Student and Instructor Experiences in the Inverted Classroom

Michael J. Herold, Thomas D. Lynch, Rajiv Ramnath, Jayashree Ramanathan
Department of Computer Science & Engineering
The Ohio State University
Columbus, Ohio 43210–1277
herold@cse.ohio-state.edu, lyncht@cse.ohio-state.edu, ramnath@cse.ohio-state.edu, jayram@cse.ohio-state.edu

***Abstract*—This paper discusses our ongoing experiences with teaching software engineering through an inverted classroom. This course format moves traditional lectures out of in-class hours and into the student's personal study time with prerecorded lectures. We support the inverted classroom with complementary techniques, such as structured discussions, weekly quizzes to ensure students watch the lectures before discussion, an innovative Lego-based workshop, a term project, and guest lectures by industry professionals. The inverted classroom allows the students to have an effective educational experience that encompasses both traditional lectures and an active learning environment. To evaluate the efficacy of this format, we use surveys and interviews of both instructors and students. We examine the time commitment of teaching with this method, from both the instructors' perspective and the students'. We also discuss the time commitment for instructor preparation, and quantitative measures of how the inverted classroom helps smooth the variance in the quality of each instructor's teaching. We also analyze the effectiveness of this technique and our methods for mitigating unintended consequences, such as students having an inexact understanding of the material. Through this evaluation, we distill the effects on student learning and instructor teaching.**

***Index Terms*—Instructor experiences, Inverted classroom, Software engineering education, Student experiences**

I. Introduction

The software industry expects fresh graduates to enter the workforce with an ever-increasing amount of knowledge. Universities struggle to balance program length with content, often teaching fundamentals in lieu of hyper-focused tools and techniques that are popular in the moment. To give their students the right balance of abstract and concrete understanding, faculty members must constantly innovate within the classroom and provide more value to the students per hour of instruction.

One such innovation is the inverted classroom format [1]. By taking the traditional lecture out of the classroom and putting it online for students to consume during their study time, educators can provide concrete lessons through active learning activities like workshops [2], interactive work time with the instructor [3], and interactive demonstrations [4].

We implemented an inverted lecture format for our senior- and graduate-level software engineering course. After using the format for eight quarters, we discovered interesting questions regarding the burden placed on students by an inverted classroom, the preparation time for instructors, the homogeneity of the instruction quality across instructors, the quantity and quality of discussion within the classroom, and methods to ensure that the students watched the prerecorded lectures before class.

This paper addresses our attempts to answer these questions. Section II provides background and related research for this work. Section III describes our inverted classroom and the materials used. Section IV discusses the purpose of this study. Section V lists the methods we used to acquire data for analysis. Section VI illustrates our data analysis. Section VII describes our results and section VIII lists our conclusions and ideas for future work.

II. Background

This section presents work related to this research.

A. Inverted Classroom

Instructors have used the inverted classroom in a number of contexts. Lage et al. originally intended to address the breadth of learning styles found in introductory economics courses [1]. The course format allowed the instructor to present diverse material in a manner that is attractive to a broad audience, yet still maintain control over course content.

Within engineering disciplines, Gannod et al. used the format in a software engineering program as a pilot to revamp their department's curriculum [3]. In this paper they discuss a framework and its possible implementation in eleven courses in the software engineering curriculum, and addresses proposed arguments against the inverted classroom. We have provided an evaluation of the authors' issue of whether students watch the pre-recorded lectures.

Day and Foley conducted an in-depth analysis of Web lectures for learning [5]. Their quasi-experimental study evaluates the efficacy of online lectures versus a traditional lecture-based course. This setup parallels the inverted classroom, where shorter lectures are provided for the students to watch during their study time. The experiment showed a significant increase in student grades, indicating that the method was successful. We have expanded upon this base of validation to further investigate the effects of pre-recorded lectures.

