Title:

Multiple learning and administrative advantages when an advanced course in genetics adopted a “flipped-classroom” format with continuous, online assessment

Running title:

Continuous, online MCQ assessment of a genetics course – no final exam

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Abstract

We instituted a flipped-classroom learning environment for teaching advanced undergraduate genetics that consisted of pre-recorded lecture material followed by face-to-face workshops. Student engagement was promoted, and learning reinforced, by a recursive arrangement of electronically delivered formative and summative multiple choice question assessment in every workshop instead of a final end of semester examination. Our teaching approach dramatically increased student attendance, and student engagement with instructors. It simplified examination administration, and adapted easily to the online-only requirements of the SARS-CoV2 pandemic of 2020. The majority of student feedback regarding the revised learning format was positive.

Background

A Chair in Genetics was first established at the University of Adelaide in 1952 [1]. For over 60 years, genetics teaching used the common large group lecture passive learning format. In the mid-2010s, student attendance at lectures was commonly less than 20%, since university policy was, and is, to record all lectures and to make these recordings and other teaching materials available to students through the online Canvas Learning Management System (LMS; Instructure, Inc., Salt Lake City, Utah, USA). In the mid-2010s, the theory-delivery components of the level 3 courses in genetics amounted, per week, to three lectures of one hour duration plus a single, one hour tutorial. The tutorials were generally regarded as lacking student interaction and as providing only limited student learning support.

A new instruction format for these students

To increase students' physical participation (teaching session attendance) in learning of theory (previously shown to be associated with improved learning outcomes [2]), and to increase tutorial-form support, we trialled a flipped-classroom format. The three lecture and one tutorial sessions per week were modified to 50 minute tutorial-like workshops, each on a separate day. An approximately 30 minute pre-recorded lecture was viewed online before each workshop. Critical to the success of the new instruction format was the imposition of summative assessment (that was also formative) at the end of each workshop (more details are given below). This encouraged students both to watch the pre-recorded lectures and to attend the workshops. Attendance at workshops was typically greater than 80% and was never below 50%. To compensate the students for the imposition of this continuous assessment, the traditional end-of-semester examination (that had previously accounted for 60% of a student's total assessment) was abandoned.

Note that workshops were also recorded to aid student revision of teaching material (for the recursive assessment described below) and so that any students unable to attend a workshop could still learn the presented material.

Continuous assessment

Over a period of four years, we evolved the assessment described herein. The overall assessment scheme is shown in Figure 1. Examples of the multiple choice questions (MCQs) are given in Supplementary Material File 1.

During the final 10 minutes of each workshop, students currently perform an 8 minute test consisting of 4 MCQs. The questions are delivered through the Canvas LMS so each student must have an internet capable device with them to access this. For better viewing of the images used in some questions, we recommend students use a laptop computer with a large display rather than a mobile phone. Each MCQ has a minimum of 5 alternative answers. The LMS is programmed so that the order of delivery to each student of each of the 4 questions is randomised and, also, the order of the possible answers to each question is randomised. The questions are delivered one at a time and students cannot review or change answers to questions once submitted. The intention of this is to inhibit students assisting each other to answer the questions, something that can occur via instant messaging between students even when silence during tests is enforced. Students are permitted to see the correct answers to the questions (for a limited time) after the test ends.

Most students require approximately one minute to answer each question. However, all students are allowed 8 minutes to complete the 4 questions (i.e. ~2 minutes per question). Note that, when students are given more than 2 minutes to answer each question, many search for answers by looking through the presented files and their own notes, i.e. the test effectively becomes “open book”. We avoid this since it puts less pressure on the students to engage with the course material.

To encourage students to attend the workshops, access to the MCQ tests requires a password/code that is only given to the students when the test is to begin. However, we have seen that the number of students performing the MCQ tests regularly exceeds the number of students attending the workshops, indicating that some students in the workshops are communicating the access code to students elsewhere. For example, for one of the later workshops in the 2018 course, of the 79 students enrolled in the course, 56 (71%) were present but 69 students completed the workshop test (i.e. 13 completed it remotely). There are a number of possible systems that could be implemented to discourage this, such as recording students’ identities when they enter the class and then subsequently disallowing test scores from non-attending students.

A recursive arrangement of MCQs to encourage review of taught material

The beneficial effects of testing on learning have been reviewed in detail by others [3,4]. These include promotion of cognitive skills/outcomes high in Bloom’s taxonomy [5] and facilitation of future learning [6]. To encourage every student to review previously presented material, including material delivered for/during a workshop that a student was unable to attend (e.g. due to a timetable clash, illness etc.), the four questions in each workshop test are created to examine the material delivered for that workshop and for the previous three workshops (see Figure 1). To simplify the process of assembling the questions for each workshop test, we developed a specific numbering system. This is described in Supplementary Material File 1.

