6 PAGE PAPER Scaling for the Future: Development of a Sustainable Model for Teaching MATLAB Programming to STEM Students

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Scaling for the Future: Development of a Sustainable Model for Teaching MATLAB Programming to STEM Students

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Abstract

An undergraduate programming language course in MATLAB has experienced explosive enrollment growth over the last decade at the Pennsylvania State University's University Park campus. To adapt to the huge growth in enrollment, the course was redeveloped in stages over several semesters to create hybrid and online versions of the course. The evaluation model was also changed to shift focus away from periodic examinations to weekly assessments. Students completed end of semester teaching evaluations for the course, and some students also participated in focus groups to discuss the effectiveness of the course redesign. Student evaluation results showed statistically significant improvements in student evaluation scores in all areas evaluated except for those areas that related specifically to the course instructor. The results of this study demonstrated that flipped classrooms can not only help programs to manage their introductory programming course enrollments, but they also increase students' perceptions of the quality of courses.

Keywords

MATLAB, flipped, hybrid, online, assessment.

Introduction

CMPSC 200 Programming for Engineers with MATLAB is a service course at the Pennsylvania State University (Penn State). The course was originally developed by the Department of Computer Science and Engineering at the request of multiple departments who had perceived a need for undergraduate students to learn the MATLAB programming language, as opposed to the C++ or FORTRAN languages that were being taught in service courses. When CMPSC 200 was initially developed, it was anticipated that the course would be offered once each year with an expected enrollment of 55 students at Penn State's University Park campus; enrollment for Spring 2008, the first semester that the course was offered as a permanently numbered course, saw 50 students enrolled in one section of the University Park course.

Enrollments in CMPSC 200 have since skyrocketed; eight sections containing a total of roughly 480 students are being offered in the Fall 2017 semester at University Park. The course is not offered at every Penn State campus, so some students who begin their academic journey at another campus location wait to take the course until they have transitioned to University Park. Enrollment had increased to the point where the logistics in scheduling rooms for the course were rapidly

becoming unmanageable; while University Park does have one classroom large enough to seat 480 students in a lecture section, that room is hard to schedule, and that room was typically only available at times perceived as undesirable to many students (*e.g.* 8:00 a.m.). In order to provide additional flexibility in delivery mode, it was determined that the School of Electrical Engineering and Computer Science required blended-learning ("hybrid") and online versions of the course.

While the course was being redeveloped, it was judged that the time was ripe to also re-evaluate the course evaluation model. While evaluation models employed in a given course at Penn State typically vary by instructor and department, at University Park most of the faculty who taught the course assessed students via a combination of computer laboratory assignments, projects, quizzes, midterm examinations, and a final examination. A significant disadvantage to that evaluative model was that students were required to hand-write their responses to computer programming prompts on the midterm exams, and – depending on the instructor – sometimes also the final examination. This study therefore also set out to discover a more appropriate evaluative technique.

A Brief Review of the Literature

It has been found that active learning can help students to better learn course content in their science courses[1]. Some authors[2] have found that "flipping" classrooms can be an effective teaching strategy. Online learning has been noted as being able to make education more available to underserved populations of students[3]. Further, hand-writing computer code on examinations is well-known to give students anxiety; historical practice in offering the course has confirmed this, and there are examples of online discussion forums where students express anxiety with the task[4].

Historical Practice

CMPSC 200 at University Park has historically been organized using a lecture-recitation-laboratory teaching model. Generally, the Monday course meeting was a "common" lecture taught by the instructor of record in a large (semesters when two lecture sections were offered) or very large (semesters when one lecture section was offered) lecture hall using traditional large lecture techniques (*i.e.* PowerPoint presentations).

For Wednesday course meetings, a recitation was held in a student computer laboratory. In general, early in the semester the recitations mostly featured lecture, with limited time allocated for students to work on practice problems under the mentorship of the instructor. As the students learned more programming techniques and were exposed to more sophisticated concepts, the instructor would reduce the amount of lecture time in recitation, and would give students more time to work through practice problems. To the extent that lectures were incorporated into the recitation, they were informally delivered, with the instructor's notes being available in the form of an outline of that day's topics. Students were encouraged to freely ask questions in recitation, and it was found in practice that the most effectively delivered recitation ultimately took the form of a dialogue with the students.

On most Friday course meetings, students were asked to complete a laboratory assignment to assess how much they had learned during the week. The laboratory assignments were generally administered by graduate teaching assistants (TAs) and by undergraduate or graduate learning assistants (LAs). Depending on who the instructor of record was, students typically had one to two

days to complete the laboratory assignment, with the expectation that students would complete at least the bulk of the assignment in the Friday laboratory session, where students could also freely ask questions.