The inverted classroom has also been used to instill lifelong learning skills in electrical engineering students [6]. The

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reactions of our students parallel the results found in this usage. Additionally, Toto et al. utilized the inverted classroom to teach select lectures within a junior-level industrial engineering course and showed significant correlations between student learning styles and attitudes toward the format [7]. We have similarly analyzed student reactions to the inverted classroom to verify their claims.

B. Instructor Concerns

A notable trend in education research is the student-centric viewpoint that most research assumes. Since, ultimately, education is about teaching the student, this view is acceptable. However, to the best of our knowledge, there is a lack of research on the effects and unintended consequences of distance learning on the instructor. We feel that the impact on the instructor is also important in evaluating teaching methods and thus we include this in our analysis.

III. The Inverted Classroom

This paper focuses on the student and instructor experiences in a course redesigned to use the inverted classroom. This course is a senior and graduate level software engineering course.

In an effort to bring a more industry-centric view to software engineering, this course was redesigned to be an end-to-end course focused on enterprise architecture. The addition of this content to an otherwise large set of material proved to be unattainable in a traditional lecture-based class.

A. Course Demographics

The course has a diverse population of students, as it is cross-listed in both the undergraduate and graduate curricula. For most of the undergraduate students, the course is required as part of the Software Systems option for the B.S. in Computer Science and Engineering. The graduate students primarily take the course as an elective, though some are required to take it by their advisor.

In the case of this study, the students were distributed across three sections that were fairly equal in total enrollment but disparate in enrollment by standing, with 36 (19 graduate, 17 undergraduate), 38 (3 graduate, 33 undergraduate), and 32 (15 graduate, 17 undergraduate) students respectively. The first section was taught in the morning, while the latter two were taught in the evening. All sections met twice per week.

B. Course Structure

The structure of the course attempts to motivate students to keep up with the lectures during their study time. We provide electronic lectures to the students before the module is assigned. These lectures come in three forms: as a video, as a slide presentation with audio attached, and as lecture notes with the slides. Each week, the students are expected to consume a lecture in any of the three forms, take notes, and engage in discussion in an email discussion group. The instructor uses the in-class time during the week to add his or her personal experience to the lecture in discussion, conduct activities with the students, and answer any questions the students have about the lecture content.

To motivate students to watch the lectures before the class session in which the lecture is discussed, we issue a quiz each week on the topic. These quizzes consist of one or two short essay questions and make up 10% of the students' grade. The wording is such that the students' answers are more about their argument and the support for it than whether they have a completely correct answer. The intent of this type of quiz is to motivate the students to internalize the concepts and think about how they interact, rather than have them focus on memorizing vocabulary and definitions.

The main component of the course is a project where the students go through all of the non-programming phases of the software development life cycle. First, the students must do a business analysis of a company of their choosing and develop an IT portfolio for that business. The students then choose one application from their portfolio and conduct each of the standard software development life cycle phases. The result is a project report detailing their work. A secondary goal of this project is to provide them with a reference for project proposals and workbooks later in their career.

C. Lecture Materials

In order to incorporate the new material within the fixed time frame of a one-quarter, three-credit-hour class, we designed the curriculum as an inverted classroom. The idea was, if we have the students watch lectures during their study time, more time would be available in the class sessions for activities and discussion.

The first iteration of the curricular materials simply consisted of slides with audio recordings that captured an entire traditional lecture. The audio was recorded to run in one contiguous segment for each slide. This produced a user experience that mimicked the problems in classroom lectures, such as the instructor not wanting to be interrupted or students forgetting questions by the time the instructor is ready to take questions; the format provided no good affordance to replay a piece of the lecture.

In addition to being frustrating for the students, the above mode of production was difficult for the instructor creating the lectures as well. Interruptions or background noise within the recording environment were more common and likely when recording long segments of dialogue, requiring major segments of the lecture to be redone.

The creation of these initial presentations provided a valuable experience in the creation of such resources. For our second iteration on the lectures, we broke the recording into smaller segments corresponding to sections of the slides that could be clicked on to replay. The shorter recordings allowed students to easily review specific sections of the lecture without having to listen to content that they already understood.

