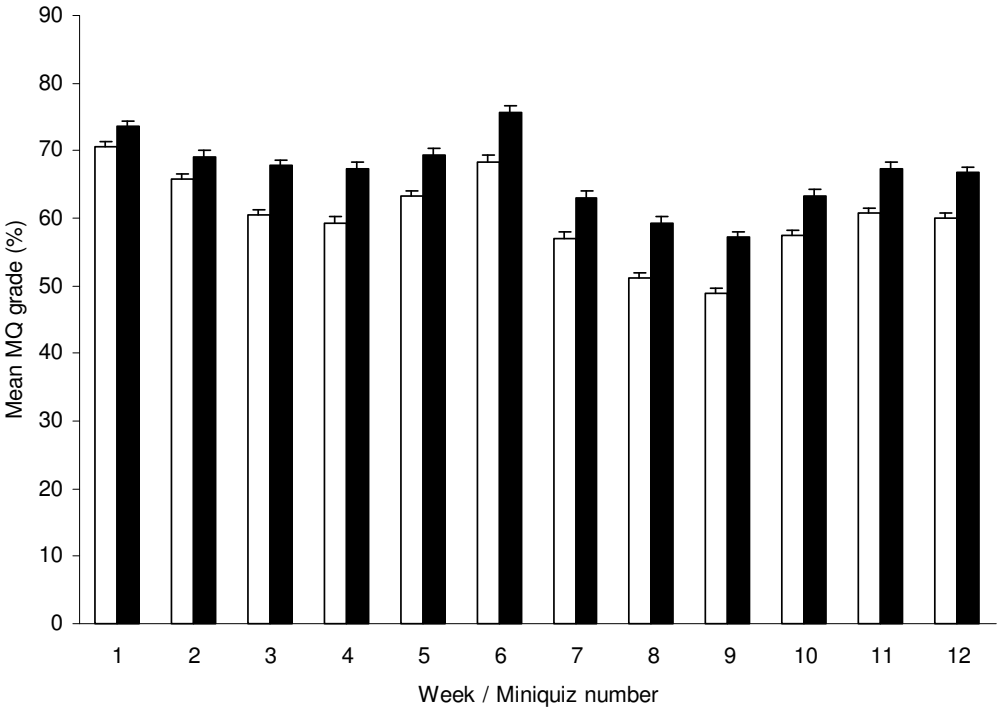
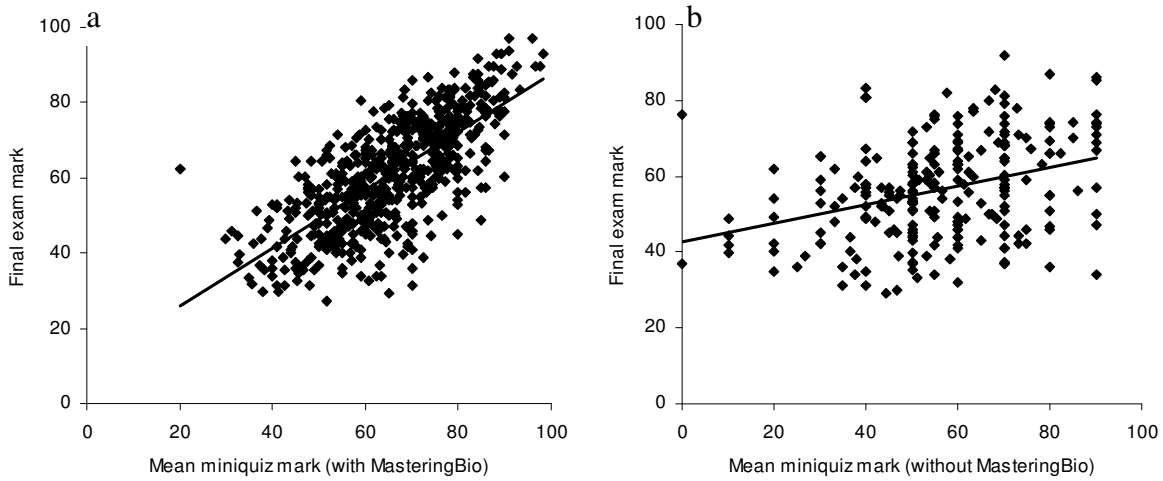


Figure 5: Weekly miniquiz mark (mean ± standard error) without MasteringBiology (2007 – open bars) and with MasteringBiology (2008 – closed bars)

Completion of MasteringBiology assignments also appeared to have a significant effect on a student's final exam performance. There was a strong, significant correlation between the average miniquiz grades of students who completed MasteringBiology assignments and their final exam percentage ($R^2 = 0.722$, $P < 0.0001$) (Figure 6a). In contrast, there was only a weak, non-significant correlation ($R^2 = 0.113$) between average miniquiz grades of students

who did not complete MasteringBiology assignments and their final exam percentage (Figure 6b).



Figures 6a & b: Final exam mark and miniquiz marks (with regression lines) of students who (a) completed MasteringBiology assignments, and (b) did not complete MasteringBiology assignments

The mean final exam mark for 2008 (61%) was significantly higher than that for 2007 (59%) (Figure 7).