Each particular workshop requires the development of four MCQs for the workshop tests and two MCQs for additional “3-Weekly” tests described below. Note that this recursive MCQ delivery scheme means that workshops near the start or end of the course require the development of more, or fewer, MCQs respectively (e.g. in the final workshop test, only one MCQ ever examines the material for that workshop).

Extended MCQ examinations every third week

To encourage further review of taught information by students, every three weeks we conduct a 40-minute test consisting of 20 MCQs covering the previous three weeks of delivered material. As for the workshop tests, the order of delivery of the questions is randomised and the order of presentation of the possible answers to each question is also randomised. The online test is accessible by the students only during the time during which a workshop would be held, but students are not required to attend the workshop venue to do the test. They are informed that access to a stable internet connection during the test is their responsibility. Since students only have ~2 minutes to complete each of the 20 questions, we believe that the randomisation in both the delivery order of the questions and the list order of the answers discourages students from assisting each other during these tests.

During one semester (12 teaching weeks), our level 3 genetics course has 48 possible workshop sessions with 4 of those given over to 3-Weekly tests. This means that 256 MCQs can be delivered during the course, (44 workshop tests of 4 MCQs each plus 4 3-Weekly tests of 20 MCQs each). While many of the MCQs may be reused in subsequent years that the course is held, and students may obtain copies of the MCQs from previous students (e.g. as screenshots from when students are permitted to view the answers to the questions), the effort required to memorise the answers to ~250 MCQs would likely achieve a learning outcome in itself. Also, MCQs can be shuffled between different workshops and between workshops and the 3-Weekly examinations to discourage cheating.

A grading scheme to account for students' inability to attend some workshops

In any system of continuous assessment, there will always be students who cannot attend a workshop session due to a timetable clash, illness, employment commitments, or other reasons. We wish to allow our students up to one timetable clash per week without penalising their ability to achieve the maximum grade. For this reason, a student's grade is assembled from the top 30 workshop test results achieved (out of up to 44), and from their best three scores of the four 3-Weekly tests. In one year, some particularly competent and strategic students achieved very high workshop test results in the first 30 workshop tests and then did not submit subsequent tests. However, our intention is to motivate students to engage with all topics within the course, and so we now aggregate a student's final workshop test grade from the 10 best workshop test results during each of three 4-week intervals during the 12 weeks of the course. Note that, to allow for one teaching clash per week during the course, it is necessary that each 3-Weekly test be held on a different day of the week (see Figure 1) so that a student completes at least three of the 3-Weekly tests.

The Canvas LMS facilitates and secures student grade collation

The ability to conduct the workshop and 3-Weekly tests online using the Canvas LMS greatly facilitated grade collation since test results are automatically entered into its "Gradebook" function and are downloadable to a spreadsheet. This obviates the need to organise, conduct, and assess large paper-based examinations, and the inherently error-prone task of transferring examination results into spreadsheets for grade calculation.

A flexibility cost

Traditional, lecture-based teaching can rapidly adapt to the need to alter/update the taught content of a course or to change the order of content delivery. The flipped-classroom with recursive testing described in this paper is less flexible since alteration/updating of taught material requires recording of new presentations (unless updates are delivered in workshops) and creation of new/revised MCQs. Also, the recursive nature of the online tests means that any changes in the order in which taught material is presented also requires changes to the particular questions included in a number of workshop tests, and in the 3-Weekly tests. We have developed an MCQ naming procedure in the Canvas LMS to facilitate this (see Supplementary Material File 1). Nevertheless, course changes in our new course format require more preparation than for changes in the traditional lecture format.

Experience with, and attitudes towards, this method of teaching and assessment

After the end of the course, anonymous surveys of students' attitudes towards the teaching delivery and assessment structures were conducted (see Supplementary Material File 2). In general, students enjoyed that grades were accumulated gradually (and the immediate feedback on performance this provided) as well as the absence of a final examination. However, a proportion of students regretted the absence of written, short answer questions through which they believed they could demonstrate better their understanding of, and synthesis with, the taught material. We will consider incorporating short, written answer questions within the 3-Weekly tests in future. Feedback from the 2020 iteration of the course indicated dissatisfaction if pre-workshop recorded lectures exceed 40 minutes and/or if workshops only revise the material presented in the pre-recorded lectures (5 of the 16 students answering the question "Which aspects of this course need improvement?" in a standard Student Experience of Learning and Teaching survey which 23 of a possible 52 students completed).