D. In-class Activities

Dale [8] found that students learn better from hands-on experiences, when compared to traditional passive methods.

This finding, called the Cone of Experience, shows that concrete experiences help inspire learning more than mere transmission. Because the inverted classroom frees up in-class time from the constraint of lecture, we utilize the in-class time through active, hands-on learning modules, as follows.

The most complex of these in-class activities is an interactive workshop in the form of a game, as discussed in [2]. In this game, the students form into small groups and learn about agile development principles. This activity takes an entire day of class, but results in the students having fun and enjoying the learning experience. Our evaluation in [2] requires further validation of whether the activity helps the students to learn better than a lecture.

Simpler experiential learning methods are also used. One instructor created an activity where the students simulate a call center. A small set of students are picked to stand in front of the class and act out the software architecture that the class as a whole designs based on the instructor's requirements. The instructor introduces conflicting requirements that the students must decide how to mitigate. After developing an architecture that meets the requirements, the students then determine how the architecture handles various incoming calls.

This short overview does not cover the entire course curriculum. For more information, see [9].

IV. Purpose of this study

After utilizing this curriculum over eleven quarters, we formulated several unanswered questions. Does the inverted classroom place a greater time burden on student study habits? Does the inverted classroom increase the quantity of discussion? What about the quality of discussion? Are weekly quizzes an effective means of ensuring students watch the lectures? Does the inverted classroom lessen the preparation time for instructors? Does the inverted classroom help make instruction quality more homogeneous across instructors than a traditional lecture format? The purpose of the present study is to address these questions and discover where the method succeeds and where it fails.

V. Teaching and Evaluation Methods

This study was designed to capture student and teacher experiences across three simultaneous sections of the senior-level software engineering course. A different instructor taught each section of the course. One instructor was an investigator in this study and is the course coordinator for the software engineering curriculum. The other two instructors were lecturers teaching in the department for the first time. Both of the instructors had teaching experience; one of them had previously taught university courses and had also taught in industry, while the other had no university teaching experience, but had taught in the Distinguished Engineer program at his company.

Each instructor used the same basic lecture for the ten course learning units. These lectures were made available in three formats: YouTube videos, PowerPoint presentations with attached audio, and written notes for each presentation. All formats were available on the course website hosted on Google Sites. The students freely chose their own method for consuming the lecture material, but were provided an incentive to actually do so by the presence of a quiz on each topic prior to the topic's designated discussion day.

Interim questionnaires, as developed by the authors, were distributed to the students in each section at three points throughout the quarter. Each survey was distributed in class to the students in attendance. Post-quarter interviews were scheduled with nine students — three from each section — and both of the new instructors. Students were recruited via an email sent to the discussion group for each section. Interviews were conducted by the graduate student first author, rather than the faculty PI, to provide a more comfortable atmosphere for the interviewees and have them speak more candidly about their experiences. The students were provided a $15 Amazon gift card for participating, whereas the instructors were not compensated.

VI. Data Analysis

This section discusses our analysis of the data obtained from three sources: surveys, interviews, and student grades.

A. Surveys

Descriptive statistics were computed for the surveys to explore the workload the inverted classroom placed on the students, as well as the level of engagement the students had for each topic. The overall response rate for the surveys was 90% (83% for the morning section, 95% for the first evening section, and 91% for the second evening section).

The surveys consisted of four items measuring three different variables of interest: two items measured time commitment, one item measured student learning, and one item measured student engagement. Time commitment was measured by one closed-ended item and one open-ended item, whereas student learning and engagement were both measured with a single closed-ended, 5-point Likert scale item.

The procedures for analyzing the surveys were as follows:

1) Compute frequency distributions for all surveys with classes aggregated to report general findings for the effect of the inverted classroom on student time commitment, learning, and engagement.
2) Compare differences between the classes for each topic to explore the effects of the inverted classroom in instruction homogeneity.