Delivering CMPSC 200 with this teaching model was not without its challenges. In Fall 2015, for example, due to the availability of computer laboratories on campus, the current course instructor taught seven 50 minute recitation sections back-to-back in sequential time periods without a break. Furthermore, administering examinations in the course had become more challenging as the course had grown in size. In particular, it had become difficult to schedule classrooms for the two hour evening midterm examinations because there were no classrooms large enough to seat the course with alternative seating; the University Registrar's office would then have to schedule the examinations across multiple classrooms, which significantly increased the complexity of the examination administration process for the instructor. The midterm examinations were graded through a combination of Scantron questions (for which automated grading is available), and open-ended questions (which must be graded by hand). The grading of the open-ended midterm examination questions required an enormous amount of grader time, and the instructor was unable to offer a laboratory assignment during the week of a midterm examination because there was not sufficient grader time available to adequately provide students with feedback for both evaluative events. To mitigate this problem to some degree, the final examination for the course was developed by the current instructor to be solely delivered via Scantron because it was judged that students at the end of the course did not require the same level of richly detailed feedback that they had been receiving throughout the balance of the semester. The Scantron final examination also facilitated the timely posting of final course letter grades.

Methods and Timeline

The course redesign was implemented over the course of multiple semesters. In the Summer 2016 offering of the course, weekly[*] assessments took the place of the laboratory assignments and the midterm examinations. The lecture and recitation format remained the same as it historically had been within the bounds of a compressed[†] summer offering of the course. Meanwhile, the instructor began recording video lectures to replace the lectures that were then-currently delivered in the Wednesday recitation sessions. One common concern with "flipping" classrooms is that students often do not watch the video lectures prior to attending class, so in the Summer 2016 semester the instructor began developing short five minute quizzes to encourage (and to reward) students to come to recitation prepared to think about problems relating to that week's course content. Each lecture video was no longer than approximately 10 minutes in length, which facilitated both student viewing and the long-term maintenance of the lecture materials by the course instructor; students then watched a series of these short videos that covered the relevant lecture content.

In the Fall 2016 semester, the recitation lecture was replaced by home-viewed video lectures. The lecture quizzes developed during the Summer 2016 semester were then implemented in lieu of the

[*]Weekly when measured on a traditional 15 week course schedule; as the course was offered in a compressed time frame, the assessments were actually administered biweekly in the Summer 2016 offering of the course.

[†]The course was offered via four 75 minute periods a week over the course of 7.5 weeks, as opposed to three 50 minute periods a week over the course of 15 weeks as would normally occur in a traditional semester. The instructor selectively cancelled a few course meetings (*e.g.* around Independence Day) to ensure that the amount of instructional time would be equivalent to a traditional semester's offering of the course.

longer quizzes that were previously utilized in the course. Students took the automated grading quiz through the University's learning management system, Canvas, during the first five minutes of recitation time; the balance of the recitation period, then, was used for students to explore practice exercises with a recitation leader (usually a TA, but occasionally a properly prepared LA), assisted by one or more assistants, depending on room size. During the Fall 2016 semester, the instructor also recorded video lectures that would eventually replace the Monday large group lectures.

The large group lecture was then replaced by video lectures in the Spring 2017 semester; at this stage of the redesign, there were no longer any live lectures delivered in the course. The weekly quizzes and assessments were modified when student feedback suggested making alterations, and the weekly quizzes were slightly refocused to cover both sets of video lectures for the week. A test bank of questions was developed to help reduce the likelihood of academic integrity violations in the course, and to improve the soundness of the evaluative techniques. Time was allocated for the instructor to re-record any lectures that may have needed further refinement as a result of student feedback.

In the Summer 2017 semester, the course was offered fully online to a relatively small (approximately 75) section of students. The section was intentionally kept to a controlled size owing to the need for the instructor to coordinate final examination proctoring through "approved proctors" for the students. Discussion forums were added to the Summer 2017 course in order to facilitate more authentic evaluation of student effort[5], and to discuss applications in the students' intended fields. The recitation practice exercises were made available to the students, and a subset of those problems were evaluated each week to provide students with feedback. Due to the unavailability of proctors, periodic quizzes and assessments were not administered.

At the end of the Fall 2016 and Spring 2017 semesters, students were invited to respond to the Student Rating of Teaching Effectiveness (SRTE) survey. This survey contained 11 ratings questions and three open-ended questions. In the Fall 2016 semester, 419 of the 446 students (94.0%) responded to the SRTE survey; in the Spring 2017 semester, 439 of the 471 students (93.2%) responded.

To further assess student perspectives and experiences, focus groups were conducted during the final weeks of both semesters. The focus groups were organized to help explore in greater depth the students' perspective of their experience in the course. Questions used in the focus groups were developed to address the students' experiences with the components of the course generally and specifically, including the lectures, recitations, assessments, and overall workload. To begin, each focus group was asked a broad question about their overall experience in the course and with the video lectures. This allowed the focus group students to introduce the thoughts and feedback of most importance to them prior to addressing more directed questions from the focus group leader.

Results

The same 11 rating questions were asked across the SRTEs in both the Fall 2016 and Spring 2017 semesters. Students were asked to rate each statement from 1 to 7, with 1 labelled as the lowest rating, 4 rated as the average rating, and 7 rated as the highest rating. Average ratings for both semesters are detailed in Table 1, as are t-test comparisons of the mean ratings.