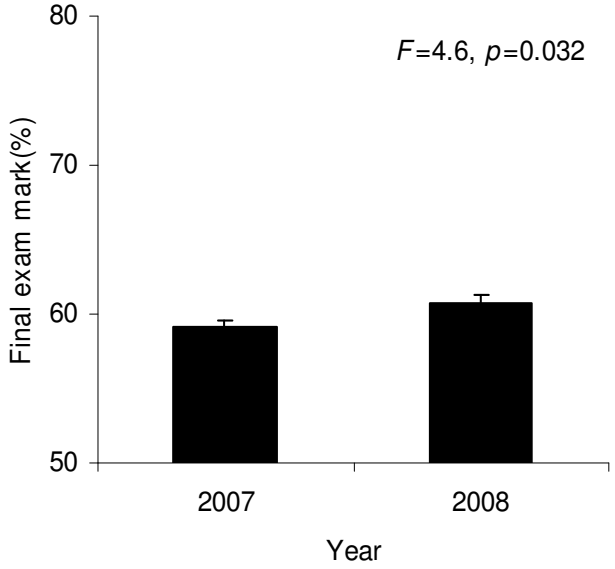


Figure 7: Final exam marks (mean ± standard error) for 2007 and 2008

Of the 390 comments provided by students on unit evaluations, 53 were directly related to the structure, usefulness and/or content of MasteringBiology. Of these, 43 comments (81%) were positive, with a consistency with regard to its value for learning and as preparation for lectures and summative assessments (below are selected, transcribed comments).

What were the best aspects of the unit?

'Structure - Mastering Biology, then lectures, then miniquiz.'

'the constructive way the mastering bio-lecture-miniquiz progression reinforced the material in differing ways. Having the compulsory mastering bio forced us to prepare properly for the lectures and classes.'

'System of set task mastering bio before a new week started and miniquiz at the end of the week. It allowed me to prepare before lectures and review learnt knowledge.'

'Masteringbio helped in learning the material and keeping up with the reading.'

'The mastering biology quizzes were annoying, but a necessary good thing because in the end, it was like forced revision every week that helps in the lead up to exams.'

'Having to do the mastering biology quizzes before the lectures meant I was able to understand and follow the lectures more easily.'

'The weekly quizzes (both blackboard and masteringbio) were what I would consider the most valuable learning aid as it forced me to keep up regular reading of the text which hasn't occurred as well in other subjects which have lengthy separation between assessments.'

'Also, the mastering biology weekly tasks were helpful. They encouraged you to study and think about the topic before it was explained in detail in lectures and then examined in mini quizzes.'

'The mastering biology tests are also very useful to gauge your understanding and problem areas, before the lab.'

'Masteringbio. didn't want to lose any marks, I HAD to read and completed the assignment before the lecture starts and that has helped me not fall behind on my readings which was very helpful.'

'The comprehensive blackboard learning system and incorporation of masteringbiology. Was awesome to play the online tutorials that had the interactive learning modules.'

'The use of the mastering biology quizzes before the lectures. It allowed me to start actively thinking about the topic before listening to the lecture material.'

'The mastering biology quizzes helped and encouraged me to study the text book whilst picking out the main aspects.'

'The labs and lectures were fantastic; making Mastering Biology compulsory was a GREAT IDEA!'

'alot of formative assessment made me stay on top of the material where I might not have if there was no weekly quiz / MasteringBiology exercise.'

The bulk of negative comments associated in any way with MasteringBiology (10 in total - 19%) related to workload or to a perceived lack of alignment between the various assessment components (see below for selected, transcribed comments).

What aspects of this unit are most in need of improvement?

> 'Mastering Biology took forever, and although it was very helpful for the next week, it could perhaps be a little more condensed.'
>
> 'With Mastering Biology and mini quizzes to do each week, as well as a practical report, sometimes the work became a bit overwhelming. That said, it did work to promote organisation, in that only organisation of one's time would result in all the work being completed.'
>
> 'Rather than bombarding with online tests and mastering bio every week. It should be once every two weeks. As we do have other subjects to study as well. Kind of get stressful.'
>
> 'MasteringBiology was a good idea in theory but it was sometimes a bit too hard to grasp the questions without having done any lectures on the material…. you said there were hints for the questions like an online tutorial (which sounded great) but the only questions with hints were the ones which weren't worth anything.'
>
> 'I think that having both the Mastering Bio and Blackboard quizs is silly, just one quiz per week is plenty for revision.'

Discussion

The introduction of MasteringBiology into the first semester Biology unit generated a number of interesting and positive outcomes, including having a constructive effect on student achievement for routine assessment tasks. This outcome is consistent with those reported for other courses that have incorporated ongoing methods self assessment (see Taras, 2008 for a review) even though the actual assessment methods and pedagogical structures may differ considerably. For example, in a first year economics unit, computer practice tests providing feedback to students, and indicating areas requiring further study, were shown by Sly (1999) to have a positive effect on subsequent exam performance. These results illustrate the relevance of, and potential for, a scaffolded approach to learning, where a syllabus is structured into discrete components, each comprising readings together with pre-lecture formative assessments, followed by the lectures, and culminating in a summative timed assessment. It also succeeds as a method of formative assessment, which Sadler (1998) contends must provide feedback on performance, and which can then be used to accelerate and improve student learning. This essentially ascribes to the principle that ongoing self assessment is as much a learning activity as it is a method of assessment practice (Boud, 1995).