B. Interviews

The post-quarter student interviews were analyzed to check that the results of the surveys matched student experiences in the classroom. The analysis also yielded a qualitative measure of instruction homogeneity by comparing responses across the three sections.

The student interviews consisted of semi-structured question sets pertaining to five different topics: student satisfaction with the inverted classroom format (six questions), student evaluation of the in-class discussion (six questions), the efficacy of

the quizzes as a motivator (four questions), the value of the active learning activities (six questions), and the impact of in-class presentations on student projects (two questions). Three questions were in 5-point Likert scale form and the others were open-ended.

The instructor interviews, which were conducted during finals week, were analyzed to provide a measure of instructor satisfaction with the inverted classroom technique. In addition, the analysis afforded a qualitative measure of the effect of the inverted classroom on instructor preparation time.

The semi-structured question sets for the instructor interviews pertained to five topics: knowledge elicitation about instructor background (two questions) , teaching preparation (three questions), the efficacy of techniques to motivate students to watch the lectures (two questions), and the effect of the inverted classroom on the instructor's teaching (six questions). One question was in 5-point Likert scale form and the others were open-ended.

C. Student Grades

The anonymized grades for the three sections were compared via a one-way ANOVA. There were eight quizzes, each covering a different topic. Each quiz was taken as a variable for analysis, with missing grades excluded.

Student grades provide a quantitative measure of instruction homogeneity. As the instructors were free to grade the student projects as they saw fit, the projects were ruled out as indicators. The quizzes for all three sections were graded by teaching assistants under the guidance of the authors, so the quality of the grading between classes was equivalent; thus the grading bias across sections was judged to be minimal.

VII. Results

The analysis for this study amalgamates the results of the three data sources to provide a holistic view of the student and instructor experiences within the inverted classroom. Qualitative data, in the form of interviews with both instructors and students, provides grounding for the quantitative data obtained from surveys, student evaluations of instruction, and student grades.

A. Impact on Student Study Time

The course in question is a three-credit-hour, senior level software engineering class. It is intended to be of average difficulty; this fact, combined with the popular heuristic of three hours of study per credit hour says that students should expect to spend nine hours studying per week.

The student interviews included three questions about the time impact of the inverted classroom on the students' study practices. Of the nine students interviewed, two students said the class required significantly more (1.75 and 2.00 times as much, respectively) out-of-class work than a standard class. Four students believed the course required about the same amount of out-of-class work as a comparable course, and two said that the course required less work than a comparable one.

The differing opinions of the students stemmed from many reasons. Three students said that they appreciated the lectures because they were forced to keep up with the work from week to week; this resulted in less cramming for the final exam. One undergraduate student said he felt an increased burden from the course format and that the burden affected his study in a negative way. However, he also stated that he was taking 22 credit hours in an effort to finish his courses before the university transitions from quarters to semesters. Additionally, the students rated their time commitment in relation to their study habits for other courses; depending on the study habits of the interviewed students, there could be a hidden bias within their responses.

Because the interviews provided conflicting data about whether the inverted classroom format placed more study burden on the students, surveys were administered to check whether students spent more than nine hours studying per week. Out of 128 responses, 84.4% of students responded that they spent one to six hours per week studying outside of scheduled class time. Broadening the window to six to twelve hours increases the percentage to 99.4% of the responses; only one response (0.06%) indicated more than twelve hours of study for the week.

Between the interviews and the survey data, there is evidence that the study burden is, on average, no more than that of a comparable course. That is, none of the data indicate an unacceptable increase in the amount of time required by the inverted classroom.

B. Quantity of Discussion

One of the stated goals of the inverted classroom was that it helped to increase the amount of two-way dialogue during class time, as the instructor was freed from lecturing and was thus able to hold hour-long discussions. In order to verify whether this was actually true, we asked students during the interviews about their beliefs regarding the quantity of discussion in the inverted classroom in comparison to discussion in a comparable, traditional course.