Table 1: Mean ratings and t-test statistics for the SRTE rating questions

	Fall 2016	**Spring 2017**	t	df
Rate the overall quality of this course.	4.928	5.252	3.520**	846
Rate the overall quality of the instructor.	5.263	5.535	2.913**	840
Rate the clarity of the instructor's presentations.	5.327	5.580	2.773**	850
Rate the effectiveness of the examples used to clarify difficult concepts.	5.099	5.385	2.885**	845
Rate the instructor's willingness to help students make progress.	5.756	5.676	-0.823	818
Rate the instructor's interest in whether or not students understood course content.	5.504	5.434	-0.648	830
Rate the adequacy of the instructor's knowledge of the subject matter.	6.277	6.312	0.460	842
Rate the organization of course material.	5.438	5.803	3.796**	846
Rate the effectiveness of homework and out-of-class assignments as contributing to the learning process.	4.886	5.130	2.138*	833
Rate the effectiveness of exams in testing understanding and not memorization.	4.473	4.916	3.584**	813
Rate the effectiveness of the course in improving problem-solving skills.	5.068	5.355	2.747**	842

$* p < 0.05$; $** p < 0.01$

Overall, the majority of the mean ratings increased significantly from the Fall semester to the Spring semester, indicating that students on average felt more highly about the course quality and about specific course aspects in the Spring. Only three mean ratings did not significantly increase on average from Fall to Spring: "instructor's willingness to help students make progress," "instructor's interest in whether or not students understood course content," and "the adequacy of the instructor's knowledge of the subject matter." These three statements, however, were the highest rated from the Fall, and all refer to the instructor's work with students. Both of these reasons may contribute as to why these three statements have the only means that did not increase significantly across semesters.

Positive changes were also evident in students' responses during the focus groups. Students' overall comments became more positive from the Fall to the Spring; students from the Fall semester reported mixed reviews about the course design changes, while students from the Spring felt that the flipped classroom organization allowed for self-pacing of the learning materials and better overall use of their time.

When specifically asked about in-class and video lectures, students in the Fall thought both types of lectures were helpful, but that the in-class lectures were adequately covered by the PowerPoints, and that the video lectures, while helpful for memorization, were not sufficiently detailed about applications and reasoning behind coding. In contrast, the students from the Spring semester reported that having both theory and example videos was helpful, though they felt that there were still not sufficient details provided about applications. Students from both semesters brought up the benefits of being able to re-watch, pause, rewind, and speed up the lecture videos.

Student opinion of the weekly assessments also shifted between the Fall and Spring semesters. In the Fall, while some students felt that the assessments encouraged them to keep on top of the course material, others felt that a lack of clear connections from week to week meant that they were "cramming" for each assessment. On the other hand, in the Spring students reported that the weekly assessments obliged them to stay on top of the lecture videos and other coursework.

Discussion

As the structure of the course became more fully flipped, students reported that the course and its instruction were of higher quality as evidenced by both the SRTE ratings and the focus group responses. Students' comments in the Fall were mixed – they felt that the in-class lectures were unnecessary and sufficiently covered by the PowerPoints, but that the video lectures lacked sufficient detail. On the other hand, the fully video nature of the lectures in the Spring was reflected in students' consistently positive review of the learning materials.

There are two potential explanations for the three ratings items that did not show a significant increase. The first is a case of regression to the mean for those statements. The survey items that did not increase between semesters were among the highest evaluation scores in both semesters. The initial rating of these statements were so high (5.4 or higher out of 7) that increases that reached levels of statistical significance would be improbable. This is especially likely for the item "[r]ate the adequacy of the instructor's knowledge of the subject matter" that started with an average of 6.277 out of 7 and increased non-significantly to 6.312. The second possible explanation centers around the topic of the statements. For the two statements that decreased between semesters, both referred to the instructor's work with students, which is an aspect of the course that changed between the two semesters. In the Fall, the course involved an in-class lecture component that transitioned online in the Spring, and this modification would have changed the student-teacher interaction dynamic. Flipped classrooms inherently take the focus off the instructor, moving the course to a more student-centered model of learning.

Conclusions and Future Work

The student evaluation and focus group results strongly suggested that the course redesign was a worthwhile endeavor. Furthermore, both the course instructor and the unit offering the course have benefited from the easier-to-administer nature of this redesigned service course. While multistage course redesigns are easier for faculty to implement, it appears in this case that there was a trade-off in student evaluation scores partway through the redesign. Course instructors should be aware that they may need to update lecture videos from time to time as circumstances require (*i.e.* due to updates in the course content – in this case, updates to the MATLAB programming language itself).

Student feedback suggested that at the present students wished to retain the live recitations, so the course has thus far only been offered online in the summer semester when students are often away from campus. Discussion forums were trialed during the Summer 2017 offering of the course, and were implemented into the Fall 2017 offering of the course. It will be important to evaluate the efficacy of the discussion forums, particularly in light of the large roster size and the need to ensure that students are evaluated through a combination of automated and authentic evaluation techniques.

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