Students acknowledged that the course structure required diligent viewing of pre-recorded presentations and review of past workshops. Students were also asked their attitudes towards performing two such courses simultaneously. Some were in favour of this while others thought the workload would be too high. When asked for their opinion on whether they retained information better from this method of teaching than from the traditional lecture format, most answers indicated that that their retention of information was equal to, or better than, that from the traditional format.

We invited students who had finished the course in 2018 and 2019 to become co-authors on this paper by completing surveys that could be included as supplementary material and by contributing to subsequent drafting/critical review of the manuscript. However, only the senior author (Lardelli) knows the identity of the students who completed any particular survey. The students were asked explicitly to give both positive and negative feedback on the course structure. The survey invitation and student responses can be viewed in Supplementary Material File 2. All the authors of this publication contributed to the submitted manuscript and supplementary materials.

It should be pointed out that all the instructors in the course, including those initially sceptical about the changes in teaching format, found it enjoyable to interact with the larger numbers of students now attending classes. This increased instructors' energy and motivation, invigorating their teaching and thus enhancing the student experience. A downside of the new structure was the initial need to develop large numbers of MCQs which was very time consuming. It is also non-trivial to develop MCQs that truly test students' comprehension of the course material. MCQ development is discussed further in Supplementary Material File 1.

Adaptation to a fully online format during the SARS-CoV2 pandemic

In 2020 this course was readily adapted to the fully online requirements of pandemic lockdown by conducting the workshops in an online format (using Zoom software). The large majority of students continued to attend the workshops in real time. However, interactivity was reduced and only a limited number of students actively engaged in asking questions of the instructors.

Summary of advantages and disadvantages of the revised course format

Advantages

- Greater student engagement with the presented material including physical participation in workshops
- Immediate and continuous summative assessment that is also formative
- Reinforcement of student learning through a recursive testing format
- Students perceived greater recall of learned material
- Online facilitation of test result collation for grade calculation
- Greater instructor satisfaction with student interaction
- Flexibility – if an instructor is forced to miss a workshop, the pre-recorded material was still accessible

Disadvantages

- Students can sometimes have difficulty in balancing course requirements with employment duties.
- Some transfer of MCQ answers between the student cohorts of different years likely occurs
- Composition of non-trivial MCQs is, initially, time-consuming and can be difficult for some instructors
- Less flexibility – changes to course structure involve recording of new presentations and creation of new MCQs while changing the order of presentations/workshops can require reorganisation of the questions included in particular workshop tests and 3-Weekly tests.

Conflict of Interest

The authors declare no conflicts of interest

References

- [1] In: Nature, (1951) Vol. 168, Page 234
- [2] M. R. Edwards, M. E. Clinton (2019) A study exploring the impact of lecture capture availability and lecture capture usage on student attendance and attainment. *Higher Education*, Vol. 77(3), Pages 403-421. DOI:10.1007/s10734-018-0275-9
- [3] J. B. Brame, R. Biel (2015) Test-Enhanced Learning: The Potential for Testing to Promote Greater Learning in Undergraduate Science Courses. *CBE-Life Sciences Education*, Vol 14, Pages 1-12. DOI: 10.1187/cbe.14-11-0208
- [4] K. B. McDermott (2020) Practicing Retrieval Facilitates Learning. *Annual Review of Psychology*, Vol. 72, Pages 23.1–23.25. DOI: 10.1146/annurev-psych-010419-051019
- [5] J. L. Jensen, M. A. McDaniel, T. A. Kummer, P. D. D. M. Godoy, B. St. Clair (2020) Testing Effect on High-Level Cognitive Skills. *CBE—Life Sciences Education*, Vol 19:ar39, Pages 1–13. DOI:10.1187/cbe.19-10-0193
- [6] H. Choi, H. S. Lee (2020) Knowing Is Not Half the Battle: the Role of Actual Test Experience in the Forward Testing Effect. *Educational Psychology Review*, Vol. 32, 765–789. DOI: 10.1007/s10648-020-09518-0

Figure 1

GENETICS level III Semester 2, 2019 TIMETABLE

- Assessment**
- A student's 10 best workshop test scores from weeks 1-4, 10 best scores from weeks 5-8, and 10 best scores from weeks 9-12, together comprise 35% of their final grade (or 70% for Genetics 3520 students)
 - A student's 3 best 40 minute exam scores comprise 15% of their final grade (or 30% for Genetics 3520 students)

Figure Legend

Figure 1. Timetable of the Level 3, Semester 2 theory course in genetics at the University of Adelaide with annotations. The arrangement of workshops and 3-Weekly tests is shown as well as the recursive nature of the MCQs in each workshop. Note that, the "Genetics 3520" course is a theory only course while other courses include practical components (not shown).