Of the nine students interviewed, eight of them said that there was noticeably more discussion during class than in a comparable class. The one dissenting student stated that there was often the traditional long pauses while the instructor waited for students to add to the discussion, but that discussion did eventually occur. His account does not match with the other two students from his section, thus weakening the conclusion that more discussion did occur than in a traditional class. However, the evidence did suggest an increase in the quantity of discussion.

C. Quality of Discussion

In addition to increasing the quantity of discussion, the inverted classroom was intended to increase the quality of discussion. To test whether this truly happened, we asked students during their interviews about the quality of discussion in the course relative to a traditional course.

Four of the nine students said the quality of discussion was better than in a comparable course. One of those four students said that she felt discussion was better, even when

compared to a traditional course that has a large discussion component. However, none of the students felt that the quality of discussion was substantially better.

The other five students said that they felt the quality of discussion was not necessarily improved by the inverted classroom, but was highly dependent on the questions that they and their classmates had for each topic. Since the course does not have a rigorous set of prerequisites, students enter the class with widely different knowledge bases. As such, the five interviewees said that some of the questions that their peers posed ranged widely afield from the heart of the course or were too simplistic to ask. They felt that the quality of discussion was lowered, not due to the inverted classroom, but due to the variance in the questions that were asked.

Based on these results, the evidence is inconclusive whether the quality of discussion is measurably better in the inverted classroom than in a comparable, traditional course.

D. Quizzes as Motivators

One concern within the inverted classroom is that students do not watch the lectures outside of class. To counter this, we introduced quizzes on each lecture that occurred at the beginning of the discussion day for each lecture. To test the efficacy of the quizzes as a method of motivating the students to watch the lectures, we asked the interviewed students and instructors whether or not the quizzes were effective.

Eight of the nine students stated that they felt the quizzes were effective. They also said that the quizzes helped to guide their study, once they were acclimated to the format of the quizzes. One student did not think the quizzes were effective as a motivator because he felt that one could skim the lectures and get "good enough" partial credit on each quiz.

Both instructors considered the quizzes effective. However, they both disliked the anxiety that the quizzes introduced. One instructor said that the time limit on the quiz made the students feel rushed and felt that their performance was degraded by that worry. The other instructor thought there were too many quizzes during the quarter and that the students felt too pressured by the presence of a quiz each week.

From these results, we concluded that the quizzes were effective as a means of ensuring students watched the lectures before the discussion date. However, there were unintended consequences in the form of increased student anxiety. Course instructors who wish to implement an inverted classroom must weigh that concern against the benefits of the format.

E. Instructor Preparation Time

Preparing for a traditional class requires creating a lecture and anticipating student questions on that lecture. However, in the inverted classroom, there is no in-class lecture, but either a discussion or activities intended to hone student understanding. As such, an important question is how the inverted classroom affects the preparation time for the instructor. To study this, we relied on self-reporting in the form of interview questions with each instructor.

TABLE I
THE MEANS AND P-VALUES FOR QUIZ SCORES BETWEEN THE THREE SECTIONS. QUIZZES WERE GRADED ON A SCALE OF 0–3.

Quiz	μ_1	μ_2	μ_3	p-value
1	2.47	2.37	2.67	0.353
2	2.44	2.63	2.12	0.0307
3	2.36	1.71	2.82	5.31e-07
4	1.83	2.08	1.42	0.0301
5	2.33	1.84	2.27	0.0504
6	2.42	2.03	2.58	0.0237
7	2.58	2.03	2.70	0.000672
8	1.83	2.26	2.76	8.45e-05

One instructor was experienced with teaching in academia, while the other was only accustomed to teaching in the context of his industry career. Both instructors stated that there was radically less preparation time required to teach this course than a traditional course, but for very different reasons.

The academic instructor found that he spent two to three times less time preparing for each class because he focused on finding the weaknesses in the recorded lectures and spent class time addressing those weaknesses. To address the lecture weaknesses, he first watched each lecture while taking notes, and then found freely available videos from outside sources to cover the topic, which consumed most of his preparation time. He used in-class examples from his industry experience to provide some grounding for his students.