The effect of MasteringBiology on improving students' final exam performance does not appear to be due to other factors, such as a possible difference in the proficiency or academic merit between the 2007 and 2008 Science intakes. The ENTER (university entrance ranking) scores for 2007 and 2008 were 75.1 and 75.0 respectively (unpublished data, Faculty of Science, Monash University). However, this apparent effect of MasteringBiology on final

exam performance contrasts with the observations, albeit in a different science discipline, of O'Byrne and Thompson (2005), who found no significant impact of MasteringPhysics on the final exam performance of first year physics students. However, this disparity is not surprising given the inherent differences between the two programs. These included differences with regard to the actual subject discipline (i.e. physics versus biology), and more importantly, in the respective ways that the 'Mastering' content was structured within the subject (6 assignments in physics versus 12 in biology) and methods of integration and implementation (pre-lecture preparation in biology, not specified for MasteringPhysics).

The decline in completions of both MasteringBiology assignments and miniquizzes is of concern, given the not inconsiderable aggregate contribution that these components make (i.e. 20%) to a student's overall mark in the unit. However, it is perhaps not surprising given the high work load in this unit, made up of formative and summative assessments, lectures, weekly practicals and essay writing exercises. A review of the unit is underway, a major objective of which is to devise a structure that will balance formative assessment to enhance student learning with development of appropriate practical and written communication skills.

An important aim of future research is to investigate possible differential effects of pre-lecture formative assessments such as MasteringBiology on students with different levels of prior learning of biology. As stated above, due to the anonymous nature of the survey, it was not possible in this study to link the level of a student's prior learning with his/her subsequent performance in MasteringBiology assignments, miniquizzes or the final exam.

The outcomes of this study suggest that programs such as MasteringBiology may offer considerable potential to enhance student learning. They enable revision and reinforcement of subject matter for students who possess prior learning and, when integrated with other learning objects, enrich learning and provide formative assessment for students without such prior learning. For both groups of students, a scaffolded learning structure, such as the one described herein, should foster active and long-term engagement with learning tasks, outcomes that educational specialists such as Ramsden (1992) consider to be essential in the promotion of deep learning.

Acknowledgements

The author acknowledges the support of staff from Pearson Education in providing student access to MasteringBiology, and the assistance of Ms Juliey Beckman (Monash University) in compiling MasteringBiology coursework materials.

References

Black, P. & William, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles, Policy and Practice, 5(1*), 7-74.

Boud, D. (1995). *Enhancing learning through self assessment*. London: Routledge

Bransford, J.D., Brown A.L, & Cocking, R.R. (2000). *How people learn*. Washington D.C.: National Academy Press.

Brown, G., Bull, J. & Pendlebury, M. (1997). *Assessing student learning in higher education*. London: Routledge

Dunn, L, Morgan, C., O'Reilly, M. & Parry, S. (2004). *The student assessment handbook: New directions in traditional and online assessment*. London: RoutledgeFalmer.

Earl, L.M. (2003). *Assessment as learning: Using classroom assessment to maximise student learning*. Thousand Oaks, Ca: Corwin Press.

Gunter, H.E., Henrickson, S.E. & Bonventre, J.V. (2005). Novel module improves learning of capillary filtration. *Proceedings of the American Society for Engineering Education Annual Conference.* Portland, OR. June 12-15, 2005.

O'Byrne, J. & Thompson, R. (2005). The tutorial benefits of online assignments: *MasteringPhysics* in first year physics at the University of Sydney. *Uniserve Science, Symposium on Blended Learning.* University of Sydney, September 2005.

Ramsden, P. (1992). *Learning to teach in higher education*. London: Routledge.

Rushton, A. (2005). Formative assessment: a key to deep learning? *Medical Teacher, 27(6),* 509-513.

Sadler, D.R. (1998). Formative assessment: revisiting the territory. *Assessment in Education*: *Principles, Policy & Practice*, *5(1),* 77-84.

Sly, L. (1999) Practice tests as formative assessment improve student performance on computer managed learning assessments. *Assessment and Evaluation in Higher Education*, *24(3)*, 339-344.

Sparrow, L. Sparrow, H. & Swan, P. (2000). Student centred learning: Is it possible? In A. Herrmann. & M.M Kulski. (Eds), *Flexible Futures in Tertiary Teaching. Proceedings of the 9th Annual Teaching Learning Forum, 2-4 February 2000.* Perth: Curtin University of Technology.

Taras, M. (2008). Summative and formative assessment: perceptions and realities. *Active Learning in Higher Education, 9(2),* 172-192.

Widanski, B.B. (2005). Preparing the students for learning during lectures. *Association for University Regional Campuses of Ohio Journal*, *Spring*, 167-172.