The non-academic instructor teaches a very similar curriculum for his industry career, so did not have to spend much time solidifying his understanding of the inverted lectures. He focused on finding good examples of the course concepts in practice, in order to ground the material for the students. Most of his preparation time was spent on arranging time for coworkers to come in and present their work to his class. He also spent time finding job-related work products that he could share with the class to show the students what each topic looked like when translated to a real work process.

Because the instructors did not have to prepare a lecture for each day of class, the preparation time was less than for a traditional class. However, the depth to which the instructor went to address perceived lecture weaknesses varied depending on personality. Thus, the inverted classroom lessened preparation time in some respects compared to a traditional class, but highlighted additional preparation challenges for the instructors.

F. Homogeneity of Instruction Across Instructors

The inverted classroom takes the responsibility of creating lectures out of the hands of the instructors and places it into the curriculum designers. As such, the quality of instruction for different instructors should be more homogeneous than in a traditional classroom where different lectures are used by different instructors. To test this, we used the anonymized student grades as indicators of the instruction quality.

The student grades were analyzed via a one-way ANOVA between each quiz for each instructor. The null hypothesis was that the means for the two sections were equal. The

alternative hypothesis was that the means for the two sections were not equal. As seen in Table I, for quizzes 1 and 5, there was insufficient evidence to reject the null hypothesis ($p = 0.05$), whereas there was sufficient evidence to reject the null hypothesis for quizzes 2, 3, 4, 6, 7 and 8. Thus, as a measure of instruction homogeneity, the student grades suggest that the quality of instruction varied across instructors.

VIII. Conclusions

The inverted classroom is a new method of teaching that requires a different balance of commitment from both the students and the instructors. As such, we had several questions that came to light after teaching in the format for several quarters. We designed metrics to validate our hypotheses about each of these questions.

Since students are required to watch lectures during their own time instead of during scheduled touch points with the instructor, we wanted to ensure that the students were not overburdened by this single class. We issued surveys to measure how much time the students were spending each week on the course. We also interviewed students to provide qualitative data on the subject. No indication of overburdening was present in any of the instruments, so instructors looking to implement an inverted classroom approach should not be concerned with it creating a burden on students.

A goal of the inverted classroom is an increase in the quantity and quality of discussion in the class. By interviewing students, we were able to assess the general feelings students have about discussion within the classroom. The evidence shows that there is a measurable increase in the quantity of discussion. However, we were unable to show an increase in the quality of discussion. According to the student interviews, the quality of discussion was highly dependent on the students in the class. As such, we must further investigate the question of measuring discussion quality.

One of the concerns with the inverted classroom approach is that students do not watch the prerecorded lectures. In order to combat this concern, we implemented a series of quizzes that were held on the discussion day for each topic. We validated the efficacy of this technique via our interviews with students and instructors. Students stated that the quizzes were an effective means of ensuring they watched the lectures. However, instructors noticed student anxiety regarding the quizzes. This shows that there is a trade-off inherent in this enforcement policy, where instructors must consider the ramifications and whether the increase in students watching the lecture is worth the additional anxiety associated with quizzes.

Given that the inverted classroom changes the way instructors have to prepare for class, we interviewed two instructors to confirm our hypothesis that the inverted classroom lessened the burden of preparation on the instructors. Both instructors indicated that it was easier to prepare for this class than for a traditional one, additionally stating that they were free to look for examples of the course concepts to share with the students.

Lastly, we hypothesized that the inverted classroom made instruction quality more homogeneous between different instructors. We were unable to validate this claim by using quiz grades as an instrument. We believe that the variance between classes is related to the instructors' use of supplementary materials, such as industry examples, extra in-class videos, and the discussion within the classroom. We will work to provide a better measure of instruction quality to further investigate this claim.

In the future, we will perform a longitudinal study to see how much of this course the students retain and can later apply. We also will investigate extending the longitudinal study into the workplace, as several students from the course graduate and begin working for local companies. Additionally, we will convert and extend the curriculum into a professional development series for local professionals.

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